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Investigation of optical properties of InP, AIN and Sapphire for applications in non-contact semiconductor process monitoring

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ABSTRACT

INVESTIGATION OF OPTICAL PROPERTIES OF INP, ALN AND SAPPHIRE FOR APPLICATIONS IN NON-CONTACT SEMICONDUCTOR PROCESS MONITORING

by
Rajasekhar Velagapudi

The objective of this thesis was to develop a reliable multi-wavelength pyrometer for simultaneous measurement of the wafer temperature and its optical properties in the wavelength range of 1 to 20 microns and temperature range of 30 to 1500 °C. The spectral emissometer has been utilized for measurement of the temperature dependent optical properties of InP, AlN and Sapphire. The experimental results presented in this thesis showed that the measurement of high temperature optical properties could be performed reliably with a novel approach using the spectral emissometer. The temperature determination capability of the emissometer was tested and verified using a standard thermocouple embedded in a silicon wafer. The temperature measurement accuracy, with the emissometer, was found to be within $\pm$ 10 °C of the thermocouple temperature for a temperature range of 30 to 300 °C. A particularly interesting results were the observed sharp peak in the emissivity of Fe doped InP at 14 microns, the deconvoluted values of the refractive indices from the measured optical properties of Fe doped InP are within $\pm$ 10 % of the limited refractive index data available in the literature, sapphire exhibiting emissivity value of ~1 at 8 microns and the refractive indices of sapphire approach high values in the wavelength range of 12 to 16 microns resulting from its high reflectance. Spectral emissometry has been established as a reliable technique for simultaneously measurement of temperature and optical properties of semiconductors.

INVESTIGATION OF OPTICAL PROPERTIES OF InP, AlN AND SAPPHIRE FOR APPLICATIONS IN NON-CONTACT SEMICONDUCTOR PROCESS MONITORING

by
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1. N.M. Ravindra, O.H. Gokce, F.M. Tong, S. Abedrabbo, **V. Rajasekhar** A. Patel, G. Williamson, W. Maszara, A. Nanda and T. Speranza, "Temperature and wavelength dependent emissivity of SIMOX", Third International Workshop on Thermal Investigation of ICs and Microstructures, Cannes "Cote d'Azur", France, September, 1997

2. N.M. Ravindra, O.H. Gokce, F.M. Tong, S. Abedrabbo, S. Amin, A. Patel, **V. Rajasekhar**, K. Linga, C.S. Wang, I. Ferguson and F. Roozeboom, "Temperature Dependent Emissivity of Non-Silicon Materials", Fifth International Conference on Rapid Thermal Processing of Semiconductors, New Orleans, Louisiana, LA, p 163-182 September, 1997

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APPROVAL PAGE

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This thesis is dedicated to my Parents

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CHAPTER 1

INTRODUCTION

Semiconductor device manufacturing involves thermal processing techniques. The most important process parameter in these techniques is the wafer temperature. In many of these processing techniques, the rate-limiting step is kinetics-limited and it is therefore controlled by surface temperature of the wafer. Consequently, small changes in the temperature can severely affect the rate of the process. Therefore, extremely tight control of wafer temperature is needed. This is particularly true in deposition processes, such as chemical vapor deposition (CVD), rapid thermal processing(RTP) and molecular beam epitaxy (MBE)[1]. The goal of the process temperature requirements is to have wafer temperature reproducibility and uniformity. The temperature measurement is only a part of the overall control system. Thus the goal must be temperature control. To control a process variable like temperature, the measurement of that variable must be more precise than the desired control.

The objective of this thesis was to develop a reliable multi-wavelength pyrometer for simultaneous measurement of the wafer temperature and its optical properties in the wavelength range of 1 to 20 microns and temperature range of 30 to 1500°C. The spectral emissometer has been utilized for measurement of the temperature dependent optical properties of InP, AlN and Sapphire. Powerbuilder, a front-end tool has been used to develop a program for deconvolution of the measured optical properties. While it has been demonstrated in this thesis that this emissometer yields reliable values of optical properties of materials as a function of temperature and wavelength, it suffers from limitations in terms of the source of heating. Work aimed at replacing the currently used source of heating in the form of oxy-acetylene or propane torch is in progress. Two possible solutions are being investigated –

1)Possible use of CO_2 laser and

2)Tungsten halogen lamp assisted heating

Both the solutions offer the possibility of non-contact heating of semiconductor wafers in the emissometer.

The investigation of the temperature dependent optical properties, in this thesis, has been distributed over the next five chapters. In chapter 2, the background for standard temperature sensors is summarized. This discussion is focused on conventional temperature sensors utilized in the semiconductor industry. These include contact methods such as thermocouples and non-contact method such as pyrometry. The fundamentals of radiative properties of semiconductors and an introduction to III-V compounds are also discussed in this chapter. In chapter 3, experimental details and methodology employed for the measurement of the radiative properties of materials have been discussed. In chapters 4-6, the measured high temperature optical properties of InP, AlN and Sapphire are presented and discussed. Conclusions and recommendations based on these studies are presented in chapter 7.

CHAPTER 2

BACKGROUND

2.1 Fundamentals of Sensors for Process Monitoring

2.1.1 Contact Sensors

Thermocouples: A junction of two dissimilar materials will, when heated, produce a voltage across the two open leads. This effect is called thermovoltaic effect and such a junction is referred to as thermocouple. When more than one of these junctions are combined in a single responsive element, it is termed as thermopile. The most important features of thermocouples are the following:

(a) Thermocouples do not measure only the junction temperature. Instead, they will measure the temperature gradient of the wire.

(b) Thermocouples never measure wafer temperature directly. Only a close approximation is the output of the thermocouple, as determined by the thermal resistance between the wafer and the thermocouple [2].

(c) The signal produced by the thermocouple is translated into temperature by a number of methods. The most common conversion is the use of a standard reference table such as the international temperature standard, ITS-90 and interpolation from a number of ITS-90 fixed points[3-4].

Although thermocouples are inexpensive and easy to use, they suffer from some limitations. The main problem with the thermocouple is its way of operation. For a thermocouple to operate, it has to be in physical contact with the surface of the wafer that means risk of contaminating the wafer. In order to minimize the contamination, real-time measurements must not involve contacting the wafer. Thermocouples can be used as temperature measurement tools in batch reactor furnaces where the wafer is in total equilibrium with its surroundings. Thus, by determining the furnace temperature, the wafer temperature can be found. In processes like RTP, the thermocouple should be embedded inside the wafer in order to find the wafer temperature since wafer temperature may be not in equilibrium with the furnace temperature. In order to obtain readings of spatial temperature distribution, several thermocouples have to be embedded across the wafer to measure the temperature across the wafer, which could introduce process related problems. On the other hand, this technique cannot be used in processes such as rapid thermal oxidation(RTO) where a layer of thermal oxide is grown on the surface of the substrate. Even though there are many limitations in using the thermocouples, it is not likely to see the disappearance of thermocouples in the semiconductor industry in the near future. The major problems with thermocouples are low reproducibility and time constants (typically about 0.2 sec). They offer a simple measurement solution if some of their disadvantages can be overcome.

2.1.2 Non-Contact Sensors

Pyrometry: It is a non-contact optical technique used to monitor the temperature of the wafer during semiconductor processing. Pyrometers are all fundamentally based on Planck's blackbody radiation equation. The pyrometer does not measure the temperature of the wafer directly. Instead, it measures the intensity of the radiation coming from the wafer, which can later be converted into temperature by using an appropriate correction factor. Thermometry using pyrometry involves measuring the thermal distribution of photons, often within a narrow wavelength band. Pyrometers are also called as photon detectors. In photon detectors, incident infrared photons are absorbed producing free charge carriers, which change electrical characteristics without causing any temperature change of the responsive element[5]. Radiation pyrometry is a valuable tool for non-contact measurement of temperature. The main advantages of using pyrometers are the following:

(a) pyrometers look directly at the wafer;

(b) can be located outside the process chamber;

(c) need no contact with the wafer;

(d) exhibit low time constants(typically about 50msec) and high resolution.

Pyrometers can also yield other information such as transmittance, reflectance and emittance of the wafer. However, there are some limitations, such as sensitivity to changing emissivity and background light. They are costly and complex and they need calibration. Wavelength, photodetection and collection optics are some key considerations to be evaluated for pyrometers. A number of sensors are placed looking at various points on the sample in order to collect the thermally radiated energy from the samples. This is because of the limitation of spatial resolution of each sensor. Thermal radiance is characterized by Planck's blackbody spectral radiance $M_{\lambda,b}$ (T, λ), the wafer emissivity ε(λ, T), and is given by[6]:

$$P\rho = A\, f(h)\, \varepsilon(\lambda, T)\, M_{\lambda,b}\,(T,\lambda) \qquad (1)$$

Where, T is the temperature, λ is the pyrometer operating wavelength, A is the area of the wafer that contribute directly to the pyrometer signal, and f(h) is a function dependent on the distance (h) between the wafer and the pyrometer. As can be seen from the above equation, the emissivity of the wafer should be known precisely in order to measure the accurate temperature of the sample. Even though there are some limitations, pyrometers are still being used as standard sensors in monitoring the temperature in many semiconductor processes such as RTP, MBE and MOCVD[1,7]. The limitations of pyrometers have compelled the researchers to investigate other non-contact techniques like the ripple technique, which has solved the two critical pyrometer related problems such as undesired background light and unknown wafer emissivity[8].

In semiconductor processes such as RTP, problem of measuring the temperature and problem of non-uniformity can be reduced greatly by emissivity reduction technique[9]. But most of these techniques seek virtual blackbody cavity. If a wafer is placed into a virtual blackbody, the effective emissivity is forced up towards one. A new technique introduced by AG Associates minimizes emissivity errors and improves temperature uniformity by placing a highly reflective surface very close to the wafer, to enhance its emissivity. A fiber sensor could also be inserted through a hole in the bottom reflector of an RTP system and look at the wafer to acquire real-time emissivity data.

2.2 Radiative Properties - Fundamentals

Transmittance: Transmittance is the term used to describe the process by which incident radiant flux leaves a surface or medium from a side other than the incident side, usually the opposite side. The spectral transmittance $\tau(\lambda)$ of a medium is the ratio of the transmitted spectral flux $\phi_{\lambda t}$ to the incident spectral flux $\phi_{\lambda I}$, or

$$\tau(\lambda) = \phi_{\lambda t} / \phi_{\lambda I}$$

Reflectance:

Reflectance is the process where a fraction of the radiant flux incident on a surface is returned into the same hemisphere whose base is the surface containing the incident radiation. Spectral reflectance is defined at a specified wavelength λ as

$$\rho(\lambda) = \phi_{\lambda r} / \phi_{\lambda I}$$

Emissivity:

Emissivity is the ratio of the radiation emitted by a given object to that of a blackbody source at the same temperature and for the same spectral and directional conditions. It mainly depends on wavelength and temperature. It is the property, which must be known for accurate temperature determination of an object by measurement of its emitted electromagnetic radiation with a radiation thermometer.

For normal incidence, the emissivity ε of a plane parallel specimen is given by[10]:

$$\varepsilon(\lambda) = [\, 1-\rho(\lambda)]\, [1-\tau(\lambda)] / [1-\rho(\lambda)\tau(\lambda)] \qquad (2)$$

Where, λ is the wavelength, $\rho(\lambda)$ is the true reflectivity and $\tau(\lambda)$ is the true transmissivity. $\tau(\lambda)$ and $\rho(\lambda)$ are related to the fundamental optical constants such as refractive index and extinction coefficient by the following relations:

$$\rho(\lambda) = [\, \{ n(\lambda) - 1\}^2 \} + k(\lambda)^2] / [\, \{ n(\lambda) +1\}^2 + k(\lambda)^2 \,] \qquad (3)$$

$$\tau(\lambda) = \exp[\, -\alpha(\lambda)\, t \,] = \exp[\, -4\pi k(\lambda)t / \lambda \,] \qquad (4)$$

Where, t is the thickness of the sample and α is the absorption coefficient. From equation (2), for a perfect opaque sample, there will be no transmission, so substituting τ

(λ) = 0 in equation (2), a simplified emittance equation is obtained:

$$\varepsilon(\lambda) = [\ 1-\rho(\lambda)] \qquad (5)$$

The experimentally measured optical properties are apparent properties since measured values of transmittance and reflectance include some extra effects such as light trapping, surface roughness, and multiple internal reflections depending on the angle of incidence. The apparent reflectance $\rho(\lambda)^*$ and transmittance $\tau(\lambda)^*$ are related to the true $\rho(\lambda)$ and $\tau(\lambda)$ by[11]:

$$\rho(\lambda)^* = \rho(\lambda)\ \{\ 1+ [\tau(\lambda)^2\ (\ 1-\rho(\lambda))^2\ /\ 1-\ \rho(\lambda)\ ^2\tau(\lambda)^2]\ \} \qquad (7)$$

$$\tau(\lambda)^* = \tau(\lambda)\{\ (1\ -\ \rho(\lambda))^2\ /\ (\ 1\ -\rho(\lambda)\ ^2T(\lambda)^2)\} \qquad (6)$$

The thermal radiation emitted by the material will depend on many factors such as the direction in which radiation is viewed, the wavelength, and on the polarization. The type of material coating, surface roughness and chamber effect could also cause changes in the radiative properties of the wafer. These factors affect the spectral emissivity, which results in temperature measurement errors in pyrometers. For example, in most RTP systems, pyrometers monitor the radiation from the backside of the wafer. If the wafer is not polished on the backside, the surface roughness can cause additional errors in temperature measurement. Several studies are in progress to investigate these effects which may cause changes in the radiative properties so that errors in processes could be compensated.

2.3 Examples of Semiconductor Processes

In semiconductor industry, the transition to larger diameter wafers and reduction in geometrical dimension of devices is occurring rapidly. In device manufacturing, semiconductor processes play an important role to achieve repeatability and maximum yield(reproducibility). Thus, processes should be reliable, efficient and practical for facilitating in further improvement in technology. In the following section, some examples of semiconductor processes are presented.

2.3.1 Rapid Thermal Processing

In semiconductor device manufacturing, the trend is to increase the wafer size and reduce the geometrical size of the device. Apart from this, there is also a need to minimize (a) the temperature-time product or the thermal budget, (b) the process-induced contamination, and (c) device failure. These requirements have led to several new processes. One such process is Rapid Thermal Processing(RTP). In the National Technology Road Map[12], RTP has been mentioned to offer "the potential to significantly reduce thermal budget, while affording single wafer granularity and cluster compatibility". RTP with inherent smaller thermal mass and tighter ambient control may also be used in the next device generation such as ULSI and GLSI. The various processes that can be performed with RTP are summarized in Table-1[13].

Table 1 - Some semiconductor device applications of RTP

APPLICATION	DESIRED PROCESS	UNDESIRED PROCESS
Shallow N^+ Doping	Extended defect removal	Arsenic diffusion
Shallow P^+ Doping	Conductivity/ Activation	Boron Diffusion, Normal + Enhanced
WSi_2 Annealing	High conductivity	Boron Diffusion
Si-Ge Superlattice	Abrupt Thin Layers	Graded Interfaces
Self Aligned $CoSi_2$	Nucleation, Smooth surfaces	Grain Growth, Rough surface
Al-Si Contacts	Form Ohmic Contact	Al Spiking
Trench Capacitor	Grow and Flow Oxide	Breakdown due to Strain, Thinning
Self Aligned MISFET	Active Source / Drain	Contact Alloying, AlGaAs Evaporation
High Mobility III-V Hetrostructure	Active Si Donors	Diffusion of Si
RTCVD	Metal and Dielectric Deposition	Temperature Non-Uniformity

Typical RTP process chambers are made of either quartz, silicon carbide or stainless steel[14]. The wafer holder is often made of quartz and the contact with the wafer is kept minimum to avoid contamination. In RTP, the wafer temperature measurement is a major problem. In contrary to a regular batch reactor, the wafer temperature and the chamber temperature are not in equilibrium in the RTP system. Therefore, thermocouples cannot be used to measure the temperature of the wafer unless it is embedded inside the wafer, which is impractical in RTP. So pyrometry, a non-contact optical method, is used to measure the temperature of the wafer in real-time. But, for pyrometers, it is necessary to know the spectral emittance in order to determine the temperature of the wafer[15]. The low reproducibility of RTP is because of difficulties in measuring wafer temperature precisely. This is still a major obstacle. In spite of this, RTP is a better process in comparison with conventional batch processing in aspects such as low particle contamination, low thermal budget and high throughput[16].

2.3.2 Molecular Beam Epitaxy

Epitaxy is a growth process by means of which a thin layer (0.5 to 20 microns) of single crystal material is deposited on single crystal substrate. If the film is the same material as the substrate, the process is called homoepitaxy. On the other hand, if the film is a material other than the substrate, the process is called hetroepitaxy. Epitaxy growth can be achieved by many techniques- one of them is molecular beam epitaxy(MBE). Molecular beam epitaxy is used in producing very high quality epitaxial layers of many semiconductors, for example, III-V compounds such as GaAs, InP, GaAlAs etc.[17]. In this case, the MBE process involves the reaction of one or more thermal beams of atoms and molecules of the III-V elements with a crystalline substrate surface held at a suitable temperature under ultra high vacuum conditions[18]. Since MBE is an ultra high vacuum evaporation technique, the growth process can be controlled in-situ by the use of appropriate process control instruments such as pressure gauge, mass spectrometer, and an electron-diffraction facility located within the MBE reactor. MBE is an excellent crystal growth technique because it provides extremely precise control over a submono-layer thickness composition and doping profile, and high uniformity of the epitaxial layer over a large area substrate. For any semiconductor process, the process variables play a vital role in obtaining the desired results. The important process variables in MBE are temperature, total pressure and gas ratio. In order to obtain uniform epitaxial layer, we should keep track of the temperature of the wafer at all times during the process to control the reactions. There are two standard techniques for temperature measurement in MBE growth of semiconductor materials. One is the use of conventional thermocouples and the other is a pyrometer[18]. However, both the techniques have some limitations. Therefore, other non-invasive techniques such as transmission spectroscopy and reflection interferometry are being developed.

2.3.3 MOCVD

Chemical vapor deposition(CVD) is a process in which a thin film is deposited on a substrate. Unlike MBE, it is a deposition process and not a growth process. CVD is one of the most important methods of film formation used in the fabrication of very large scale integrated circuits. In this process, the chemicals in gas or vapor phase react at the surface of the substrate where they form a thin layer over the substrate. This process is relatively a low temperature process. For example, refractory oxide glasses and metals can be deposited at temperature of 500 °C. This feature is very important in advanced VLSI device technology with short channel lengths and shallow junctions, where lateral and vertical diffusion of dopants must be minimized.

The process of deposition occurs in two phases. In the first phase, mass transport occurs and in the next phase, surface reaction takes place. The first phase is weakly dependent on temperature. On the other hand, the second phase is a strong function of temperature[19]. Therefore, in order to obtain film thickness uniformity on a substrate, a good control over a temperature is needed.

Metalorganic chemical vapor deposition(MOCVD) is one of the methods of CVD process. MOCVD is an important epitaxial crystal growth technique in semiconductor device manufacturing. Through this technique, it is possible to grow a high quality low dimensional structure for semiconductor devices[17]. MOCVD technique is often used in industry for growing films on a substrate because of its simplicity, ability to grow uniform layers, and sharp interfaces when compared with other growth techniques. By rapid changes of gas composition in the reaction chamber, it is possible to produce multiquantum wells, heterostructures and superlattices with sharp switch-on and switch-off transitions in composition as well as doping profiles. Using this technique, multilayer structures with thickness as thin as few atomic layers can be prepared. The disadvantages of MOCVD technique are the use of high quantities of poisonous gases such as AsH3 and PH3, and difficulty in performing in-situ characterization during the growth process.

2.4 General Introduction to III-V Compounds

As the world approaches the 21st century, semiconductor industry faces major challenges in terms of a demand for increasing chip speeds while reducing the cost. Experts in industry believe that III-V compounds are more advantageous than conventional semiconductor materials such as silicon especially in the opto-electronics field. Two reasons for which these compounds are of interest in opto-electronics are as follows:

1) They emit light efficiently. Thus they are useful for fabricating light emitting diodes and lasers;

2) They are ideal for producing very high-speed electronic devices since electrons move much faster in some of these materials than in silicon.

While silicon process technology is more advanced than that of any semiconductor materials, III-V compounds are attractive because of two key properties. Firstly, mixed crystals with semiconductor properties can be formed from the elements Al, Ga, In, P, As and Sb. Secondly, the resulting binary, ternary and quaternary mixtures exhibit direct bandgaps between 0.18 and 2.4 eV leading to novel applications in bandgap engineering[20]. Now-a-days, lot of research is being performed on compound semiconductors because of their wide range of energy band gaps, that can lead to super-high efficiency optoelectronic devices. Intensive study is being made in this field. Most of the III-V compound devices are based on the layered structures and the device performance mostly depends on the quality of the process. Use of transient thermal processing in III-V semiconductor technology has been discussed by Pearton et. al.[21], Transient processing is employed for numerous steps in the processing of III-V electronic and photonic devices[21]. Growth of III-V alloys for laser based structures by metal organic chemical vapor deposition is becoming more popular[22].

GaAs has enjoyed a unique position in the electronics industry for more than two decades. The first bipolar transistor device was made with this material. It is emerging as the starting material for integrated circuits with more than one million transistors per chip. Research is also being performed on InP because it was realized that InP based hetrostructures had numerous advantages, which include the low surface-recombination velocities of InP and related compounds. The high thermal conductivity of InP substrates and the superior electron transport properties of InP permit the possibility of fabricating high gain submicron devices[23].

InP has a thermal conductivity 50 percent higher than that of GaAs. This feature allows for lower sensitivity of InP based device parameters to temperature. Efforts are being made to find ways for the application of InP high electron mobility transistors. Electrical properties of these devices are being improved to be comparable with those of GaAs based devices. It is time to switch to InP from GaAs based devices because InP based devices are more advantageous than their GaAs based counterparts due to inherent superior material properties of InP. InP has higher peak electron velocities and saturated electron velocities than GaAs, giving the InP based materials lower parasitic resistances and shorter transit times[23]. AlN is a wide bandgap semiconductor with high thermal conductivity and high electrical resistivity. Hence it is an attractive ceramic and a possible susceptor material for applications in Rapid Thermal Processing. In addition, AlN is also used as a substrate in the present day GaN based blue lasers and light emitting diodes.

Sapphire is a III-VI compound with very attractive properties that makes it useful as an infrared window material.

In this thesis, InP, AlN and Sapphire have been investigated for high temperature optical properties. The temperature dependent optical data of these compounds is generally not available in the 1-20 micron wavelength range in the literature. The optical constants such as refractive index and extinction coefficient of InP, AlN, and Sapphire have been deconvoluted from the measured optical properties.

CHAPTER 3

EXPERIMENTAL DETAILS

3.1 EMISSOMETER-Description of the Apparatus

A spectral emissometer has been used to measure the optical properties of the materials investigated in this study. This instrument measures the radiative properties of a sample over a wide spectral range, in the near and mid-infrared, from 12,500 cm^{-1} to 500 cm^{-1} (0.8 to 20 μm). The schematic of the spectral emissometer is shown in Fig.1. It consists of a hemi-ellipsoidal mirror having two foci, both inside the mirror. At one focus, the exciting source which is a near black body is placed and the sample under investigation at the other focus. A microprocessor controlled motorized chopper facilitates to measure radiance, reflectance and transmittance of the sample simultaneously. When the chopper closes, the black body source, the detector detects only directional radiance of the sample and when chopper is open , the measured radiance will include both the emitted radiation of the sample and the black body radiation reflected by the sample. The Fourier transform infrared data collection system consisting of Ge (0.8 - 1.6 μm) and HgCdTe (1.6 - 20 μm) detectors, is synchronized with the two states of the chopper allowing for the distinction of sample radiation from reflected/transmitted radiation. A carefully adjusted set of five mirrors provide the optical path for measurement of the optical properties. Three intersecting He-Ne laser beams are used to align the sample precisely at the focal point of the mirror. Propane torch has been used to heat the wafer during measurements. A high resolution Bomem FTIR detector, interfaced with a Pentium processor, permits data acquisition of the measured optical properties. This on-line computer enables the user to flip the mirrors to acquire transmission / reflection spectra via a software called Spectra Calc. This instrument has applications for: 1) industrial quality control of radiative properties of processed materials, 2) research and development of new materials, and 3) temperature measurement by optical techniques in the near and mid-IR.

3.2 Methodology

Temperature Measurements:

By using the spectral emissometer, it is possible to measure radiance, reflectance, transmittance and the temperature of the sample simultaneously. A microprocessor controlled motorized chopper facilitates to measure the spectral properties of the sample. When the chopper is closed, the directional spectral radiance of the sample is given as follows[24].

$$R_v(T) = \varepsilon_v(T)\, R^b_v(T) \qquad (8)$$

where $\varepsilon_v(T)$ is the emissivity of the sample at temperature T, and R^b_v is the theoretical Planck's function at temperature T.

when the chopper is open, the measured radiation is given by,

$$M_o = R_v(T) + \rho_v(T) R^b_v(T_{bb}) \qquad (9)$$

where T_{bb} is the constant blackbody source temperature which is maintained at 900°C and ρ_v is the spectral directional-hemispherical reflectivity. The difference in the two measurements yields $\rho_v(T) R^b_v(T_{bb})$.

$$M_o - R_v(T) = \rho_v(T) R^b_v(T_{bb}) \qquad (10)$$

The constant source radiation is quantified by replacing the sample with the perfect reflector (a gold mirror, $\rho_v^{gold} \simeq 1.0$) and measuring the spectrum in the chopper open condition.

$$M_v^{ref} = \rho_v^{gold}(T)R^b_v(T_{bb}) = R^b_v(T_{bb}) \quad (11)$$

The ratio of Eq. (10) to Eq. (11) results in the measurement of the directional hemispherical reflectance of the sample, ρ_v, at the unknown temperature T.

$$M_o - R_v(T) / M_v^{ref} = \rho_v(T)R^b_v(T_{bb}) / R^b_v(T_{bb}) = \rho_v(T) \quad (12)$$

For an opaque sample, the spectral emittance, ε_v, can be determined from $\varepsilon_v = 1 - \rho_v$. Once the spectral emissivity is known, the precise sample temperature can be determined by rearranging Eq. (8).

$$R^b_v(T) = R_v(T) / \varepsilon_v(T) \quad (13)$$

Comparing Eq. (13) with Planck function leads to temperature evaluation:

$R^b_\lambda = c_1 \lambda^{-5} / (\exp[c_2/\lambda T] - 1)$ where c_1 and c_2 are constants.

An on-line computer does all the mathematical operations on the raw data using spectra Calc. It transforms the interferograms into spectra, calculates spectral emittance from reflectance and transmittance data and automatically determines the temperature from radiance data.

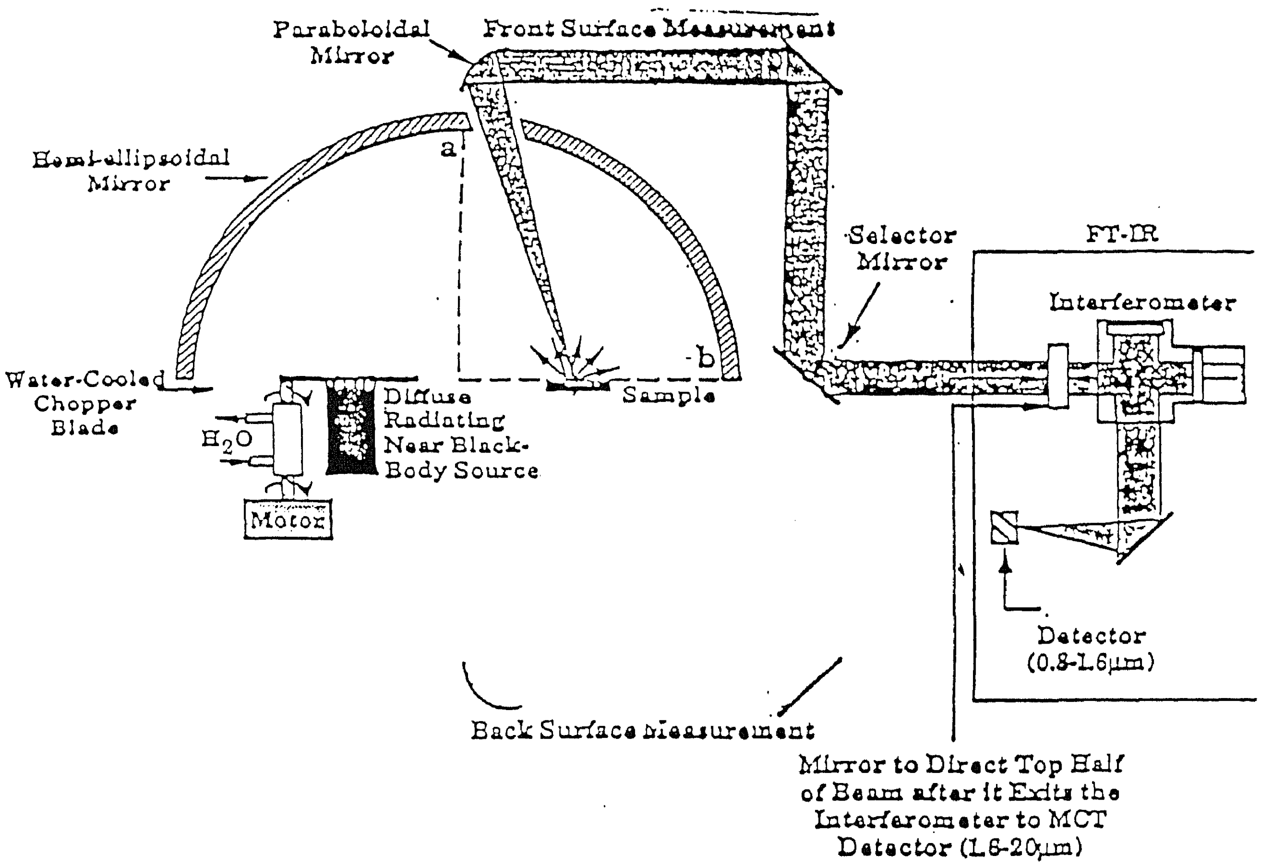


Fig.1 Schematic of Bench top emissometer

CHAPTER 4

INDIUM PHOSPHIDE

4.1 Background

Indium Phosphide is a direct band-gap semiconductor with applications in optoelectronics and high frequency electronic devices. InP can be formed by many growth techniques. Bulk growth techniques include liquid encapsulated Czochralski (LEC), single Crystal Bridgman technique, and float zone (FZ) processes. Thin film epitaxy crystal growth includes liquid phase epitaxy (LPE), molecular beam epitaxy (MBE) and metal organic chemical vapor deposition (MOCVD). The advances in bulk crystal growth technique and epitaxial crystal growth technique of InP has made InP based materials very useful for ultra high-speed electronic devices and as a substrate for high performance optoelectronic circuits. For the state of the art silica based optical telecommunication, the minimum dispersion is at 1.27 micrometers and minimum attenuation is at 0.085, 1.27 and 1.55 micrometers[17]. Thus devices that are working in the range of 0.8 - 1.6 micrometers are best suited.

When GaInAs and GaInAsP are lattice matched to InP, the band gap range of 0.92 - 1.6 micrometers of this ternary and quaternary alloy systems enables to fabricate a laser that meets these conditions. The alloys like GaInAs and GaInAsP, grown lattice matched to InP substrate are the materials used for long-haul, high-data-rate, fiber-optic communication systems.Among the III-V semiconductors, InP is now emerging as a preferred topic for research and is substituting GaAs in many applications due to the following advantages.

1) Higher thermal conductivity, which makes the InP based device parameters less sensitive to temperature.

2) Superior surface passivation capabilities, which makes the circuits more reliable.

3) Improved thermal properties, which makes the devices suitable for higher current densities.

The mobility of the electrons in InP is much higher than that of GaAs. High-speed electronic devices such as hetrojunction bipolar transistors(HBT) and high-electron mobility transistors are being made from GaInAs on InP substrate[25]. InP is a direct bandgap semiconductor i.e. both the valence band maxima and the lowest conduction band minima occurs at k=0, and it has a band gap of 1.34 eV. The various properties of InP are summarized in the following section.

4.2 Summary of Properties

In the table below, some of the mechanical, electrical, optical properties of InP are summarized. As can be seen from the table, thermal conductivity of InP is 0.68 ($Wcm^{-1}K^{-1}$) which is higher than that of GaAs [0.46 ($W\ cm^{-1}K^{-1}$)]. Thermal resistivity is an important parameter in the design of power dissipating devices such as lasers. InP has a microhardness of 430 $Kgmm^{-2}$ as compared to GaAs [721 $Kgmm^{-2}$].

Table 2- Summary of Properties of InP[5,23,26]

Melting Temperature (K)	1323 - 1343	Lattice constant(A°)	5.8687
Thermal Expansion (10^{-6}/°C)	4.5	Density (g cm^{-3})	4.81
Heat Capacity (J/g K)	0.3117	Debye temperature (K)	321
Knoop Hardness ($Kgmm^{-2}$)	430	S_{11}^{Γ} (TPa)	1.650
Molecular Weight (amu)	145.80	S_{12}^{Γ} (TPa)	-0.594
Specific Gravity	4.8	S_{44}^{Γ}(TPa)	2.170
n near E_g	3.41	1/n dn/dT (K^{-1})	$2.7*10^{-5}$
$\varepsilon(0)$	12.61	$\varepsilon(\infty)$	9.61
Thermal Conductivity ($Wcm^{-1}K^{-1}$)	0.68	Crystal system	Cubic
Elastic Moduli (GPa)	89	Bulk Moduli (GPa)	72.7

S^{Γ} is the elastic compliance (10^{-12} $cm^2 dyne^{-1}$)

4.3 Literature Data of Optical Properties

In this section, the optical properties of InP, in the literature, are presented. Table 3 summarizes the refractive index and extinction coefficient values in the wavelength range of 2 to 20 microns. The plots of the refractive index and extinction coefficient versus wavelength are shown in Figure(2).

Table 3- Refractive index and extinction coefficient values from literature[27]

λ((μm)	n	λ(μm)	k
1.00	3.327	.975	.0000113
1.50	3.172	12.0	.000527
2.0	3.134	13.08	.000667
5.0	3.08	14.0	.000886
6.0	3.07	14.4	.00128
7.0	3.07	15.0	.00371
8.0	3.06	15.52	.00563
9.0	3.06	16.0	.00712
10.0	3.05	17.0	.00177
12.0	3.05	18.0	.00181
14.0	3.04	19.51	.00384
14.85	3.03	20.0	.00794

4.4 Experimental Data of Optical Properties

The optical properties of two InP samples, one Fe doped, 550 micron thick highly resistive and the other S doped, 450 micron thick, are investigated using the spectral emissometer at various wavelengths. The radiative properties of Fe-doped InP sample at temperatures of 51, 234, 265, 374 and 479 °C while heating the sample and at a temperature of 40 °C

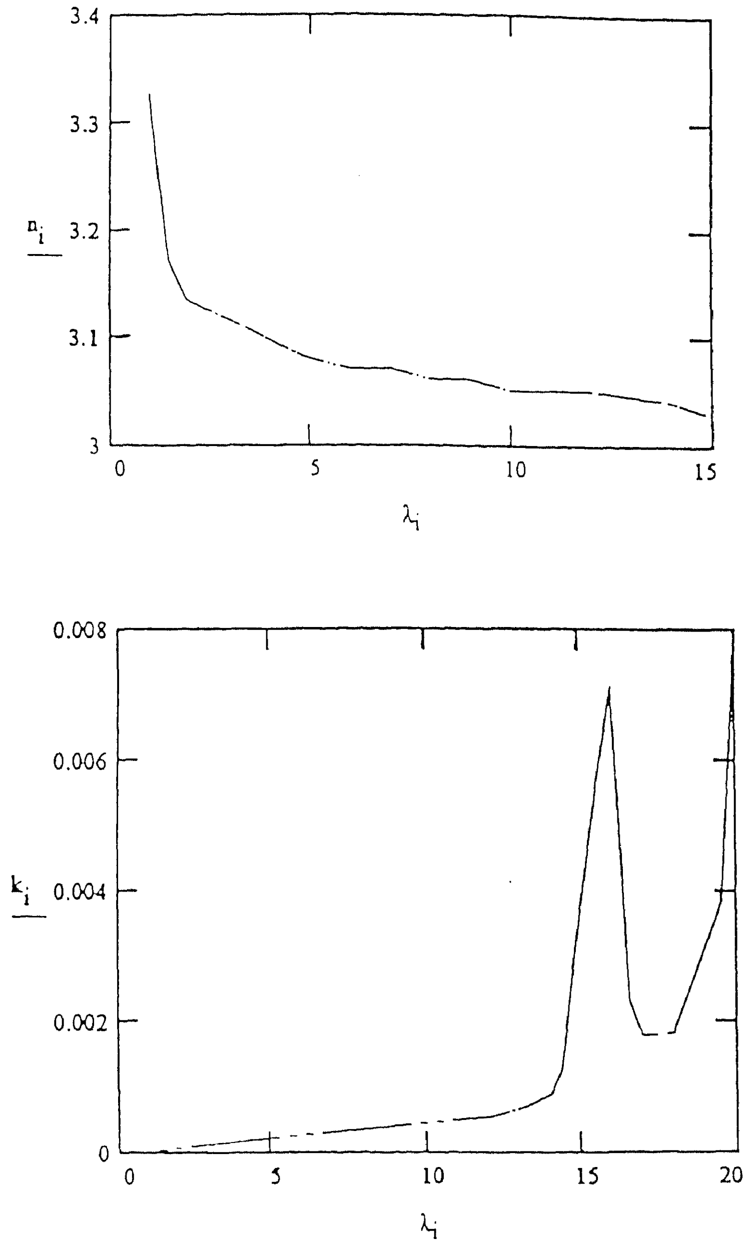


Fig.2 Refractive index and extinction coefficient Vs Wavelength of InP from literature.

after cooling down the sample are shown in Figs(3-5). The radiative properties of S-doped InP sample at temperatures of 99, 199, 350, 421 and 519°C while heating the sample and at a temperature of 92°C after cooling down the sample are shown in Figs(6-8). The experimental data has been deconvoluted to yield the fundamental optical constants of this material. For Fe-doped InP sample, the emissivity is very low and almost constant in the wavelength range of 1 to 10 microns. At 14 microns, there is a sharp peak in the emissivity possibly due to multi-phonon absorption. The steep increase in the emissivity of InP at 479°C at 1.2 microns is due to band-gap absorption. The feature at 14 microns is even sharper at this temperature[28]. For S-doped InP sample, the emissivity increases as the temperature of the sample increases and reaches high values at 519°C. The rationale for measuring the high temperature optical properties and then subsequently cooling the sample in air and recording the room temperature data was to account for possible changes in the chemical composition of the sample.

Tables 4 & 5 show some of the fundamental optical constants of InP at various wavelengths and temperatures. In Appendix A, full range of data of the optical properties between 1 to 20 microns are presented. The data available on high temperature optical constants of InP in the literature are very limited. Whenever possible, Comparisons have been made in the following section.

4.5 Comparative Study of Optical Properties

In Figs. 9 & 10, refractive index and extinction coefficient data available in the literature is compared with the data obtained from the experiment at room temperature respectively[27]. As can be seen from the figures, the data of the optical constants deconvoluted from the measured optical properties of Fe-doped InP samples is in accordance with that of the literature. In S-doped InP sample, S contributes to increase in free carriers of InP. Where as in Fe-doped InP sample, Fe does not contribute to free carriers of InP. It forms a precipitate with a deep levels in the valence band of InP. Thus, it is anticipated that the emissivity values of Fe-doped samples are close to that of intrinsic InP. Further studies are in progress to analyze and understand the influence of S doping effects on the emissivity of InP.

Table 4- Refractive index and extinction coefficient values of InP (S-doped) at two different temperatures - 99°C and 350°C

$\lambda(\mu m)$	n(99)	k(99)	n(350)	k(350)
1.00	3.055	.000212	3.569	.000483
1.501	3.056	.000056	3.166	.000136
2.002	2.852	.000115	2.811	.000217
5.005	2.641	.002274	2.586	.002852
6.03	2.564	.004422	2.509	.004936
7.01	2.514	.006699	2.464	.005766
8.056	2.49	.008933	2.458	.007223
9.072	2.389	.009819	2.402	.008407
10.217	2.274	.010903	2.311	.009269
12.131	2.045	.015282	2.121	.011445
14.27	1.689	.012836	1.845	.011961
14.928	1.553	.015104	1.740	.011455

Table 5- Refractive index and extinction coefficient values of InP (Fe-doped) at two different temperatures - 51°C and 374°C

λ(μm)	n(51)	k(51)	n(374)	k(374)
1.00	3.335	.000029	3.427	.000368
1.501	3.234	.000031	3.225	.000035
2.002	3.142	.000029	3.090	.000040
5.005	3.082	.000065	3.004	.000118
6.03	3.056	.000089	2.97	.000161
7.01	3.034	.000093	2.965	.000165
8.056	3.067	.000077	2.977	.000169
9.072	3.051	.000096	2.957	.000211
10.217	2.978	.000173	2.904	.00028
12.131	2.942	.000216	2.887	.000373
14.27	2.928	.00085	2.939	.001148
14.928	3.044	.002548	3.081	.003103

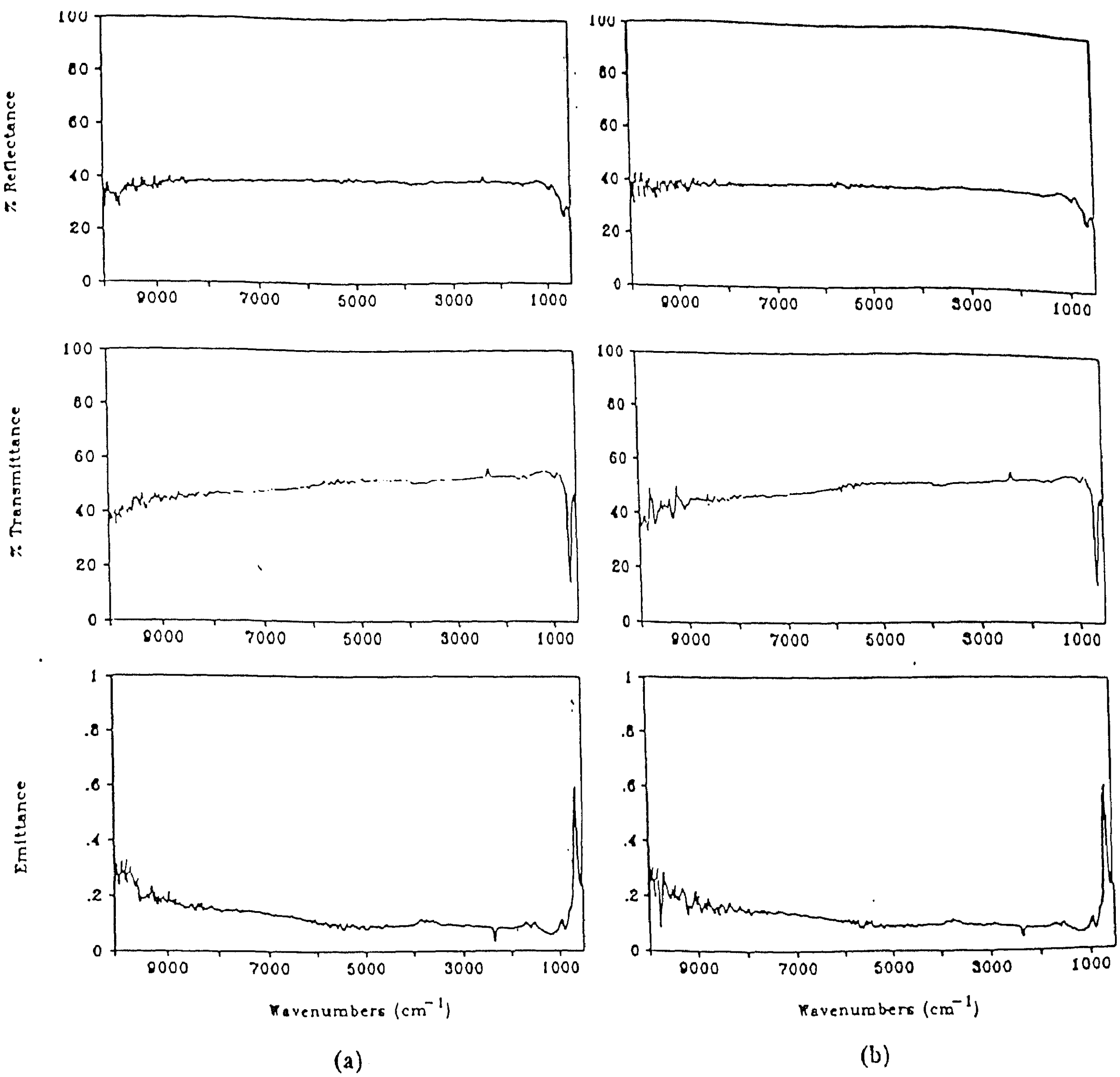


Fig.3 Temperature dependent optical properties of Fe-doped InP:
(a) 234 °C (b) 51 °C.

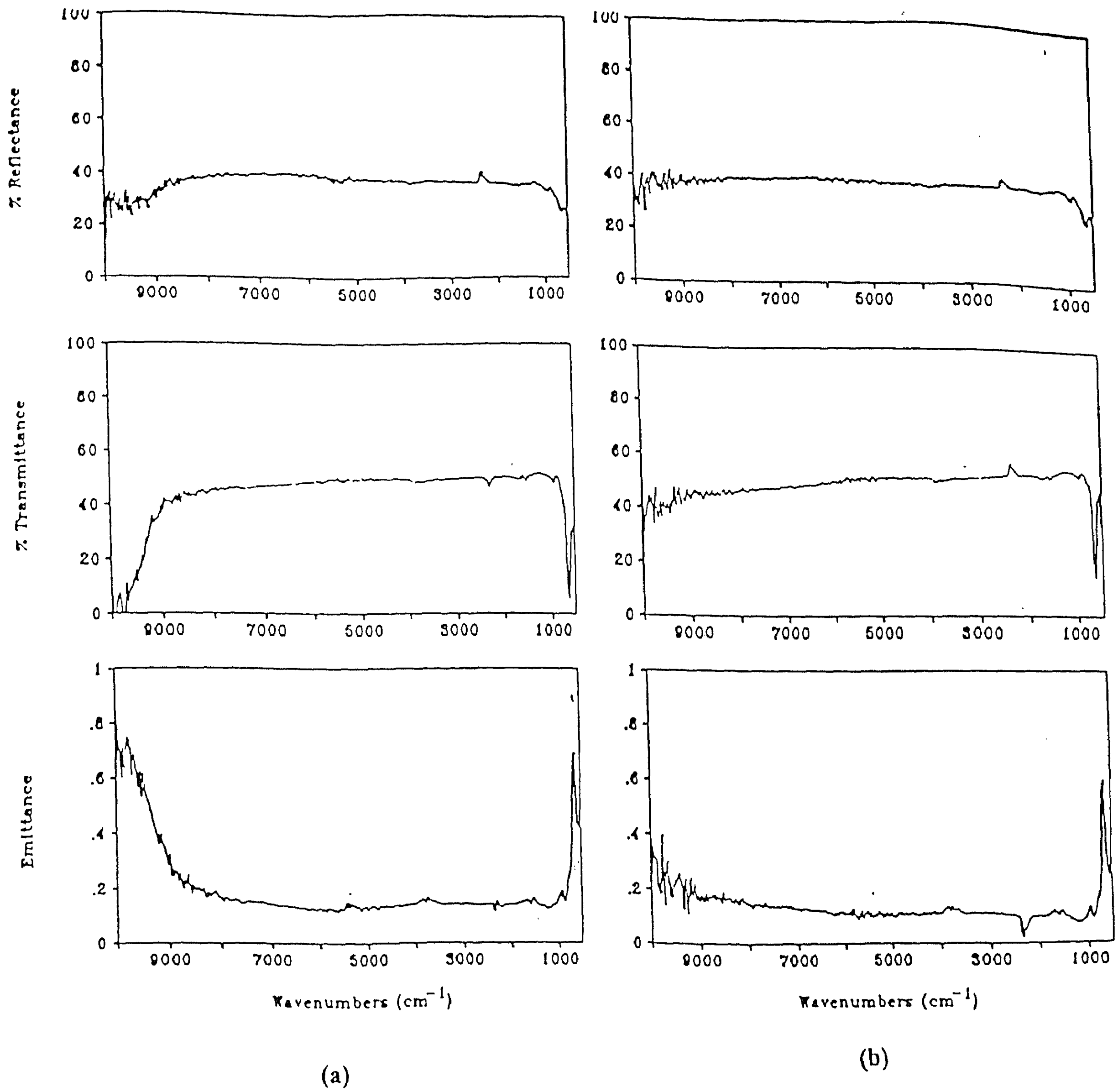


Fig.4 Temperature dependent optical properties of Fe-doped InP:
(a) 374 °C (b) 265 °C.

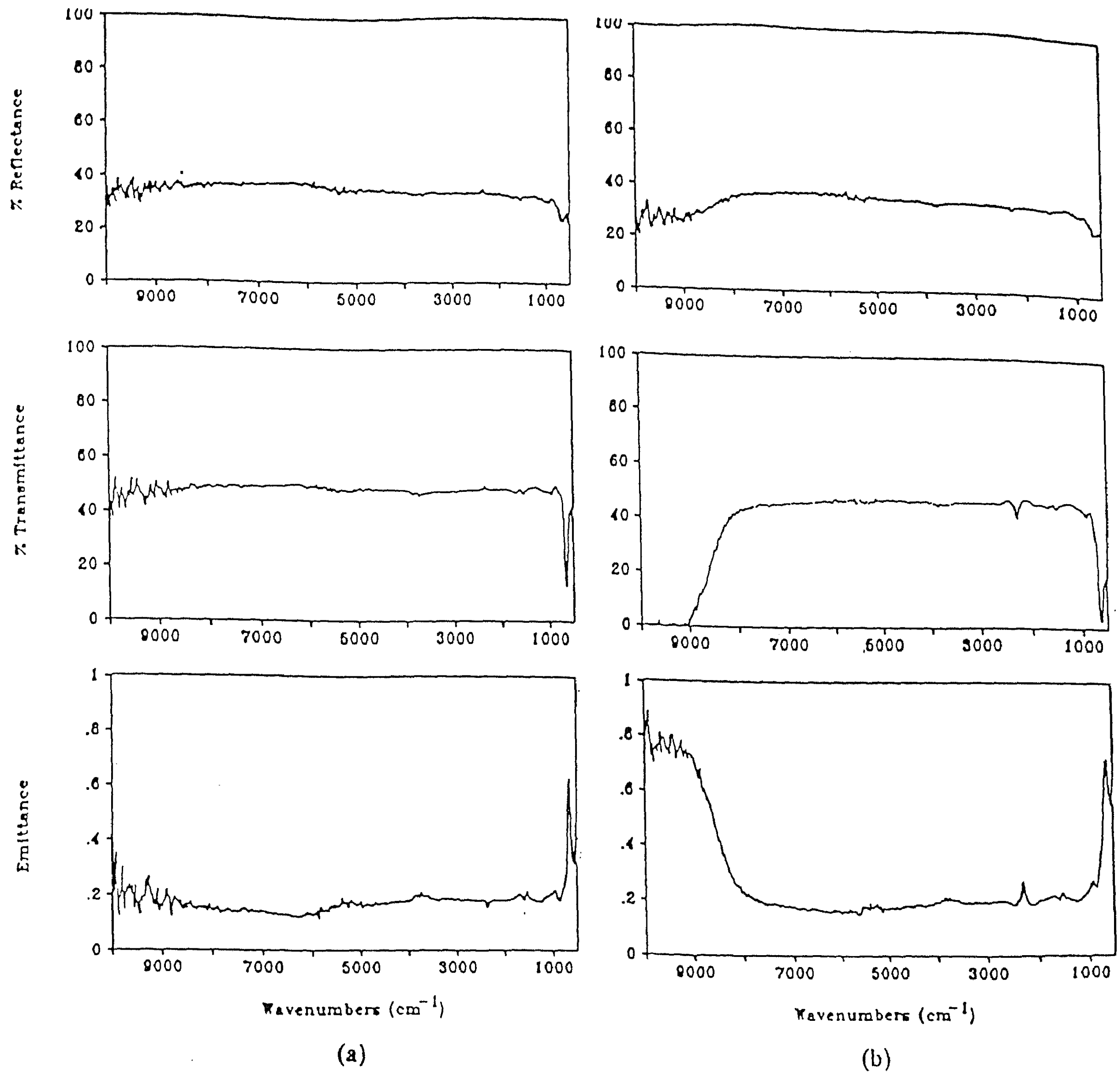


Fig.5 Temperature dependent optical properties of Fe-doped InP:
(a) 40 °C (b) 479 °C.

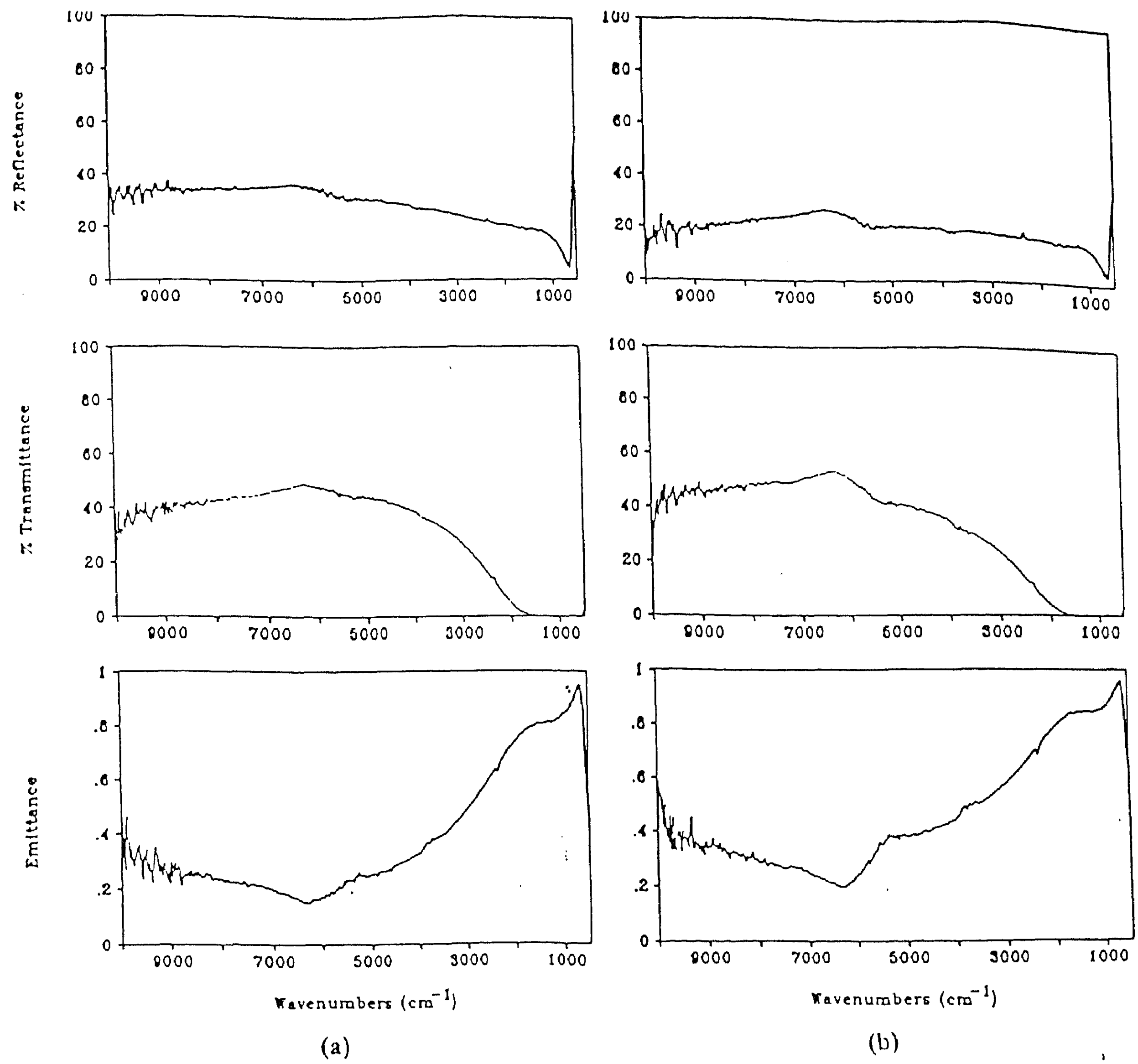


Fig.6 Temperature dependent optical properties of S-doped InP:
(a) 99 °C (b) 199 °C.

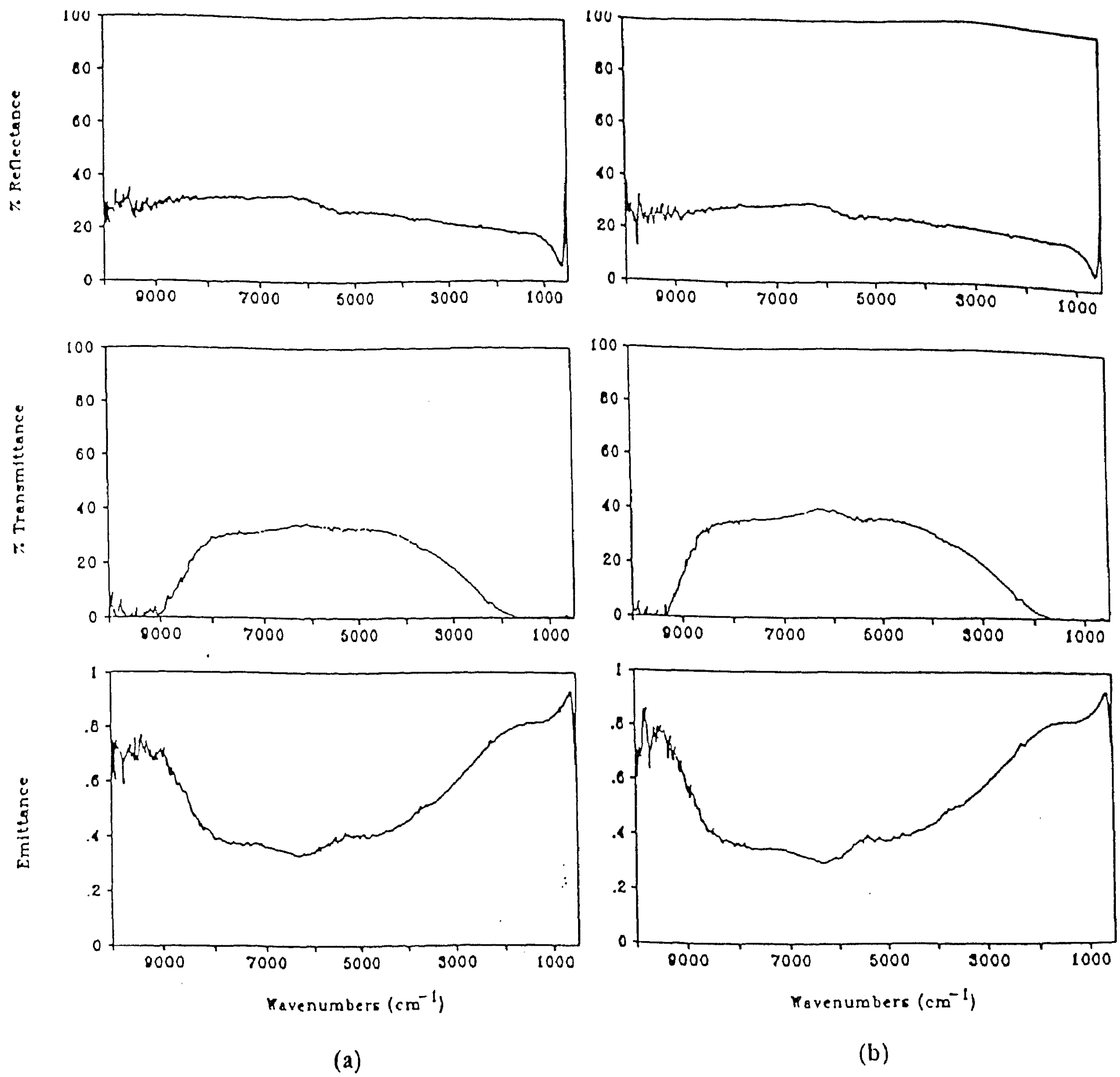


Fig.7 Temperature dependent optical properties of S-Doped InP:
(a) 350 °C (b) 421 °C.

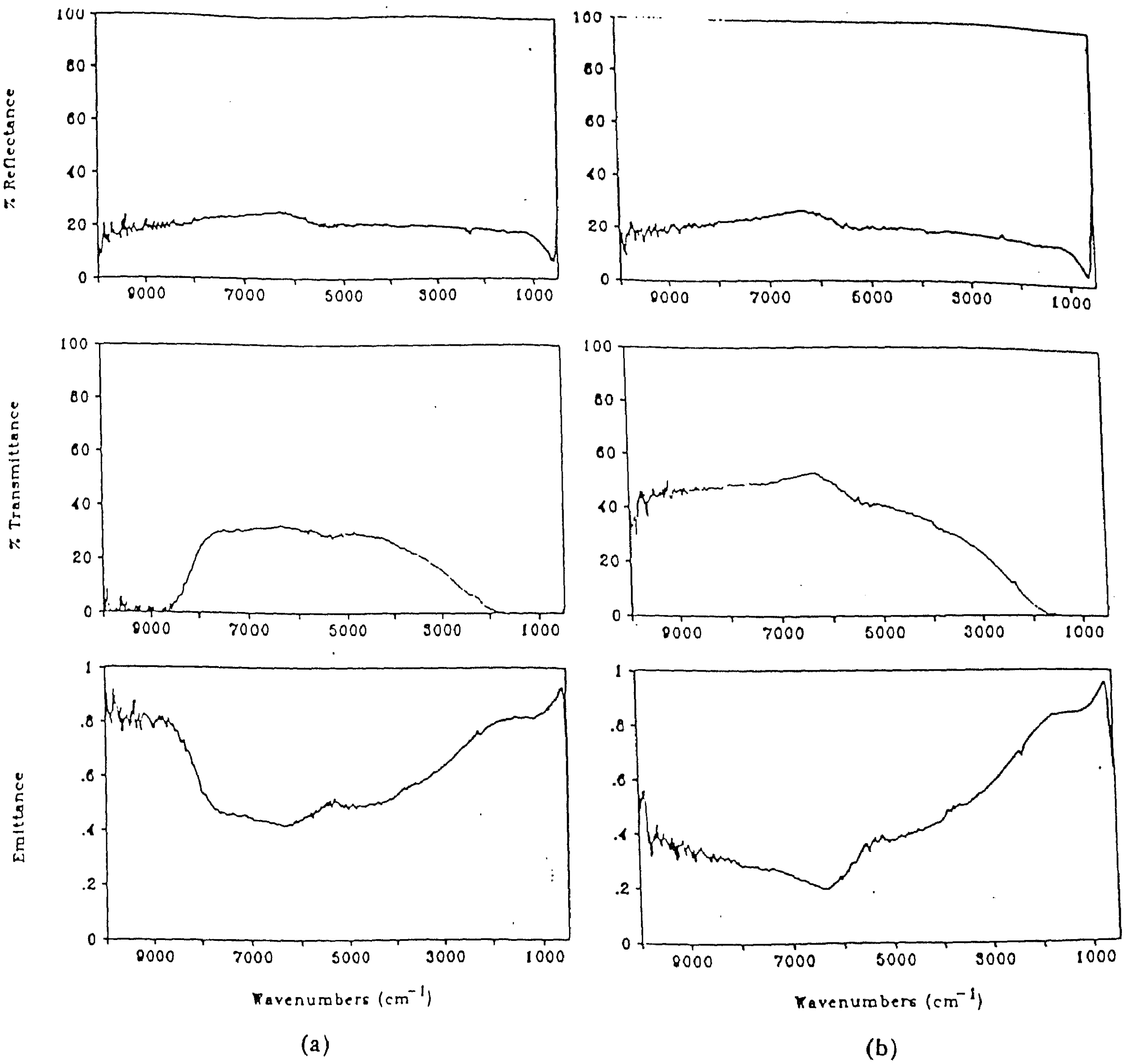


Fig.8 Temperature dependent optical properties of S-doped InP:
(a) 519 °C (b) 92 °C.

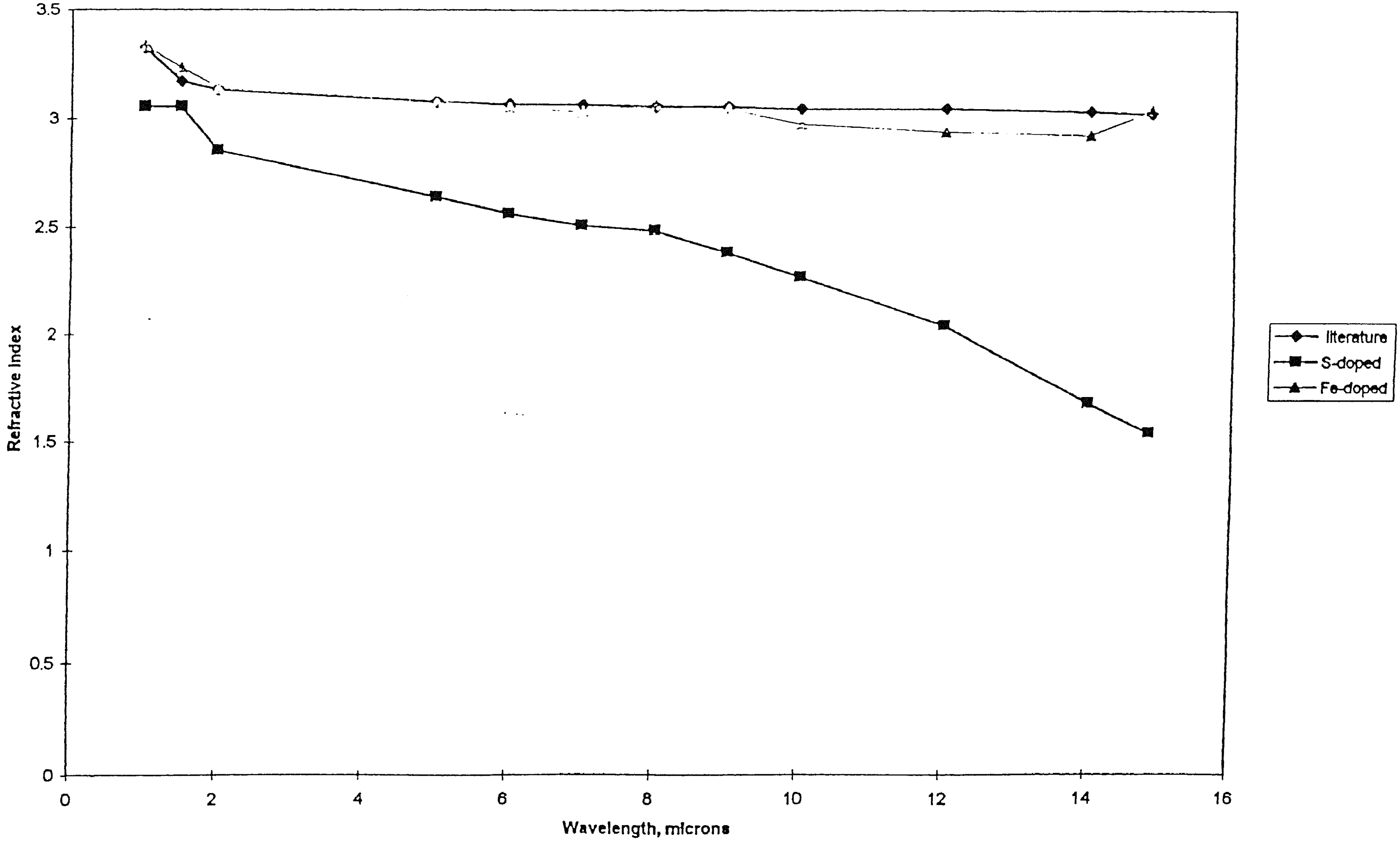


Fig.9 Comparison of literature and experimental values of Refractive index Vs Wavelength of InP

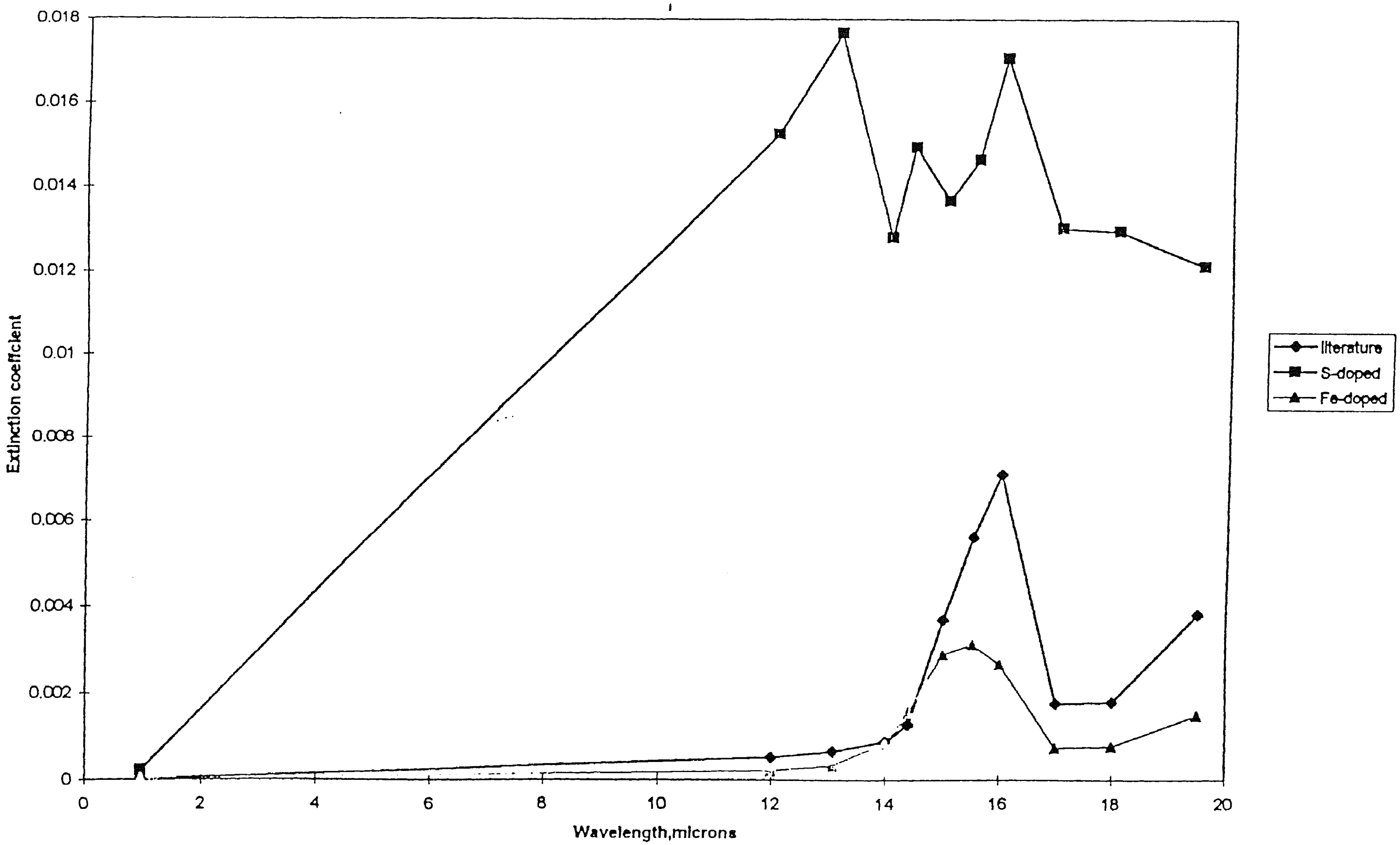


Fig.10 Comparison of literature and experimental values of Extinction coefficient Vs Wavelength of InP

CHAPTER 5

ALUMINUM NITRIDE

5.1 Background

Aluminum Nitride (AlN) is a direct bandgap semiconductor with an energy gap of 4.64 eV. AlN is a ceramic material with a high thermal conductivity and a high electrical resistivity. The scaling of devices and a higher integration of chips is an ever increasing demand in semiconductor industry. In high density packages, heat dissipation from electronic devices is an important parameter to achieve thermal management. Thus the material used for packaging must have high thermal conductivity and high electrical resistance[29-30].

AlN has excellent properties as a good packaging material. AlN mainly serves as a replacement to BeO, a material that causes toxicity. AlN offers safety without sacrificing product reliability[31]. In addition, AlN has become the choice of material in the fabrication of GaN based blue LEDs and laser diodes[32].

5.2 Summary of Properties

In Table 6, some of the mechanical, electrical and optical properties of AlN are presented. Aluminum Nitride has a hexagonal crystal structure. The thermal conductivity of AlN is 3.28 $Wcm^{-1}K^{-1}$, which makes this material useful for high density packaging. The physical properties of AlN are superior to that of alumina ceramics but they depend on the chemical purity of the material[33].

Table 6- Summary Of Properties of AlN [5,26]

Melting Temperature (K)	3273	lattice constant (A°)	a=3.1127 c=4.9816
Thermal Expansion (10^{-6}/K)	5.27(a) 4.15(c)	Density (g cm^{-3})	3.257
Poisson's ratio	0.26	S^{Γ}_{11} (TPa)	3.53
Hardness (Kg/mm^2)	1230	S^{Γ}_{12} (TPa)	-1.01
Molecular Weight (amu)	40.988	S^{Γ}_{44} (TPa)	8.47
Heat Capacity(J/g K)	0.796	Thermal Conductivity ($Wcm^{-1}K^{-1}$)	3.28
Debye Temperature (K)	950	Crystal System	Hexagonal
Elastic Moduli (GPa)	294	Bulk Moduli (GPa)	202

$S^{\Gamma}$is the elastic compliance (10^{-12} cm^2dyne^{-1})

5.3 Experimental Data of Optical Properties

The radiative properties of a 500 micron thick double side polished AlN sample was investigated using the spectral emissometer in the wavelength range of 1 to 20 microns and temperatures of room to 858°C. The optical spectra of this material is presented at temperatures of 161, 382, 657 and 858°C in Figs. 11 & 12. The emissivity of AlN is high and constant at 0.8 from 1 to 2 microns. A big absorption band is observed in the wavelength range of 5 to 10 microns. This absorption band is steady and is independent of temperature. The experimental data has been deconvoluted to yield the fundamental optical constants of this material. In Table 7, some of these constants at certain representative wavelengths are presented. In Appendix B, the full range of data of the wavelength dependent optical constants are given. The deconvoluted values of the refractive index, at various temperatures, are plotted as function of wavelength in Fig.13. The refractive index of AlN does not change significantly with changes in temperature and wavelength.

Table 7- Refractive index and extinction coefficient values of AlN at two different temperatures - 161°C and 858°C

λ(μm)	n(161)	k(161)	n(858)	k(858)
1.10	2.128	.000555	2.195	.000578
1.501	2.112	.000694	2.104	.000661
2.002	2.136	.000697	2.224	.000659
5.005	2.038	.000851	2.008	.001066
6.03	1.923	.001147	1.939	.001962
7.675	1.703	.006908	1.777	.005946
8.056	1.669	.007361	1.746	.004869
9.611	1.407	.008704	1.524	.007504
11.693	12.622	.006268	6.510	.004719
12.131	16.268	.008231	8.185	.001125
12.363	19.783	.004287	9.922	.001788

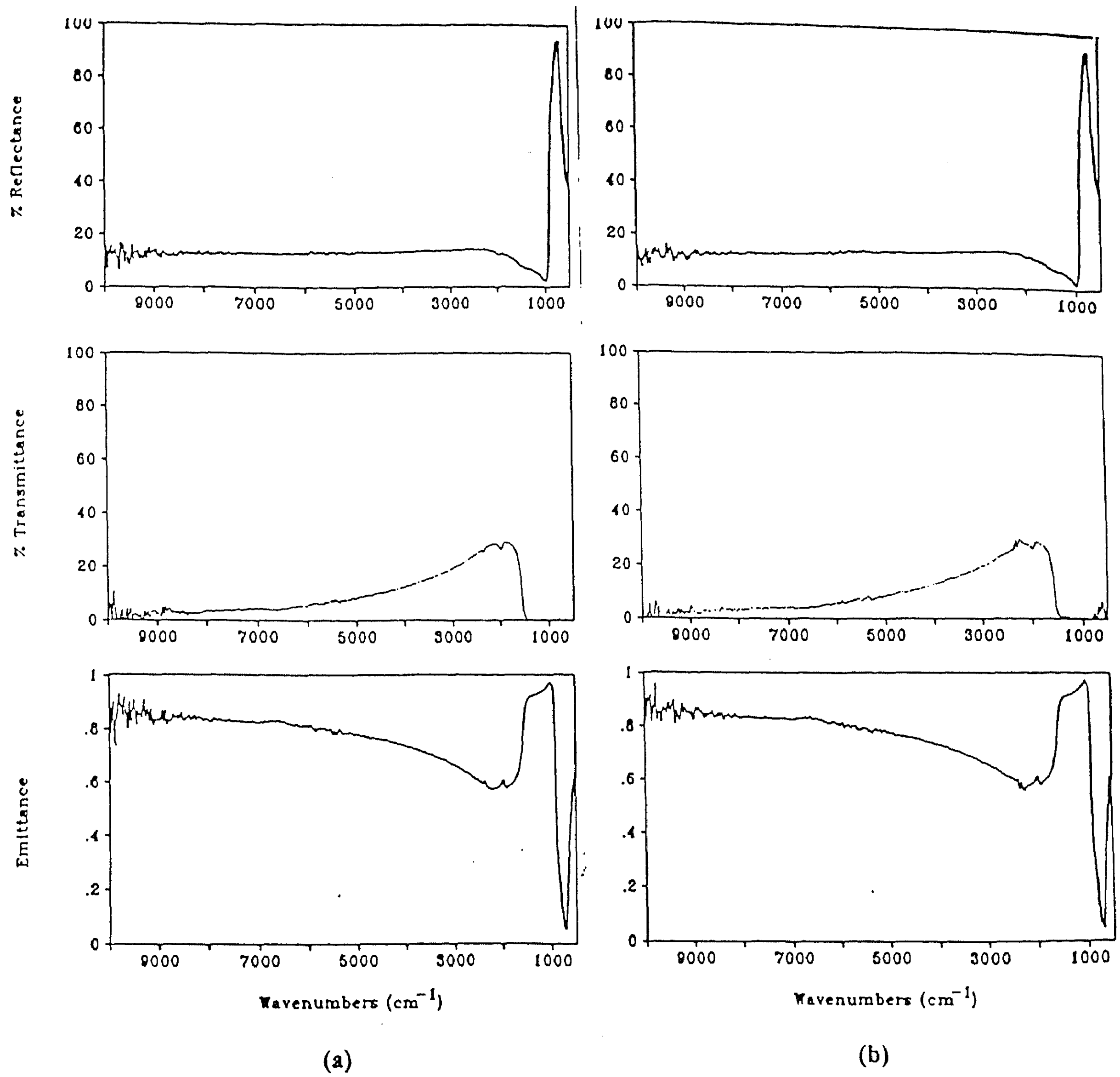
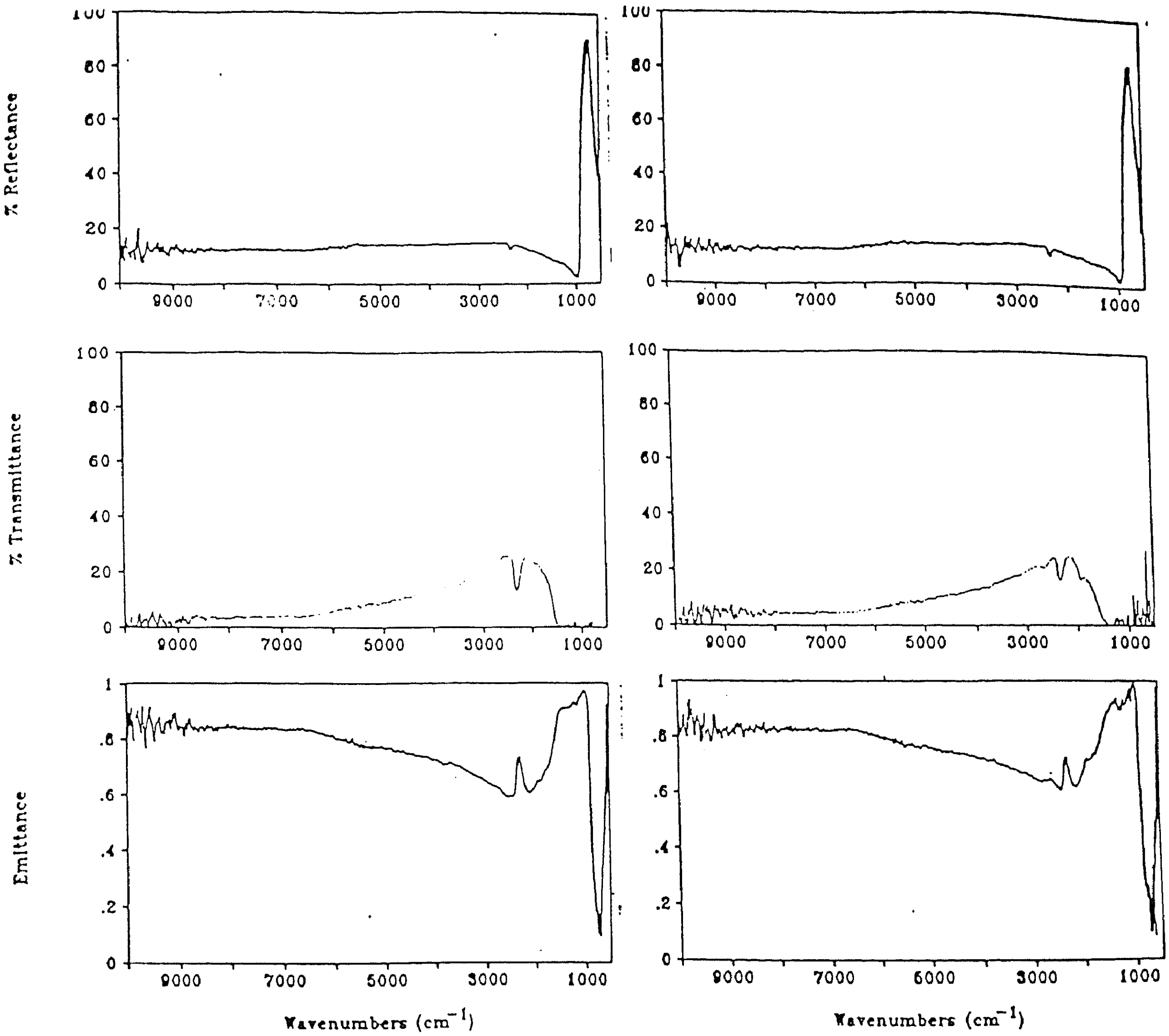


Fig.11 Temperature dependent optical properties of AlN:
(a) 161 °C (b) 382 °C.



(a) (b)

Fig.12 Temperature dependent optical properties of AlN:
(a) 657 °C (b) 858°C.

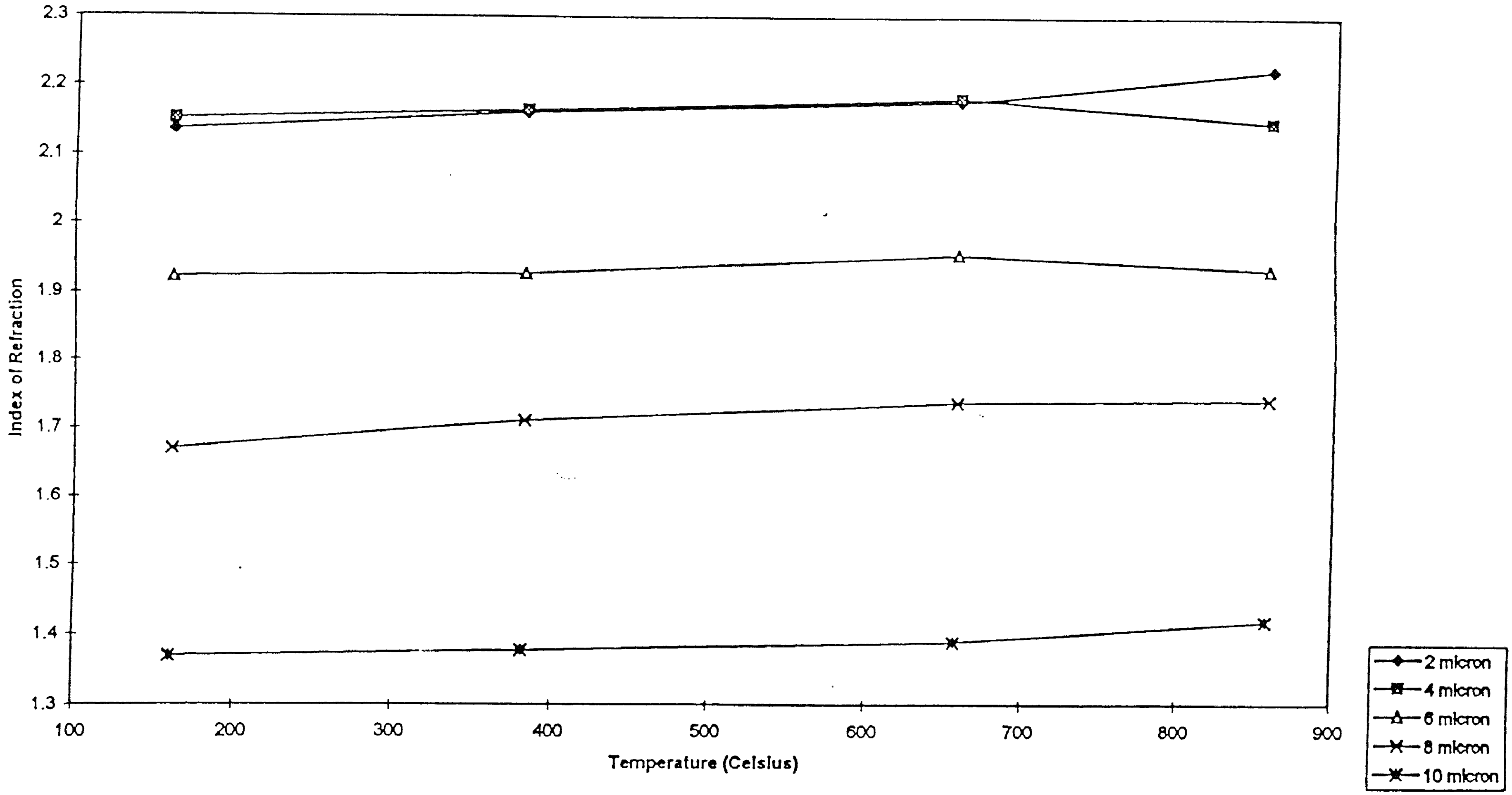


Fig.13 Refractive index of AlN as a function of temperature for 5 specific wavelengths.

CHAPTER 6

SAPPHIRE

6.1 Background

Sapphire is a direct bandgap semiconductor. It is widely used as an optical material. The main applications include infrared windows, substrate material for infrared detector, light emitting diodes, lasers and photodetector fabrication, silicon-on-sapphire (SOS), optical fibers etc.[5,34]. Sapphire can also be used as an optical fiber sensor. The advances in sapphire optical fiber sensor intended for use in high temperature environments were discussed by Wang Anbo[35]. The practical methods of improving reliability of high temperature measurements of sapphire fiber sensors have been discussed by Schietinger[36].

6.2 Summary of Properties

Thermal conductivity of sapphire is very low when compared with AlN. Sapphire is a very hard ceramic material with knoop hardness of 2250 kg/mm^2. It is easy to polish and less susceptible to handling damage. In Table 8, some of the properties of sapphire are summarized.

6.3 Literature Data of Optical Properties

In this section, the data on refractive index available in the literature[5] are presented. Table 9 shows the refractive index of sapphire between 1 to 6 micron wavelength range. The plot of refractive index versus wavelength is also shown in the Fig.14.

Table 8- Summary of Properties of Al_2O_3[5,26]

Melting Temperature (K)	2319	lattice constant (A°)	a=4.759 c=12.989
Thermal Expansion (10^{-6}/K)	6.65 (a), 7.15 (c)	Density (g cm^{-3})	3.987
Poisson's ratio	0.23	S^{Γ}_{11} (TPa)	2.38
Hardness (Kg/mm^2)	2250	S^{Γ}_{12} (TPa)	-0.70
Molecular Weight(amu)	101.96	S^{Γ}_{44} (TPa)	7.03
Heat Capacity(J/g K)	0.777	Thermal Conductivity ($Wcm^{-1}K^{-1}$)	0.46
DebyeTemperature (K)	1030	Crystal System	Hexagonal
Elastic Moduli (GPa)	400	Bulk Moduli (GPa)	250

S^{Γ} is the elastic compliance (10^{-12} cm^2dyne^{-1})

6.4 Experimental Data of Optical Properties

The optical properties of a 254 micron thick sapphire substrate was measured using the spectral emissometer at different wavelengths and various temperatures. In Figs.15 and 16, the measured spectra of sapphire at temperatures of 67, 754 and 53°C are presented. Sapphire is characterized by a very large transmission in the IR with subsequent decrease at 6 microns. Sapphire is highly absorbing in the wavelength range of 7 to 10 microns. Its emissivity approaches 1 at about 8 microns. The influence of high temperature is to broaden the peak in the long wavelength absorption in sapphire.

Table 9- Refractive index values of Al_2O_3 from literature[5]

λ(microns)	n
1.01398	1.75547
1.52952	1.74660
2.1526	1.73444
2.4374	1.72783
3.2439	1.70437
3.3026	1.70231
3.5070	1.69504
3.7067	1.68746
4.2553	1.66371
4.954	1.62665
5.1456	1.61514
5.419	1.59735
5.577	1.58638

Cooling the sample to 53°C is seen to reproduce the low temperature optical data of sapphire. Thus, heating the sapphire to 754°C has not changed the chemical composition of the sample. This is shown in Fig.15. The experimentally measured data of the optical properties have been deconvoluted to yield the fundamental optical constants. Table 10 presents some of these optical constants at various wavelengths. In Appendix C, the full

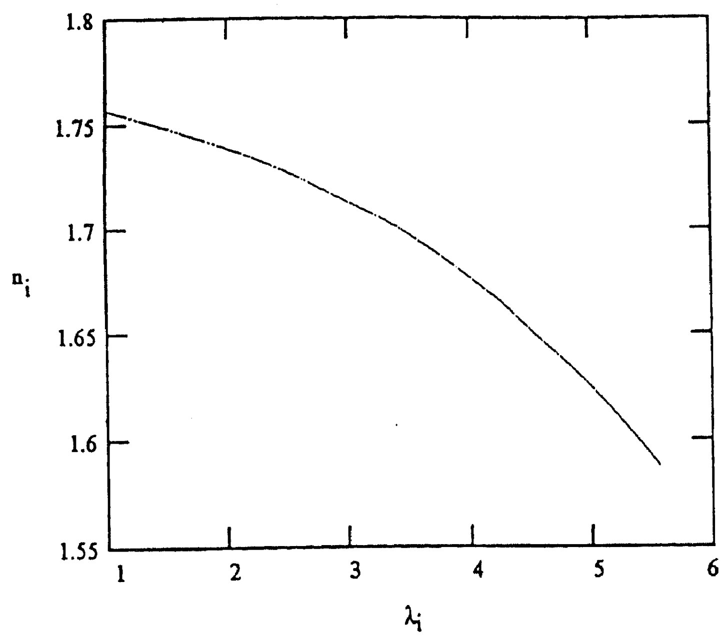


Fig.14 Refractive index Vs Wavelength of Sapphire from literature.

range of data of the optical properties are given. The deconvoluted values of refractive index, at 67°C, are plotted as function of wavelength in Fig.17. In the wavelength range of 12 to 16 microns, the refractive index of sapphire approaches high values resulting from its high reflectance.

Table 10- Refractive index and extinction coefficient values of Al_2O_3 at two different temperatures - 67°C and 658°C

λ(μm)	n(67)	k(67)	n(658)	k(658)
1.10	1.661	.000016	1.799	.000003
1.501	1.749	.000003	1.757	.000001
4.222	1.649	.000018	1.223	.000417
5.005	1.616	.000027	1.579	.000186
6.03	1.547	.000419	1.575	.001146
7.675	1.383	.007702	1.442	.010985
8.056	1.337	.008133	1.422	.011067
9.201	1.21	.010863	1.276	.013874
11.486	14.872	.008286	6.021	.014814
12.854	39.51	.00499	13.730	.008748
14.27	63.704	.001955	15.705	.004140

6.5 Comparative Study of Optical Properties

The measured values of emissivity of sapphire are in complete accordance with those available in the literature[37-38]. The refractive index data available in the literature were also compared with the experimental data in the available wavelength range. As can be seen from Fig.18, experimental results of the wavelength dependent refractive index of sapphire are in good agreement with those in the literature[5]. The experimental values of refractive index differ by literature values by about $\pm$ 1 %, this is reasonable because of the approximations used in deconvoluting the experimental data to yield optical constants.

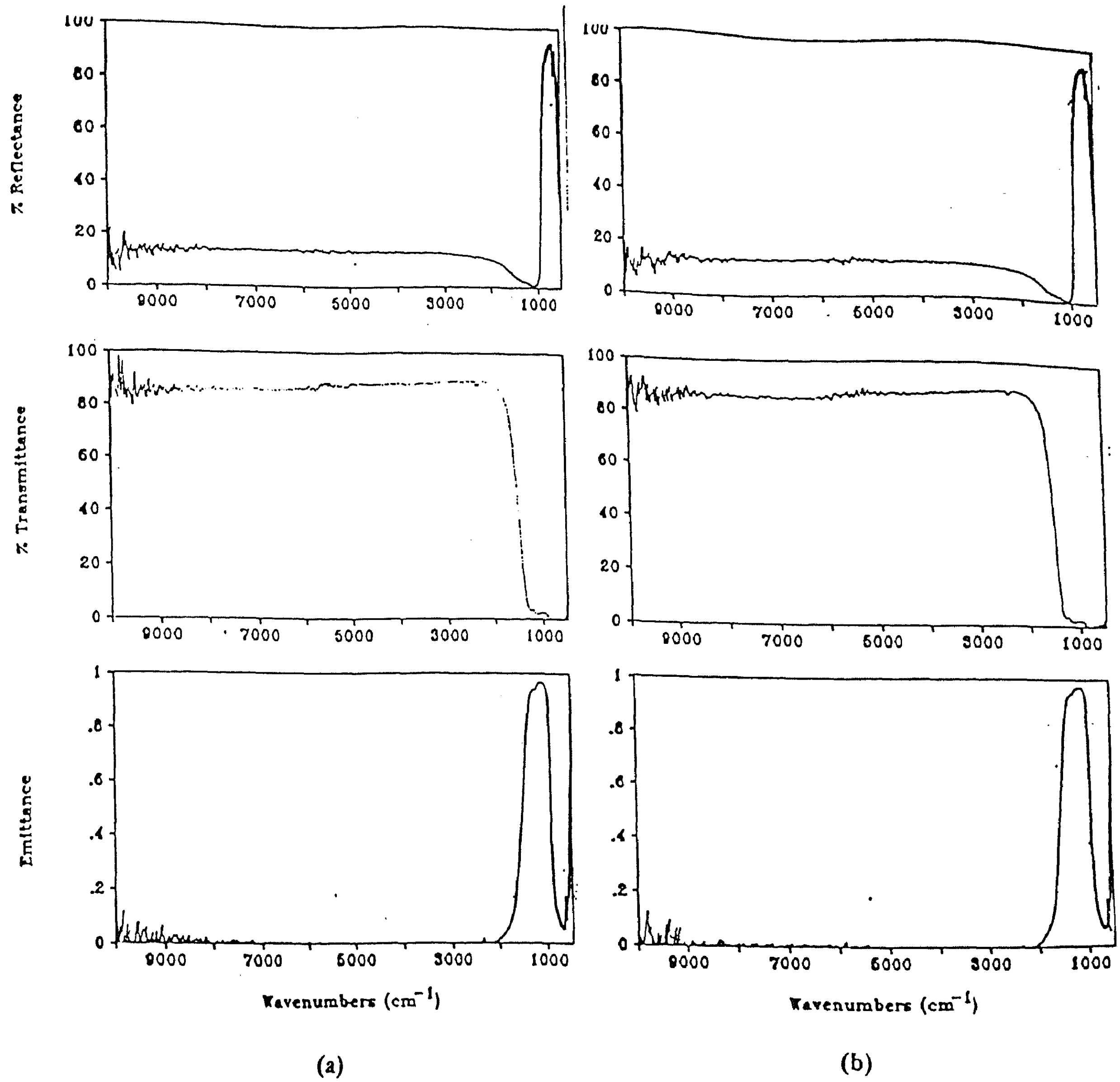


Fig.15 Temperature dependent optical properties of Sapphire:
(a) 67 °C (before heating) (b) 53 °C (after cooling)

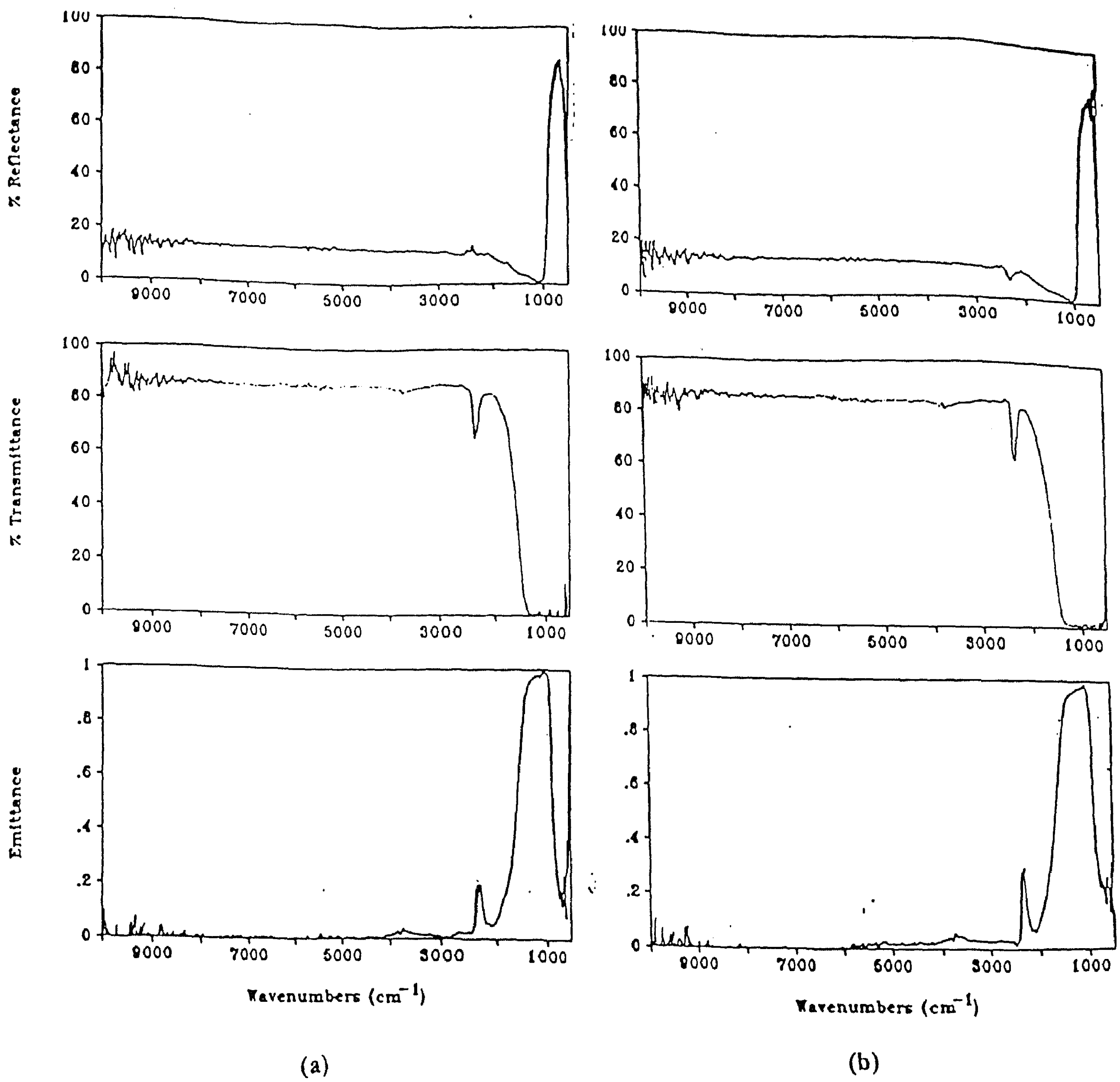


Fig.16 Temperature dependent optical properties of Sapphire:
(a) 460°C (b) 754 °C.

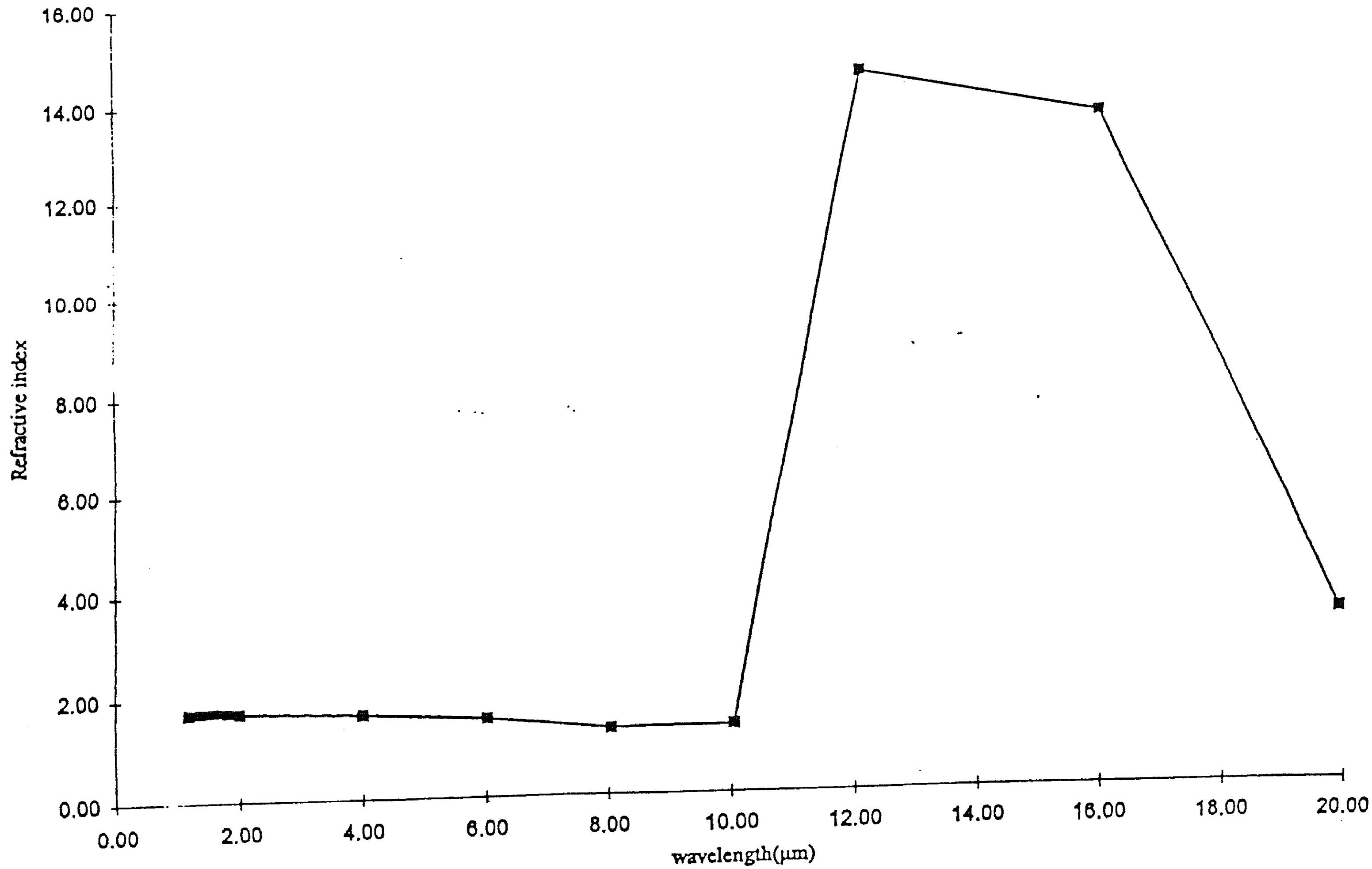


Fig.17 Refractive index Vs Wavelength of Sapphire at 67 °C.

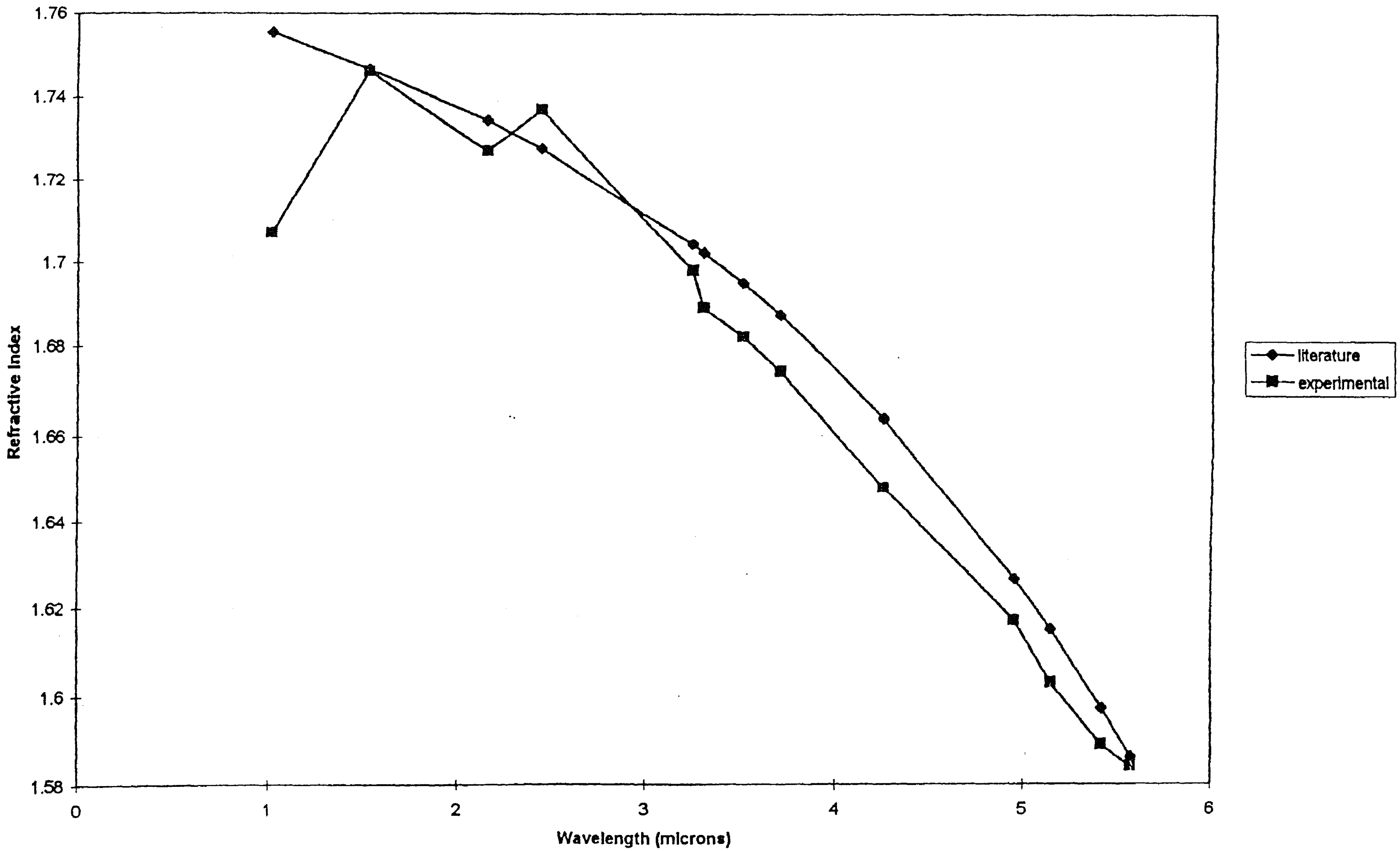


Fig.18 Comparison of literature and experimental values of Refractive index Vs Wavelength of Sapphire

CHAPTER 7

CONCLUSIONS

The experimental results presented in this thesis showed that the measurement of high temperature optical properties over the wavelength range of 1 to 20 microns and temperature range of 30 to 1500 °C could be performed reliably with a novel approach based on the use of a spectral emissometer. The temperature determination capability of the emissometer was tested and verified using a standard thermocouple embedded in a silicon wafer. The temperature measurement accuracy, with the emissometer, was found to be within ± 10 °C of the thermocouple temperature in the temperature range of 30 to 300 °C. The reliability of the measured temperature dependent optical properties of the semiconductor materials investigated in this thesis was established in the following manner:

- For Fe doped InP sample, the steep increase in its emissivity at 479 °C at 1.2 microns is due to band gap absorption. This wavelength, indeed, corresponds to the absorption edge of InP.
- The observed sharp peak in the emissivity of Fe doped InP at 14 microns is in complete accord with literature [28] and is due to multi-phonon absorption in InP.
- The deconvoluted values of the refractive indices from the measured optical properties of Fe doped InP are within ± 10 % of the limited refractive index data available in the literature.
- Sulfur doped InP shows increase in emissivity with temperature due to increase in carrier concentration. Unlike Fe, which as a deep level in the valence band of InP,

sulfur is a shallow donor and consequently influences the free carrier concentration in InP.

- Emissivity of AlN is high and constant at 0.8 from 1 to 2 microns because of its high absorption.
- Sapphire exhibits emissivity approaching 1 at 8 microns. In the wavelength range of 12 to 16 microns the refractive indices of sapphire approach high values resulting from its high reflectance.

The deconvoluted wavelength dependent values of refractive index of sapphire are within $\pm$ 5 % of the literature data.

Recommendations:

Spectral emissometry has thus been established as a reliable technique for simultaneous measurement of temperature and optical properties of semiconductors. In order to make this technique user-friendly and clean, the following improvements in the measuring system needs to be incorporated:

A better method of non-contact heating should be developed as opposed to high temperature flames or torches.

A sample chamber with a controlled environment would be very helpful in keeping the measurement process and surface conditions of the sample free of contaminants.

It is proposed that future work be aimed at integrating the portable emissometer with a rapid thermal processing chamber for in-line, real-time measurement and control of process temperature and thickness of grown / deposited films.

APPENDICES

APPENDIX A1: InP S-DOPED OPTICAL CONSTANTS DATA AT 99 °C

LAMBDA	EXTCOEF	REFINDEX	EPSILON1	EPSILON2	ALPHA
1	0.000212	3.055	9.334	0.0013	0.002669
1.002	0.000192	3.302	10.905	0.00127	0.002407
1.003	0.000117	3.075	9.458	0.00072	0.001462
1.005	0.000107	2.916	8.5	0.00063	0.001342
1.006	0.000098	3.335	11.125	0.00066	0.001229
1.008	0.000086	3.319	11.013	0.00057	0.001073
1.01	0.000089	3.087	9.532	0.00055	0.001113
1.011	0.000105	3.133	9.815	0.00066	0.001309
1.013	0.000095	3.217	10.349	0.00061	0.001178
1.014	0.000085	3.022	9.134	0.00051	0.00105
1.016	0.000065	3.245	10.529	0.00042	0.000799
1.017	0.000057	3.34	11.153	0.00038	0.000704
1.019	0.000075	3.087	9.53	0.00046	0.000925
1.021	0.000068	3.221	10.377	0.00044	0.000837
1.022	0.000031	3.361	11.298	0.00021	0.000386
1.024	0.000032	3.236	10.474	0.00021	0.000398
1.026	0.000067	2.834	8.03	0.00038	0.00082
1.027	0.000082	2.735	7.481	0.00045	0.001002
1.029	0.000083	2.86	8.178	0.00048	0.001018
1.03	0.000085	3.182	10.127	0.00054	0.001042
1.032	0.000096	3.205	10.271	0.00061	0.001167
1.034	0.000093	3.102	9.623	0.00057	0.001126
1.035	0.000071	3.44	11.832	0.00049	0.000863
1.037	0.00006	3.225	10.399	0.00038	0.000723
1.039	0.000077	3.08	9.488	0.00047	0.00093
1.04	0.000072	3.343	11.176	0.00048	0.000875
1.042	0.000054	3.349	11.213	0.00036	0.000654
1.044	0.000062	3.257	10.606	0.0004	0.000747
1.045	0.000068	3.308	10.942	0.00045	0.000818
1.047	0.00007	3.147	9.901	0.00044	0.000843
1.049	0.000082	2.948	8.691	0.00048	0.000977
1.05	0.00009	2.877	8.275	0.00052	0.001077
1.052	0.00008	2.984	8.905	0.00048	0.000961
1.054	0.000073	3.09	9.549	0.00045	0.000872
1.056	0.00007	3.159	9.978	0.00044	0.000829
1.057	0.000068	3.26	10.627	0.00044	0.000807
1.059	0.000069	3.429	11.761	0.00047	0.000813
1.061	0.00008	3.207	10.284	0.00052	0.000952
1.063	0.000076	2.973	8.838	0.00045	0.000902
1.064	0.000081	3.087	9.53	0.0005	0.000954
1.066	0.000088	3.16	9.985	0.00056	0.001042
1.068	0.000073	3.146	9.9	0.00046	0.000859
1.07	0.000056	3.248	10.55	0.00037	0.000663
1.071	0.000065	3.236	10.469	0.00042	0.000765
1.073	0.000091	3.085	9.518	0.00056	0.001062
1.075	0.000081	3.055	9.335	0.0005	0.000948
1.077	0.00007	3.192	10.192	0.00044	0.000813
1.078	0.000072	3.233	10.452	0.00046	0.000837
1.08	0.000066	3.056	9.337	0.0004	0.000768

1.082	0.000073	3.064	9.391	0.00045	0.000844
1.084	0.00007	3.113	9.694	0.00043	0.000809
1.086	0.000073	3.061	9.369	0.00045	0.000848
1.088	0.000074	3.025	9.148	0.00045	0.000858
1.089	0.00006	3.105	9.639	0.00038	0.000698
1.091	0.000071	3.097	9.591	0.00044	0.000823
1.093	0.000079	3.012	9.074	0.00048	0.000909
1.095	0.000083	3.034	9.207	0.0005	0.00095
1.097	0.00008	3.049	9.299	0.00049	0.000922
1.099	0.000075	3.052	9.316	0.00046	0.000858
1.1	0.000072	3.09	9.549	0.00045	0.000826
1.102	0.000064	3.109	9.667	0.0004	0.000735
1.104	0.000069	3.1	9.611	0.00043	0.000783
1.106	0.000076	3.035	9.212	0.00046	0.000863
1.108	0.000069	3.015	9.092	0.00042	0.000787
1.11	0.000064	3.044	9.265	0.00039	0.000723
1.112	0.000073	3.037	9.225	0.00044	0.000827
1.114	0.000086	3.057	9.348	0.00053	0.000971
1.116	0.000082	3.084	9.512	0.00051	0.000924
1.118	0.000063	3.11	9.675	0.00039	0.000706
1.12	0.00006	3.085	9.52	0.00037	0.000672
1.121	0.000072	3.163	10.002	0.00046	0.000808
1.123	0.000079	3.171	10.053	0.0005	0.000884
1.125	0.000082	3.031	9.187	0.0005	0.000914
1.127	0.00008	3.027	9.162	0.00049	0.000896
1.129	0.000073	3.145	9.888	0.00046	0.000818
1.131	0.00007	3.186	10.15	0.00045	0.00078
1.133	0.000062	3.156	9.962	0.00039	0.000683
1.135	0.000065	3.077	9.465	0.0004	0.000715
1.137	0.000071	3.042	9.252	0.00043	0.000782
1.139	0.00007	3.092	9.56	0.00043	0.000771
1.141	0.000071	3.123	9.753	0.00045	0.000787
1.143	0.000066	3.121	9.739	0.00041	0.000729
1.145	0.000066	3.11	9.67	0.00041	0.000724
1.147	0.00007	3.057	9.343	0.00043	0.000763
1.149	0.000069	3.06	9.363	0.00042	0.000755
1.151	0.000065	3.068	9.416	0.0004	0.000715
1.153	0.000065	2.99	8.94	0.00039	0.000706
1.155	0.000066	3.023	9.137	0.0004	0.000716
1.158	0.000067	3.06	9.363	0.00041	0.000731
1.16	0.000068	3.09	9.548	0.00042	0.000741
1.162	0.000066	3.156	9.958	0.00042	0.000715
1.164	0.000064	3.119	9.725	0.0004	0.000688
1.166	0.000067	3.125	9.764	0.00042	0.000721
1.168	0.000067	3.167	10.032	0.00042	0.00072
1.17	0.000069	3.19	10.177	0.00044	0.000743
1.172	0.000076	3.147	9.903	0.00048	0.00082
1.174	0.00007	3.085	9.515	0.00043	0.000744
1.176	0.000062	3.103	9.631	0.00038	0.00066
1.179	0.000066	3.088	9.535	0.00041	0.000704
1.181	0.000071	3.077	9.466	0.00044	0.000755

1.183	0.000067	3.149	9.916	0.00042	0.000711
1.185	0.000066	3.137	9.844	0.00041	0.000697
1.187	0.000069	3.083	9.508	0.00042	0.000728
1.189	0.000071	3.098	9.597	0.00044	0.000755
1.192	0.000073	3.114	9.697	0.00045	0.000765
1.194	0.00007	3.1	9.613	0.00043	0.000737
1.196	0.000068	3.03	9.182	0.00041	0.000715
1.198	0.000068	2.995	8.971	0.00041	0.000718
1.2	0.00007	3.041	9.247	0.00043	0.000738
1.203	0.000072	3.044	9.268	0.00044	0.000747
1.205	0.000069	3.056	9.341	0.00042	0.00072
1.207	0.000066	3.084	9.514	0.00041	0.000686
1.209	0.000067	3.095	9.58	0.00041	0.000692
1.212	0.000067	3.089	9.539	0.00042	0.000697
1.214	0.00007	3.064	9.39	0.00043	0.000722
1.216	0.000072	3.066	9.4	0.00044	0.000749
1.219	0.000073	3.071	9.434	0.00045	0.000755
1.221	0.000073	3.04	9.243	0.00044	0.000748
1.223	0.000071	3.052	9.312	0.00044	0.000734
1.225	0.000074	3.049	9.299	0.00045	0.000759
1.228	0.000075	3.029	9.174	0.00045	0.000764
1.23	0.00007	3.056	9.342	0.00043	0.000715
1.232	0.00007	3.048	9.289	0.00043	0.000715
1.235	0.000072	3.037	9.221	0.00044	0.00073
1.237	0.000071	3.063	9.38	0.00043	0.000719
1.24	0.000067	3.071	9.433	0.00041	0.000684
1.242	0.000066	3.049	9.299	0.0004	0.000671
1.244	0.000069	3.055	9.333	0.00042	0.000699
1.247	0.000066	3.087	9.527	0.0004	0.000661
1.249	0.000066	3.069	9.42	0.0004	0.000659
1.252	0.000069	3.068	9.411	0.00042	0.000695
1.254	0.000068	3.061	9.37	0.00041	0.000679
1.256	0.000064	3.083	9.507	0.00039	0.000639
1.259	0.000064	3.109	9.666	0.0004	0.000637
1.261	0.000065	3.078	9.474	0.0004	0.00065
1.264	0.000065	3.066	9.402	0.0004	0.00065
1.266	0.000067	3.08	9.486	0.00041	0.000661
1.269	0.000066	3.092	9.559	0.00041	0.00065
1.271	0.000065	3.098	9.598	0.0004	0.00064
1.274	0.000065	3.091	9.552	0.0004	0.000643
1.276	0.000066	3.064	9.385	0.00041	0.000653
1.279	0.000064	3.079	9.479	0.00039	0.00063
1.281	0.000062	3.089	9.541	0.00038	0.000608
1.284	0.000065	3.108	9.66	0.0004	0.000633
1.286	0.000066	3.122	9.745	0.00041	0.000643
1.289	0.000066	3.096	9.586	0.00041	0.000639
1.291	0.000066	3.074	9.449	0.00041	0.000647
1.294	0.000067	3.063	9.383	0.00041	0.00065
1.297	0.000067	3.057	9.345	0.00041	0.00065
1.299	0.000066	3.075	9.456	0.00041	0.000642
1.302	0.000066	3.065	9.393	0.0004	0.000637

1.304	0.000067	3.051	9.312	0.00041	0.000648
1.307	0.000067	3.07	9.425	0.00041	0.000643
1.31	0.000066	3.072	9.437	0.0004	0.000632
1.312	0.000067	3.058	9.351	0.00041	0.00064
1.315	0.000067	3.066	9.399	0.00041	0.000638
1.318	0.000065	3.088	9.534	0.0004	0.000617
1.32	0.000064	3.077	9.466	0.00039	0.000605
1.323	0.000064	3.073	9.446	0.00039	0.000606
1.326	0.000065	3.072	9.439	0.0004	0.000617
1.329	0.000066	3.062	9.377	0.0004	0.000625
1.331	0.000067	3.058	9.35	0.00041	0.000633
1.334	0.000065	3.066	9.403	0.0004	0.000616
1.337	0.000064	3.076	9.459	0.00039	0.0006
1.34	0.000065	3.079	9.479	0.0004	0.000609
1.342	0.000065	3.066	9.401	0.0004	0.000611
1.345	0.000065	3.056	9.342	0.0004	0.000609
1.348	0.000066	3.062	9.375	0.00041	0.000618
1.351	0.000066	3.075	9.455	0.00041	0.000614
1.354	0.000065	3.07	9.422	0.0004	0.000608
1.356	0.000066	3.041	9.249	0.0004	0.000615
1.359	0.000066	3.053	9.319	0.00041	0.000614
1.362	0.000067	3.062	9.377	0.00041	0.000618
1.365	0.000066	3.053	9.319	0.0004	0.000608
1.368	0.000065	3.049	9.298	0.00039	0.000595
1.371	0.000065	3.062	9.377	0.0004	0.000593
1.374	0.000064	3.067	9.404	0.00039	0.000586
1.377	0.000064	3.054	9.329	0.00039	0.000588
1.38	0.000066	3.065	9.392	0.0004	0.000597
1.382	0.000066	3.066	9.403	0.00041	0.000601
1.385	0.000066	3.059	9.359	0.0004	0.000598
1.388	0.000066	3.044	9.265	0.0004	0.000594
1.391	0.000065	3.045	9.27	0.0004	0.000591
1.394	0.000065	3.045	9.275	0.0004	0.000588
1.397	0.000066	3.045	9.27	0.0004	0.000593
1.4	0.000065	3.059	9.355	0.0004	0.000588
1.403	0.000066	3.042	9.256	0.0004	0.000589
1.406	0.000065	3.044	9.265	0.0004	0.000582
1.41	0.000064	3.064	9.388	0.00039	0.000568
1.413	0.000063	3.066	9.401	0.00039	0.000561
1.416	0.000063	3.055	9.333	0.00039	0.00056
1.419	0.000064	3.052	9.316	0.00039	0.000567
1.422	0.000062	3.063	9.381	0.00038	0.000551
1.425	0.000062	3.068	9.415	0.00038	0.000546
1.428	0.000062	3.061	9.37	0.00038	0.000545
1.431	0.000061	3.05	9.301	0.00037	0.00054
1.435	0.000062	3.057	9.346	0.00038	0.000543
1.438	0.000061	3.07	9.424	0.00038	0.000536
1.441	0.00006	3.066	9.402	0.00037	0.000525
1.444	0.000059	3.056	9.34	0.00036	0.000515
1.447	0.00006	3.052	9.317	0.00036	0.000517
1.451	0.00006	3.051	9.311	0.00036	0.000516

1.454	0.00006	3.055	9.332	0.00036	0.000515
1.457	0.00006	3.065	9.396	0.00037	0.000518
1.46	0.000059	3.061	9.371	0.00036	0.000504
1.464	0.000058	3.044	9.265	0.00035	0.000497
1.467	0.000059	3.039	9.234	0.00036	0.000506
1.47	0.000059	3.055	9.333	0.00036	0.000504
1.474	0.000059	3.051	9.309	0.00036	0.000507
1.477	0.00006	3.037	9.223	0.00036	0.00051
1.48	0.000058	3.041	9.249	0.00035	0.000492
1.484	0.000057	3.049	9.294	0.00035	0.000487
1.487	0.000058	3.053	9.322	0.00035	0.000489
1.491	0.000057	3.058	9.35	0.00035	0.00048
1.494	0.000057	3.057	9.346	0.00035	0.000476
1.498	0.000057	3.053	9.323	0.00035	0.000475
1.501	0.000056	3.056	9.338	0.00034	0.000471
1.505	0.000057	3.057	9.345	0.00035	0.000472
1.508	0.000056	3.056	9.342	0.00034	0.000468
1.512	0.000056	3.059	9.36	0.00034	0.000466
1.515	0.000057	3.051	9.308	0.00035	0.000473
1.519	0.000057	3.041	9.249	0.00035	0.000471
1.522	0.000056	3.047	9.283	0.00034	0.000461
1.526	0.000055	3.052	9.315	0.00033	0.00045
1.529	0.000054	3.063	9.38	0.00033	0.000447
1.533	0.000055	3.063	9.383	0.00034	0.00045
1.537	0.000055	3.054	9.328	0.00033	0.000448
1.54	0.000054	3.059	9.36	0.00033	0.000438
1.544	0.000053	3.066	9.4	0.00032	0.000428
1.548	0.000053	3.054	9.326	0.00032	0.00043
1.551	0.000053	3.044	9.267	0.00032	0.000428
1.555	0.000053	3.045	9.27	0.00032	0.000428
1.559	0.000053	3.045	9.271	0.00032	0.000426
1.563	0.000052	3.049	9.296	0.00031	0.000415
1.566	0.000051	3.057	9.342	0.00031	0.000409
1.57	0.000052	3.056	9.34	0.00032	0.000414
1.574	0.000052	3.052	9.317	0.00032	0.000413
1.578	0.000051	3.048	9.292	0.00031	0.000403
1.582	0.00005	3.048	9.291	0.00031	0.0004
1.586	0.000051	3.046	9.277	0.00031	0.000408
1.589	0.000052	3.036	9.219	0.00032	0.000411
1.593	0.000051	3.041	9.246	0.00031	0.000404
1.597	0.000052	3.051	9.307	0.00032	0.00041
1.601	0.000052	3.052	9.313	0.00032	0.000405
1.605	0.000051	3.038	9.232	0.00031	0.000403
1.609	0.000054	3.044	9.266	0.00033	0.000422
1.613	0.000055	3.037	9.222	0.00034	0.000431
1.617	0.000055	3.012	9.074	0.00033	0.000431
1.621	0.000054	3.013	9.078	0.00033	0.000421
1.625	0.000054	3.016	9.096	0.00033	0.000421
1.629	0.000055	3.013	9.075	0.00033	0.000426
1.634	0.000055	3.008	9.046	0.00033	0.000421
1.638	0.000056	3.001	9.009	0.00034	0.000432

1.642	0.000059	3.002	9.011	0.00035	0.000451
1.646	0.00006	3.008	9.05	0.00036	0.000457
1.65	0.000058	3.012	9.073	0.00035	0.000444
1.654	0.000057	3.014	9.085	0.00034	0.000434
1.659	0.000058	3.024	9.142	0.00035	0.000438
1.663	0.000059	3.034	9.207	0.00036	0.000446
1.667	0.00006	3.011	9.066	0.00036	0.00045
1.672	0.00006	2.988	8.927	0.00036	0.00045
1.676	0.000059	3.005	9.029	0.00036	0.000445
1.68	0.000063	3.003	9.021	0.00038	0.000472
1.685	0.000067	2.981	8.883	0.0004	0.000496
1.689	0.000065	3.001	9.009	0.00039	0.000481
1.693	0.000063	3.015	9.09	0.00038	0.000468
1.698	0.000064	3.005	9.029	0.00038	0.000471
1.702	0.000064	2.979	8.875	0.00038	0.000475
1.707	0.000065	2.977	8.86	0.00038	0.000475
1.711	0.000068	2.98	8.878	0.0004	0.000498
1.716	0.000073	2.949	8.699	0.00043	0.000532
1.72	0.000072	2.949	8.695	0.00042	0.000526
1.725	0.00007	2.977	8.862	0.00042	0.000509
1.73	0.000072	2.974	8.845	0.00043	0.000523
1.734	0.000072	2.964	8.783	0.00043	0.000521
1.739	0.000073	2.954	8.727	0.00043	0.000529
1.744	0.000073	2.954	8.726	0.00043	0.000527
1.748	0.000071	2.97	8.821	0.00042	0.000512
1.753	0.000074	2.945	8.675	0.00044	0.000533
1.758	0.000079	2.874	8.261	0.00045	0.000562
1.763	0.000082	2.853	8.137	0.00047	0.000586
1.767	0.000083	2.911	8.475	0.00048	0.000591
1.772	0.000084	2.94	8.642	0.00049	0.000592
1.777	0.000081	2.917	8.511	0.00047	0.000572
1.782	0.000081	2.875	8.263	0.00047	0.000572
1.787	0.000082	2.891	8.356	0.00047	0.000574
1.792	0.000083	2.947	8.686	0.00049	0.000582
1.797	0.000088	2.925	8.555	0.00051	0.000615
1.802	0.000092	2.876	8.269	0.00053	0.000639
1.807	0.00009	2.857	8.163	0.00052	0.000628
1.812	0.00009	2.841	8.071	0.00051	0.000626
1.817	0.000094	2.873	8.252	0.00054	0.000649
1.822	0.00009	2.906	8.444	0.00053	0.000624
1.827	0.000087	2.899	8.403	0.00051	0.000601
1.832	0.000088	2.899	8.403	0.00051	0.000601
1.838	0.000095	2.84	8.065	0.00054	0.000648
1.843	0.0001	2.822	7.966	0.00057	0.000685
1.848	0.000098	2.845	8.093	0.00056	0.000669
1.853	0.000099	2.86	8.18	0.00056	0.000669
1.859	0.000102	2.872	8.247	0.00058	0.000689
1.864	0.000104	2.879	8.289	0.0006	0.000702
1.869	0.000106	2.857	8.163	0.0006	0.000711
1.875	0.000108	2.845	8.094	0.00062	0.000727
1.88	0.00011	2.89	8.352	0.00064	0.000736

1.886	0.000104	2.891	8.357	0.0006	0.000693
1.891	0.0001	2.856	8.158	0.00057	0.000663
1.897	0.000098	2.848	8.113	0.00056	0.000652
1.902	0.000098	2.882	8.306	0.00056	0.000646
1.908	0.000103	2.868	8.225	0.00059	0.000678
1.914	0.000107	2.853	8.138	0.00061	0.000702
1.919	0.000105	2.879	8.289	0.00061	0.000689
1.925	0.000107	2.865	8.206	0.00061	0.000701
1.931	0.000114	2.812	7.908	0.00064	0.000741
1.936	0.000115	2.83	8.007	0.00065	0.000745
1.942	0.000109	2.842	8.075	0.00062	0.000708
1.948	0.000109	2.825	7.978	0.00061	0.000702
1.954	0.000111	2.846	8.1	0.00063	0.000714
1.96	0.000111	2.849	8.117	0.00063	0.000711
1.966	0.00011	2.865	8.21	0.00063	0.000701
1.972	0.00011	2.878	8.283	0.00063	0.000701
1.978	0.000111	2.868	8.228	0.00064	0.000707
1.984	0.000111	2.852	8.135	0.00063	0.000705
1.99	0.000111	2.845	8.092	0.00063	0.000699
1.996	0.000112	2.858	8.169	0.00064	0.000703
2.002	0.000115	2.852	8.135	0.00066	0.000725
2.009	0.000113	2.851	8.13	0.00065	0.00071
2.015	0.000114	2.868	8.224	0.00066	0.000713
2.021	0.000121	2.836	8.042	0.00069	0.000752
2.027	0.000125	2.809	7.889	0.0007	0.000774
2.034	0.000123	2.848	8.111	0.0007	0.000762
2.04	0.00012	2.868	8.227	0.00069	0.00074
2.047	0.000123	2.839	8.058	0.0007	0.000753
2.053	0.000124	2.83	8.01	0.0007	0.000759
2.06	0.000122	2.847	8.104	0.00069	0.000744
2.066	0.000121	2.847	8.105	0.00069	0.000736
2.073	0.000122	2.857	8.163	0.00069	0.000737
2.08	0.000123	2.857	8.165	0.0007	0.000742
2.086	0.000125	2.829	8.001	0.00071	0.000752
2.093	0.000127	2.818	7.94	0.00072	0.000764
2.1	0.000129	2.835	8.036	0.00073	0.00077
2.107	0.000128	2.834	8.034	0.00073	0.000767
2.113	0.000127	2.831	8.016	0.00072	0.000758
2.12	0.000127	2.847	8.108	0.00072	0.000754
2.127	0.000131	2.844	8.086	0.00075	0.000775
2.134	0.000134	2.832	8.023	0.00076	0.00079
2.141	0.000135	2.823	7.967	0.00076	0.000795
2.149	0.000137	2.834	8.033	0.00077	0.0008
2.156	0.000139	2.847	8.108	0.00079	0.000809
2.163	0.000139	2.828	7.995	0.00078	0.000806
2.17	0.000136	2.843	8.081	0.00077	0.000785
2.177	0.000135	2.871	8.24	0.00078	0.00078
2.185	0.000139	2.848	8.11	0.00079	0.000798
2.192	0.000141	2.827	7.99	0.0008	0.000811
2.2	0.000141	2.829	8.001	0.0008	0.000808
2.207	0.000141	2.831	8.015	0.0008	0.000803

2.215	0.000144	2.825	7.981	0.00081	0.000817
2.222	0.000147	2.819	7.948	0.00083	0.000831
2.23	0.000148	2.824	7.975	0.00084	0.000835
2.238	0.000151	2.823	7.967	0.00085	0.000849
2.245	0.000154	2.823	7.972	0.00087	0.000863
2.253	0.000154	2.819	7.948	0.00087	0.000858
2.261	0.000153	2.811	7.899	0.00086	0.000848
2.269	0.000153	2.814	7.919	0.00086	0.000848
2.277	0.000154	2.819	7.944	0.00087	0.000851
2.285	0.000157	2.818	7.942	0.00089	0.000865
2.293	0.000159	2.82	7.954	0.0009	0.00087
2.301	0.00016	2.817	7.936	0.0009	0.000876
2.309	0.00016	2.824	7.973	0.00091	0.000873
2.318	0.000162	2.817	7.938	0.00091	0.000881
2.326	0.000164	2.803	7.858	0.00092	0.000887
2.334	0.000164	2.82	7.953	0.00092	0.000883
2.343	0.000166	2.839	8.058	0.00094	0.000892
2.351	0.00017	2.828	8	0.00096	0.000909
2.36	0.000172	2.813	7.915	0.00097	0.000915
2.369	0.000172	2.814	7.92	0.00097	0.000912
2.377	0.000174	2.814	7.918	0.00098	0.000919
2.386	0.000176	2.807	7.878	0.00099	0.000929
2.395	0.000178	2.807	7.878	0.001	0.000934
2.404	0.00018	2.815	7.923	0.00101	0.000941
2.413	0.000183	2.812	7.909	0.00103	0.000952
2.422	0.000185	2.815	7.922	0.00104	0.000959
2.431	0.000187	2.812	7.906	0.00105	0.000966
2.44	0.00019	2.806	7.871	0.00107	0.000979
2.449	0.000191	2.801	7.844	0.00107	0.000982
2.459	0.000195	2.791	7.792	0.00109	0.000995
2.468	0.000198	2.796	7.816	0.00111	0.001008
2.477	0.0002	2.79	7.783	0.00112	0.001016
2.487	0.000201	2.785	7.756	0.00112	0.001016
2.496	0.000204	2.79	7.786	0.00114	0.001026
2.506	0.000206	2.791	7.788	0.00115	0.001033
2.516	0.000207	2.79	7.786	0.00116	0.001036
2.526	0.000212	2.781	7.735	0.00118	0.001057
2.535	0.000214	2.778	7.719	0.00119	0.001062
2.546	0.000219	2.783	7.745	0.00122	0.00108
2.556	0.000224	2.772	7.686	0.00124	0.001103
2.566	0.000228	2.768	7.663	0.00126	0.001118
2.576	0.000236	2.771	7.677	0.00131	0.001149
2.586	0.000238	2.779	7.721	0.00132	0.001158
2.597	0.000242	2.756	7.598	0.00133	0.001172
2.607	0.000246	2.759	7.615	0.00136	0.001188
2.618	0.000245	2.777	7.71	0.00136	0.001177
2.628	0.000243	2.767	7.658	0.00135	0.001164
2.639	0.000246	2.761	7.626	0.00136	0.001174
2.65	0.000256	2.746	7.539	0.0014	0.001213
2.661	0.000267	2.739	7.5	0.00146	0.001259
2.672	0.000268	2.763	7.633	0.00148	0.00126

2.683	0.000264	2.773	7.687	0.00146	0.001238
2.694	0.000264	2.777	7.713	0.00147	0.001233
2.705	0.000268	2.781	7.735	0.00149	0.001246
2.716	0.000271	2.771	7.679	0.0015	0.001256
2.728	0.000274	2.762	7.626	0.00151	0.001261
2.739	0.000277	2.758	7.605	0.00153	0.00127
2.751	0.000279	2.766	7.648	0.00155	0.001277
2.763	0.000282	2.776	7.708	0.00157	0.001284
2.775	0.000285	2.763	7.633	0.00158	0.001293
2.786	0.000289	2.75	7.565	0.00159	0.001306
2.799	0.000291	2.763	7.637	0.00161	0.001305
2.811	0.000292	2.777	7.711	0.00162	0.001305
2.823	0.000293	2.782	7.739	0.00163	0.001306
2.835	0.000296	2.788	7.774	0.00165	0.001311
2.848	0.0003	2.789	7.779	0.00167	0.001322
2.86	0.000303	2.786	7.759	0.00169	0.00133
2.873	0.000307	2.781	7.736	0.00171	0.001344
2.886	0.000312	2.781	7.737	0.00174	0.001361
2.899	0.000315	2.771	7.679	0.00175	0.001366
2.912	0.000318	2.77	7.675	0.00176	0.001373
2.925	0.000325	2.773	7.691	0.0018	0.001396
2.938	0.000331	2.77	7.674	0.00183	0.001416
2.952	0.000335	2.769	7.666	0.00186	0.001428
2.965	0.000339	2.766	7.65	0.00188	0.001439
2.979	0.000345	2.761	7.624	0.00191	0.001457
2.992	0.00035	2.762	7.631	0.00193	0.00147
3.006	0.000353	2.759	7.612	0.00195	0.001478
3.02	0.000361	2.747	7.546	0.00198	0.001502
3.035	0.000368	2.753	7.577	0.00202	0.001523
3.049	0.00037	2.764	7.641	0.00205	0.001526
3.063	0.000375	2.764	7.638	0.00207	0.001537
3.078	0.000385	2.759	7.613	0.00213	0.001574
3.093	0.000394	2.757	7.6	0.00217	0.001601
3.107	0.000399	2.745	7.534	0.00219	0.001616
3.122	0.000404	2.746	7.539	0.00222	0.001625
3.138	0.00041	2.758	7.604	0.00226	0.001644
3.153	0.000414	2.757	7.598	0.00228	0.001651
3.168	0.000418	2.749	7.554	0.0023	0.001658
3.184	0.000425	2.753	7.58	0.00234	0.001678
3.2	0.000431	2.76	7.62	0.00238	0.001692
3.215	0.000438	2.754	7.586	0.00242	0.001714
3.232	0.000446	2.75	7.564	0.00245	0.001736
3.248	0.00045	2.747	7.544	0.00247	0.001743
3.264	0.000458	2.746	7.539	0.00252	0.001764
3.281	0.000468	2.742	7.518	0.00257	0.001793
3.297	0.000476	2.74	7.505	0.00261	0.001815
3.314	0.000486	2.739	7.503	0.00266	0.001844
3.331	0.000494	2.748	7.55	0.00271	0.001863
3.349	0.000501	2.753	7.578	0.00276	0.001881
3.366	0.000514	2.737	7.489	0.00281	0.00192
3.383	0.000525	2.735	7.48	0.00287	0.001952

3.401	0.000532	2.743	7.522	0.00292	0.001965
3.419	0.00054	2.74	7.51	0.00296	0.001987
3.437	0.000548	2.74	7.508	0.00301	0.002005
3.456	0.000559	2.735	7.482	0.00306	0.002032
3.474	0.000573	2.729	7.446	0.00312	0.002072
3.493	0.000582	2.727	7.437	0.00318	0.002096
3.512	0.000593	2.728	7.444	0.00324	0.002124
3.531	0.000604	2.727	7.435	0.0033	0.002152
3.55	0.000615	2.717	7.379	0.00334	0.002176
3.57	0.000628	2.715	7.369	0.00341	0.002211
3.59	0.000641	2.717	7.381	0.00349	0.002246
3.61	0.000654	2.714	7.368	0.00355	0.002279
3.63	0.000667	2.708	7.331	0.00361	0.002309
3.651	0.000678	2.707	7.327	0.00367	0.002334
3.671	0.000691	2.715	7.373	0.00375	0.002367
3.692	0.000706	2.72	7.4	0.00384	0.002404
3.713	0.00072	2.721	7.405	0.00392	0.002437
3.735	0.000735	2.718	7.388	0.004	0.002474
3.756	0.000755	2.709	7.341	0.00409	0.002526
3.778	0.000773	2.707	7.329	0.00419	0.002573
3.801	0.000787	2.71	7.346	0.00426	0.002602
3.823	0.000804	2.705	7.318	0.00435	0.002643
3.846	0.000823	2.702	7.3	0.00445	0.002691
3.869	0.00084	2.699	7.285	0.00454	0.002731
3.892	0.00086	2.692	7.245	0.00463	0.002778
3.915	0.000879	2.69	7.236	0.00473	0.002822
3.939	0.000898	2.695	7.265	0.00484	0.002867
3.963	0.000919	2.692	7.25	0.00495	0.002916
3.988	0.000942	2.688	7.227	0.00506	0.002969
4.013	0.000965	2.692	7.249	0.00519	0.003022
4.037	0.000982	2.694	7.256	0.00529	0.003057
4.063	0.001003	2.692	7.246	0.0054	0.003103
4.088	0.00103	2.689	7.23	0.00554	0.003167
4.114	0.001058	2.682	7.194	0.00568	0.003233
4.141	0.001083	2.684	7.205	0.00581	0.003288
4.167	0.001102	2.695	7.261	0.00594	0.003324
4.194	0.001114	2.698	7.278	0.00601	0.00334
4.222	0.001134	2.705	7.319	0.00613	0.003376
4.25	0.001154	2.727	7.438	0.0063	0.003415
4.278	0.00118	2.737	7.494	0.00646	0.003467
4.306	0.001243	2.708	7.335	0.00673	0.00363
4.335	0.001291	2.692	7.247	0.00695	0.003743
4.364	0.001324	2.689	7.231	0.00712	0.003813
4.394	0.001359	2.687	7.219	0.0073	0.003889
4.424	0.001399	2.684	7.206	0.00751	0.003976
4.454	0.001437	2.68	7.182	0.0077	0.004056
4.485	0.001475	2.674	7.151	0.00789	0.004134
4.516	0.00152	2.665	7.104	0.0081	0.004232
4.548	0.001557	2.664	7.097	0.0083	0.004304
4.58	0.001597	2.665	7.102	0.00851	0.004382
4.613	0.001645	2.663	7.089	0.00876	0.004484

4.646	0.00169	2.66	7.077	0.00899	0.004572
4.679	0.001735	2.654	7.042	0.00921	0.00466
4.713	0.001787	2.652	7.031	0.00948	0.004765
4.748	0.001845	2.657	7.061	0.0098	0.004885
4.783	0.001907	2.655	7.048	0.01013	0.005012
4.819	0.001959	2.652	7.035	0.01039	0.005112
4.855	0.002002	2.657	7.062	0.01064	0.005185
4.891	0.002057	2.655	7.047	0.01092	0.005287
4.929	0.002123	2.652	7.031	0.01126	0.005415
4.966	0.002194	2.649	7.019	0.01162	0.005553
5.005	0.002274	2.641	6.975	0.01201	0.005713
5.044	0.002341	2.639	6.963	0.01235	0.005834
5.084	0.002419	2.636	6.948	0.01275	0.005982
5.124	0.002494	2.626	6.897	0.0131	0.00612
5.165	0.002536	2.629	6.909	0.01333	0.006174
5.206	0.002612	2.635	6.942	0.01377	0.006308
5.248	0.002727	2.631	6.92	0.01434	0.006531
5.291	0.002846	2.625	6.89	0.01494	0.006763
5.335	0.002919	2.626	6.897	0.01533	0.006879
5.379	0.00301	2.62	6.865	0.01577	0.007034
5.424	0.003125	2.607	6.796	0.0163	0.007244
5.47	0.003179	2.61	6.811	0.0166	0.007307
5.517	0.003316	2.609	6.807	0.0173	0.007557
5.564	0.003479	2.602	6.773	0.01811	0.00786
5.612	0.003564	2.601	6.764	0.01854	0.007984
5.661	0.003586	2.588	6.698	0.01856	0.007963
5.711	0.003698	2.574	6.624	0.01903	0.008139
5.762	0.003911	2.578	6.647	0.02017	0.008533
5.814	0.004081	2.568	6.596	0.02096	0.008824
5.866	0.004173	2.564	6.576	0.0214	0.008943
5.92	0.004181	2.567	6.592	0.02147	0.008878
5.975	0.004267	2.56	6.554	0.02185	0.008978
6.03	0.004422	2.564	6.576	0.02268	0.009218
6.087	0.004759	2.567	6.588	0.02443	0.009829
6.145	0.00495	2.57	6.604	0.02544	0.010128
6.204	0.005019	2.572	6.616	0.02582	0.010171
6.264	0.004981	2.564	6.572	0.02554	0.009997
6.325	0.005154	2.545	6.477	0.02623	0.010243
6.387	0.005718	2.531	6.408	0.02895	0.011254
6.451	0.005751	2.525	6.375	0.02904	0.011207
6.516	0.006083	2.525	6.373	0.03071	0.011736
6.582	0.007764	2.525	6.375	0.03921	0.014829
6.65	0.006543	2.523	6.366	0.03302	0.012369
6.719	0.005945	2.517	6.336	0.02993	0.011124
6.789	0.006268	2.508	6.291	0.03144	0.011605
6.861	0.006983	2.52	6.351	0.03519	0.012794
6.935	0.006787	2.524	6.373	0.03427	0.012304
7.01	0.006699	2.514	6.321	0.03368	0.012014
7.087	0.006765	2.516	6.332	0.03405	0.012001
7.165	0.00697	2.522	6.359	0.03515	0.012229
7.245	0.008217	2.514	6.32	0.04131	0.014258

7.497	0.008969	2.5	6.251	0.04485	0.01504
7.584	0.009405	2.488	6.192	0.04681	0.015589
7.675	0.009228	2.473	6.115	0.04564	0.015116
7.766	0.008991	2.478	6.142	0.04456	0.014553
7.86	0.00983	2.491	6.205	0.04897	0.015721
8.056	0.010186	2.488	6.188	0.05068	0.015895
8.158	0.008933	2.49	6.198	0.04448	0.013765
8.262	0.008293	2.481	6.155	0.04115	0.01262
8.369	0.007869	2.463	6.069	0.03877	0.01182
8.478	0.007896	2.455	6.028	0.03877	0.011708
8.591	0.008962	2.442	5.961	0.04376	0.013115
8.825	0.009999	2.414	5.827	0.04827	0.014244
8.947	0.010377	2.393	5.727	0.04967	0.014581
9.072	0.009819	2.389	5.705	0.04691	0.013606
9.201	0.009464	2.393	5.725	0.04529	0.01293
9.334	0.01002	2.386	5.693	0.04782	0.013496
9.471	0.010386	2.367	5.601	0.04916	0.013786
9.611	0.010142	2.35	5.525	0.04768	0.013266
9.756	0.010114	2.339	5.471	0.04731	0.013032
9.905	0.010608	2.314	5.353	0.04909	0.013463
10.217	0.010903	2.274	5.169	0.04958	0.013416
10.381	0.010301	2.27	5.153	0.04677	0.012475
10.55	0.011773	2.249	5.057	0.05295	0.014029
10.725	0.011874	2.224	4.947	0.05282	0.013918
10.905	0.011163	2.2	4.839	0.04911	0.012868
11.092	0.011503	2.167	4.697	0.04986	0.013037
11.285	0.011564	2.149	4.619	0.04971	0.012882
11.486	0.010714	2.125	4.515	0.04553	0.011727
11.693	0.011225	2.095	4.39	0.04704	0.012068
11.908	0.015093	2.073	4.297	0.06257	0.015934
12.131	0.015282	2.045	4.183	0.06251	0.015836
12.363	0.012253	2.015	4.061	0.04939	0.01246
12.604	0.012739	1.975	3.899	0.05031	0.012706
12.854	0.018207	1.912	3.655	0.06961	0.017807
13.114	0.017662	1.858	3.451	0.06562	0.016931
13.385	0.013809	1.826	3.333	0.05042	0.01297
13.668	0.012689	1.792	3.21	0.04547	0.011671
13.962	0.012429	1.745	3.045	0.04338	0.011191
14.27	0.012836	1.689	2.852	0.04335	0.011308
14.592	0.014966	1.618	2.618	0.04844	0.012894
14.928	0.015104	1.553	2.413	0.04693	0.01272
15.28	0.013697	1.529	2.338	0.04189	0.011269
15.65	0.014667	1.564	2.445	0.04588	0.011782
16.037	0.017069	1.645	2.706	0.05616	0.01338
16.445	0.013962	1.833	3.361	0.0512	0.010674
16.873	0.01267	2.236	5.001	0.05667	0.00944
17.324	0.013065	2.858	8.171	0.07469	0.009481
17.801	0.015944	3.582	12.828	0.11421	0.01126
18.304	0.012993	4.364	19.048	0.11341	0.008923
18.837	0.012123	4.979	24.794	0.12073	0.008091
19.401	0.012173	5.199	27.027	0.12657	0.007888

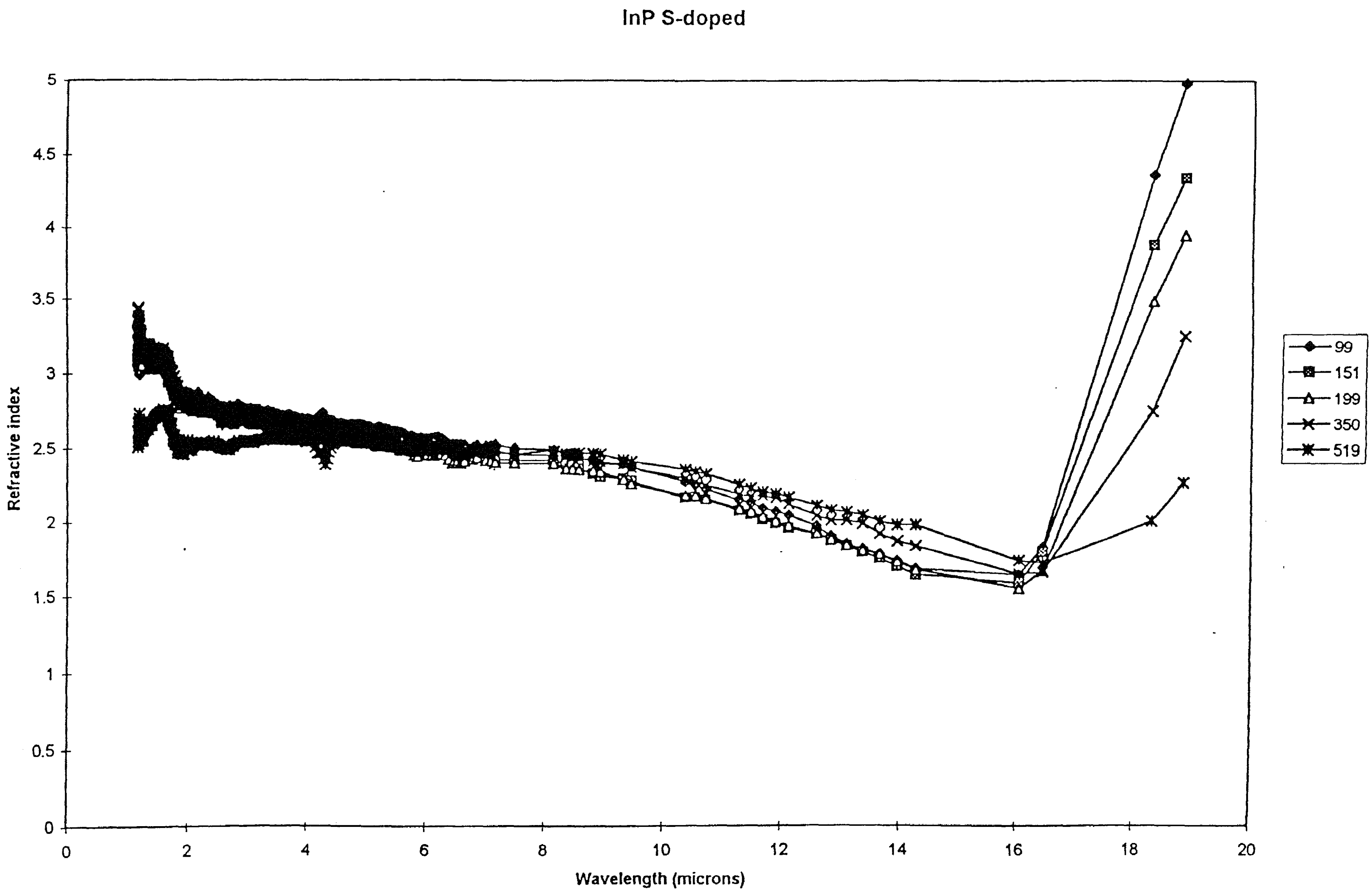


Fig.A1.1 Refractive index Vs Wavelength plot of InP, S -doped at different temperatures

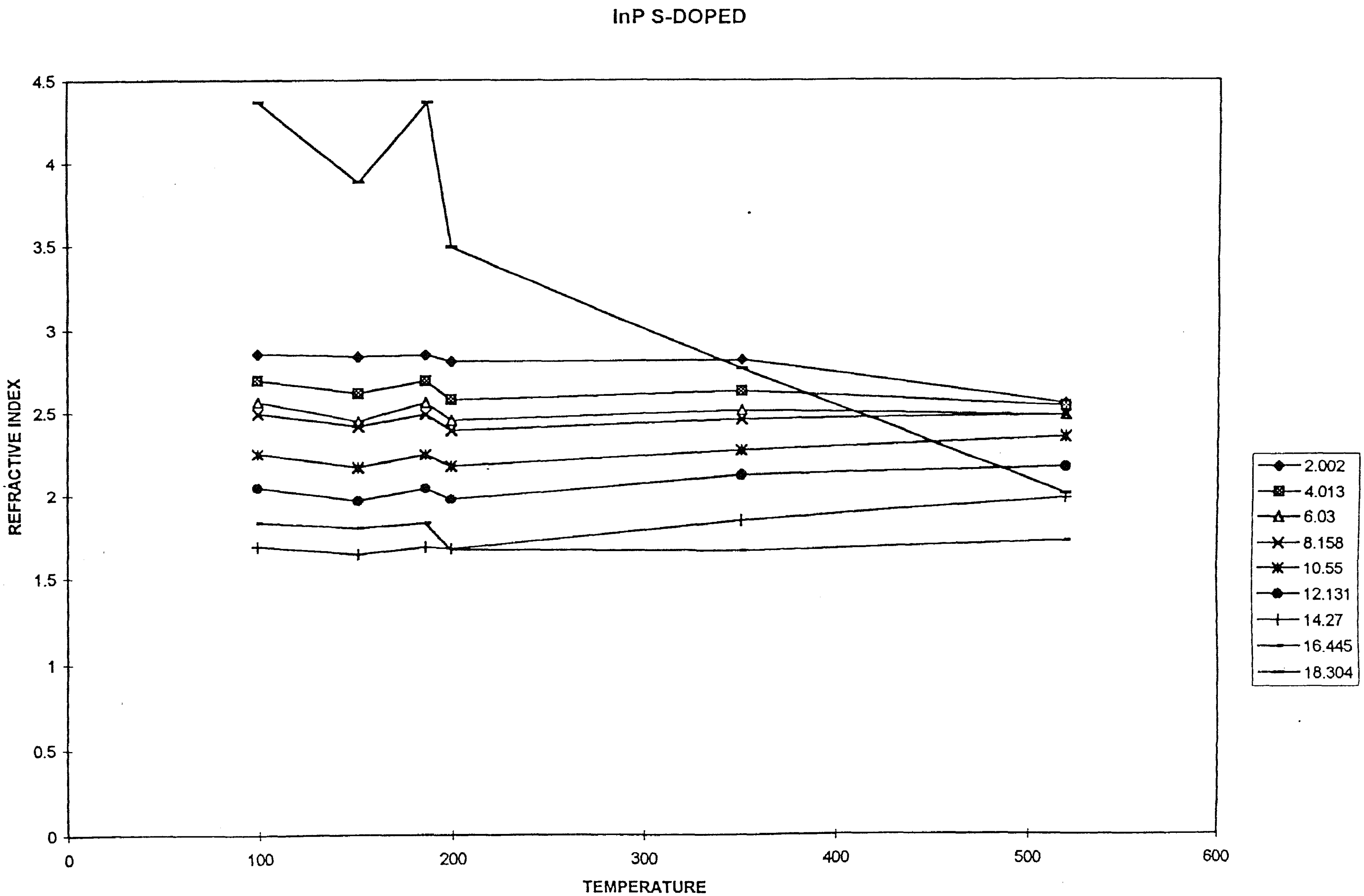


Fig.A1.2 Refractive index Vs Temperature plot of InP, S -doped at different wavelengths

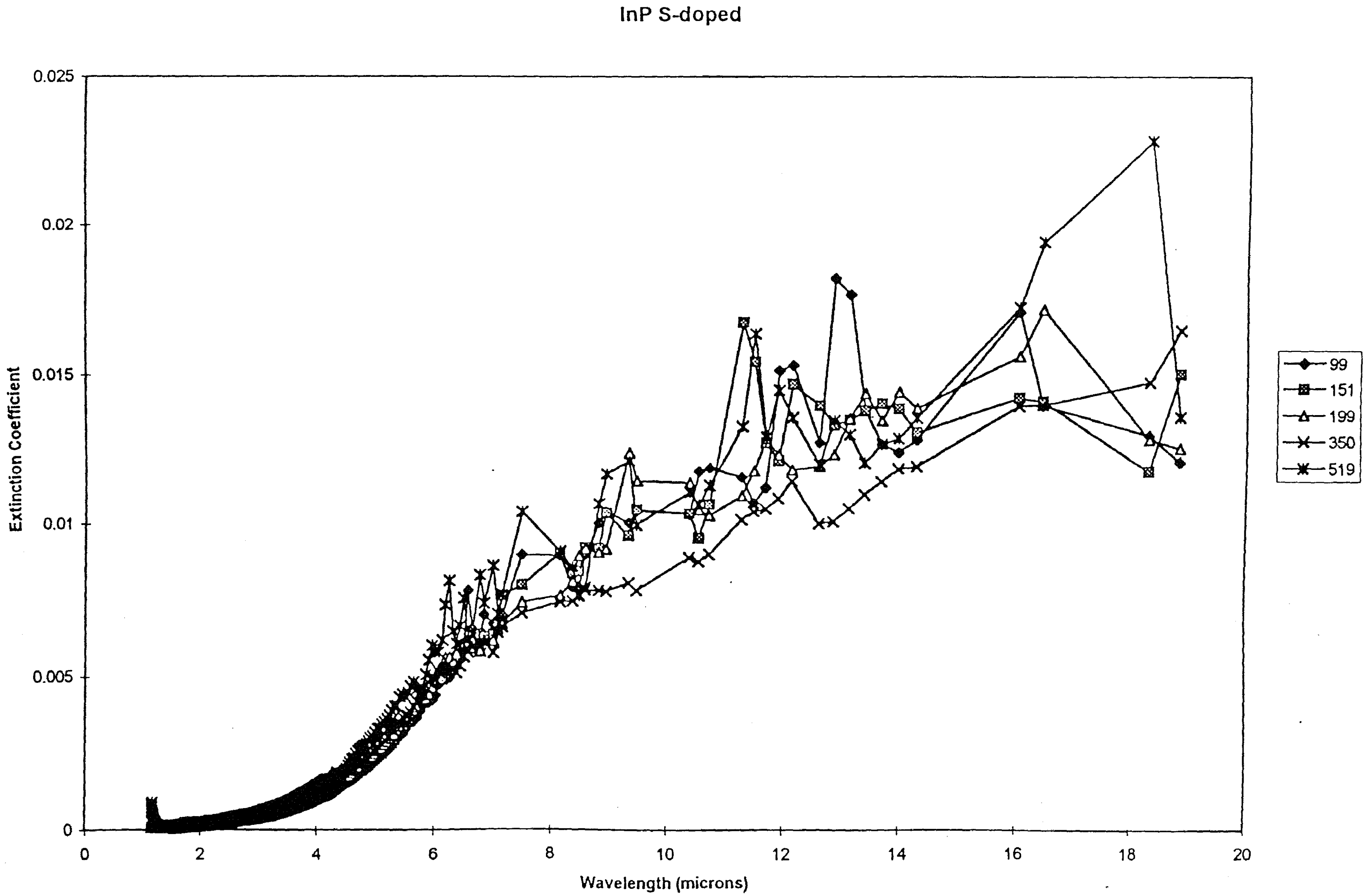


Fig.A1.3 Extinction coefficient Vs Wavelength plot of InP, S -doped at different temperatures

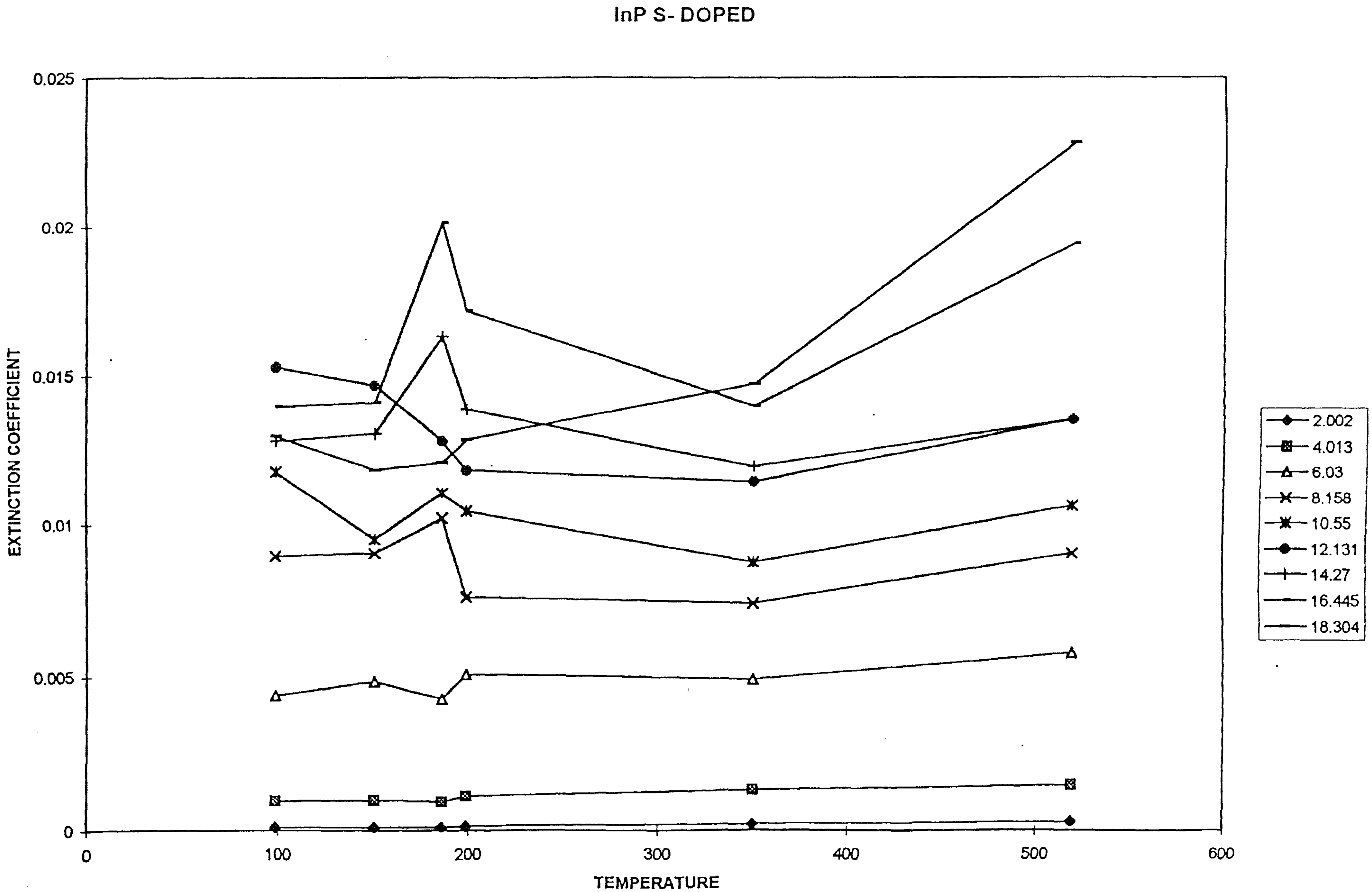


Fig.A1.4 Extinction coefficient Vs Temperature plot of InP, S -doped at different wavelengths

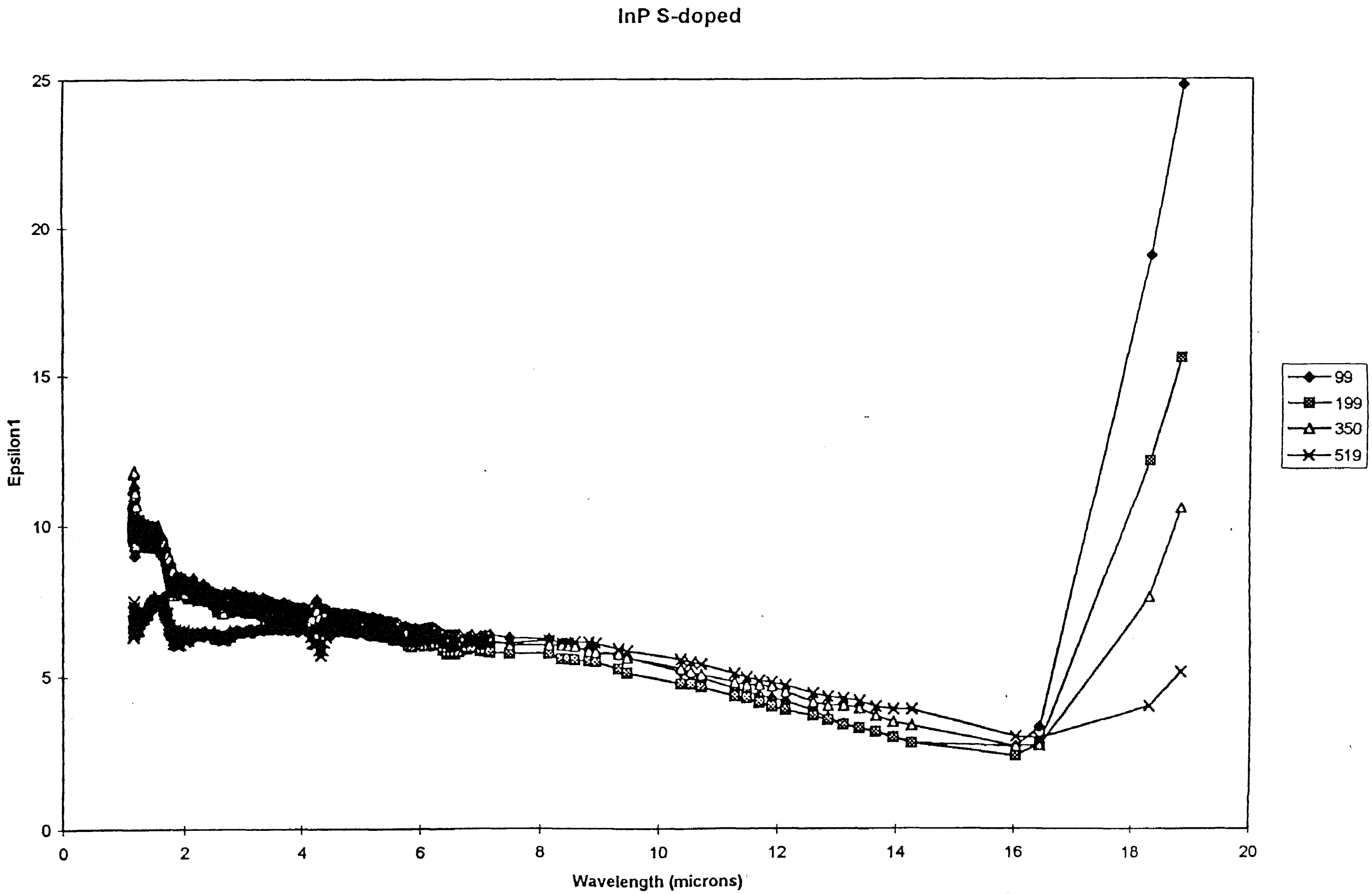


Fig.A1.5 Real part of Complex dielectric constant Vs Wavelength plot of InP, S - doped at different temperatures

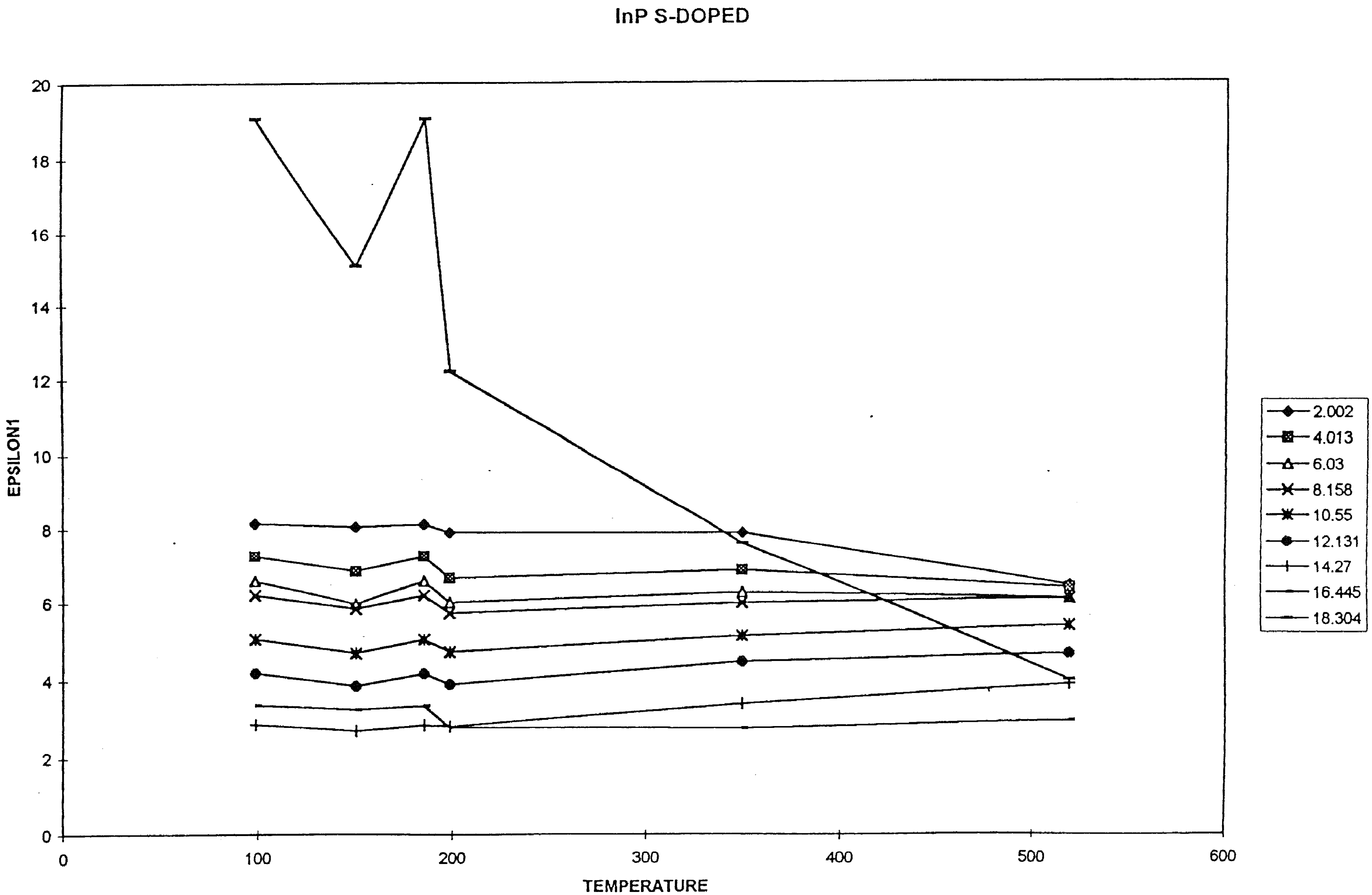


Fig.A1.6 Real part of Complex dielectric constant Vs Temperature plot of InP, S - doped at different wavelengths

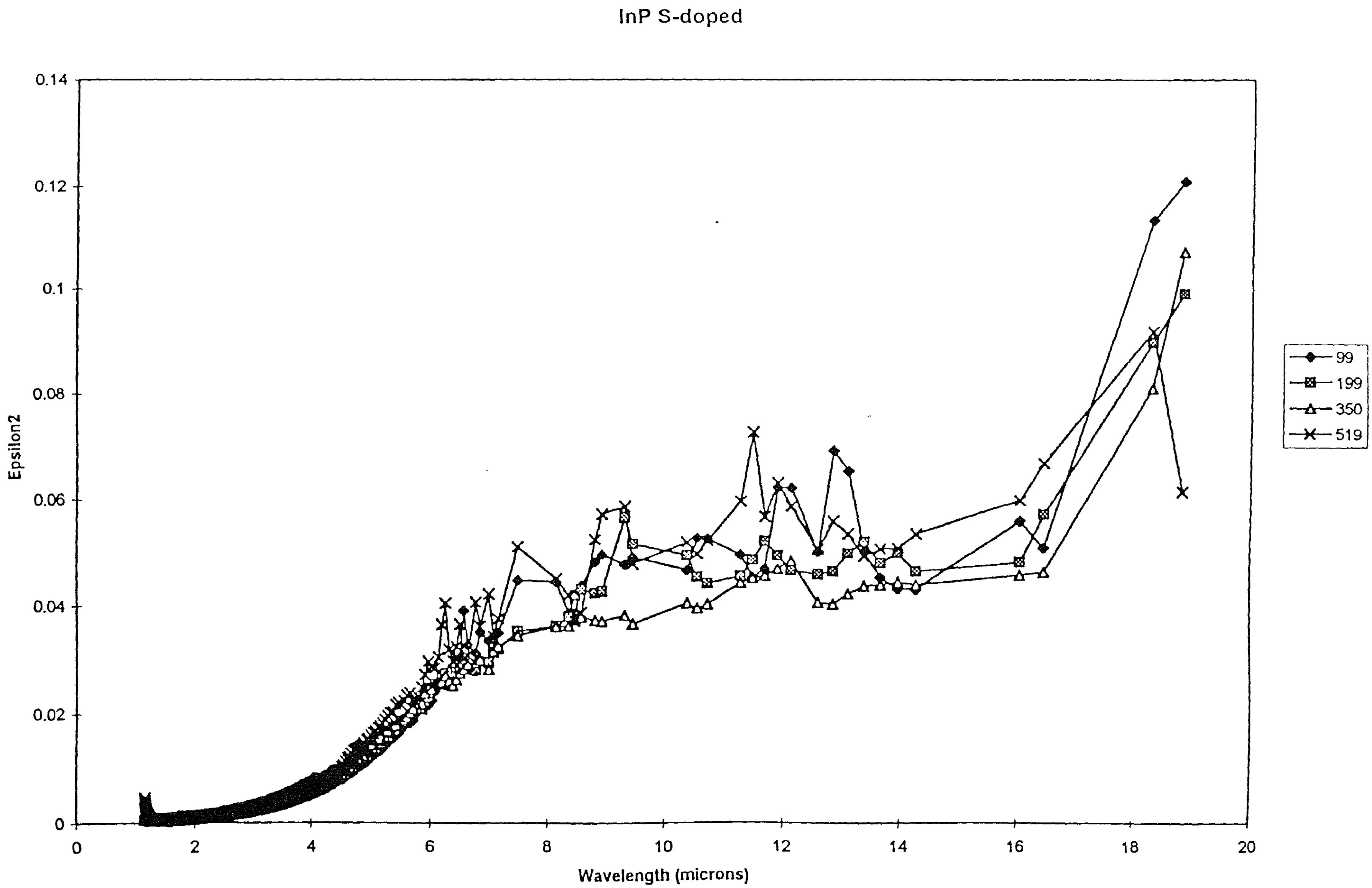


Fig.A1.7 Imaginary part of Complex dielectric constant index Vs Wavelength plot of InP, S -doped at different temperatures

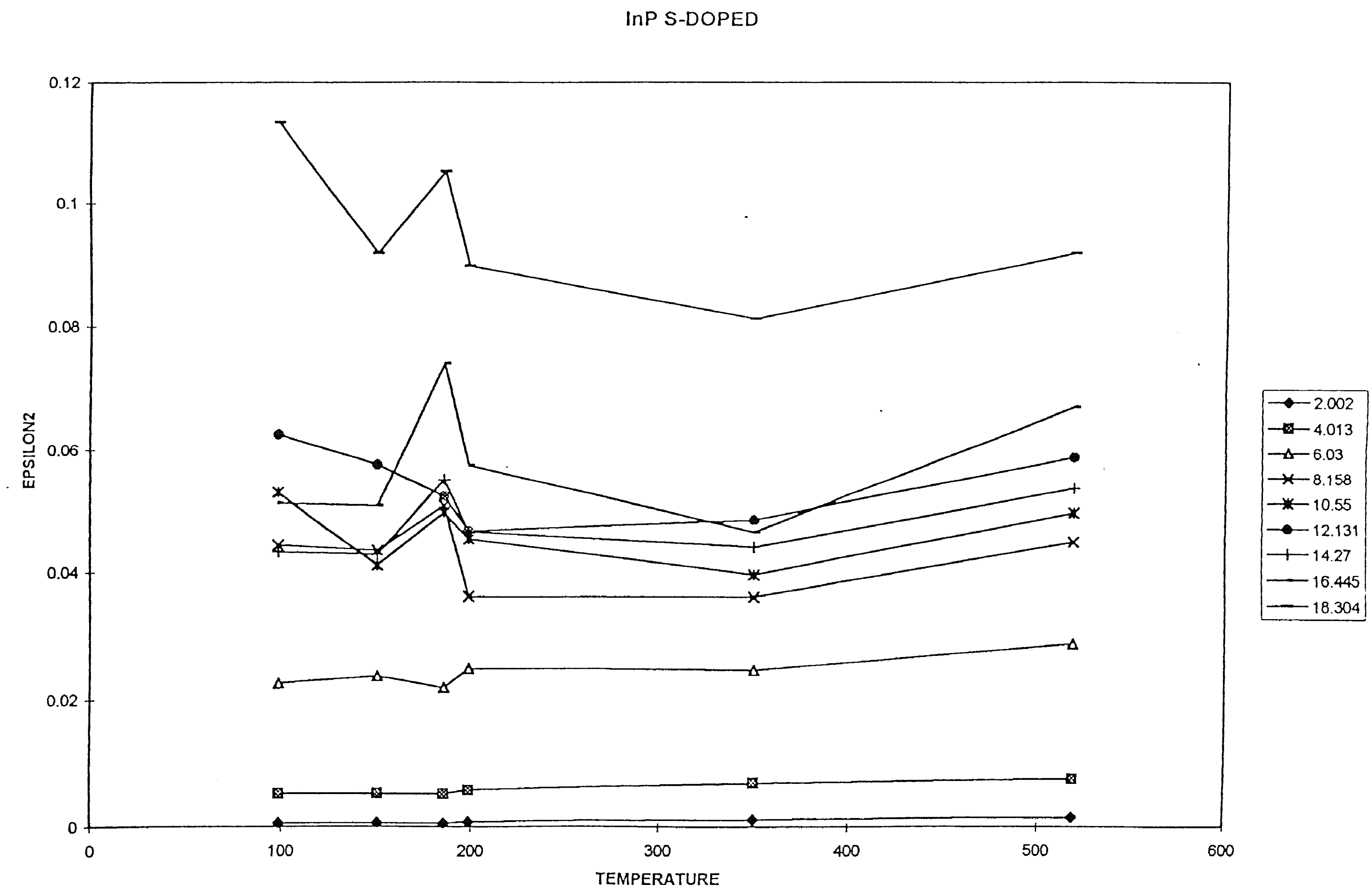


Fig.A1.8 Imaginary part of Complex dielectric constant Vs Temperature plot of InP, S - doped at different wavelengths

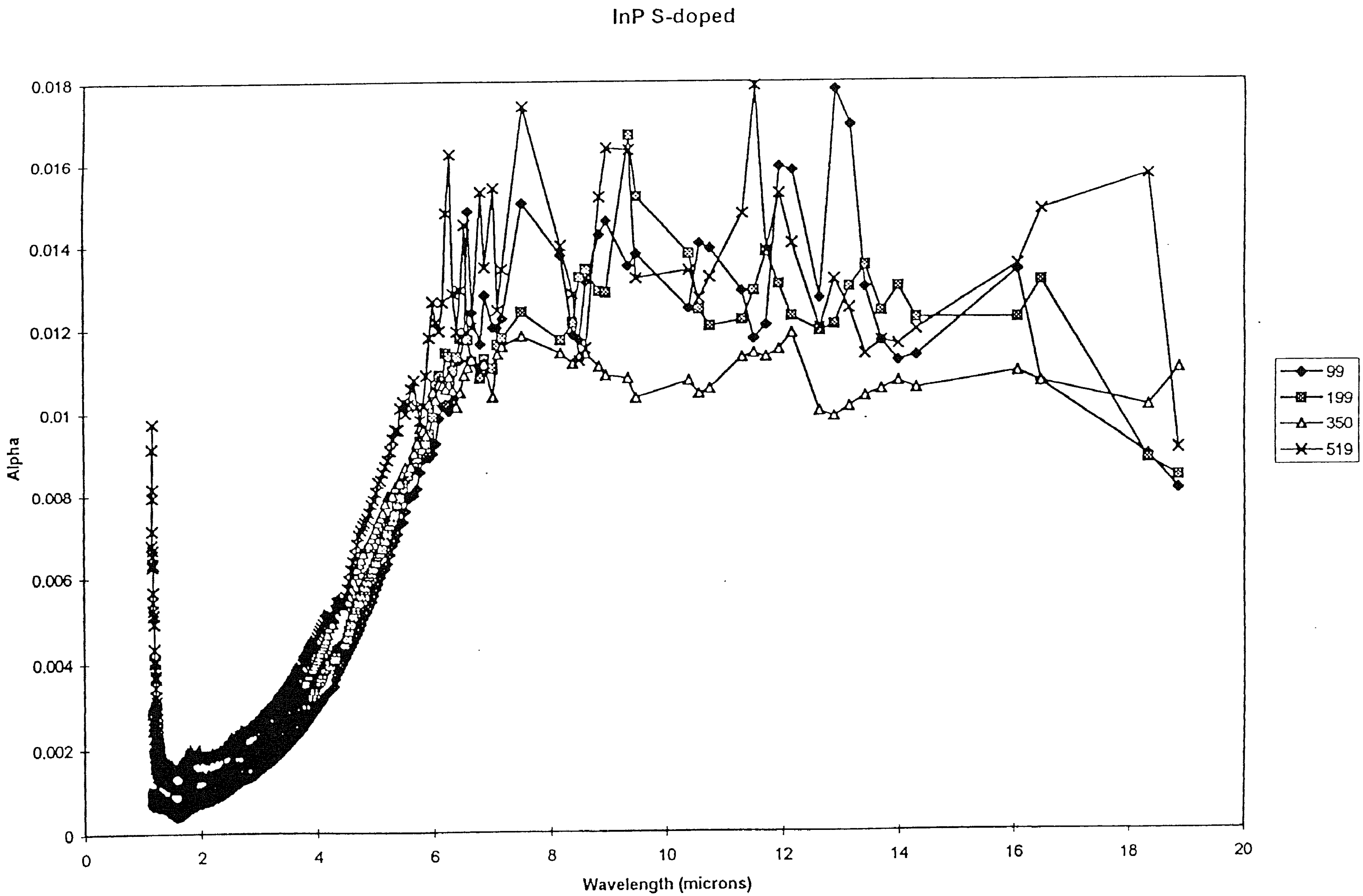


Fig.A1.9 Absorption coefficient Vs Wavelength plot of InP, S-doped at different temperatures

APPENDIX A2: InP Fe-DOPED OPTICAL CONSTANTS DATA AT 51 °C

LAMBDA	EXTCOEF	REFINDEX	EPSILON1	EPSILON2	ALPHA
1	0.000029	3.335	11.123	0.00019	0.000365
1.002	0.000038	3.27	10.694	0.00025	0.000475
1.003	0.000061	3.094	9.575	0.00038	0.00076
1.005	0.000054	3.471	12.048	0.00038	0.000679
1.006	0.000049	3.541	12.536	0.00035	0.000613
1.008	0.00005	3.435	11.799	0.00034	0.000624
1.01	0.000061	2.974	8.847	0.00036	0.000754
1.011	0.000052	3.142	9.874	0.00033	0.000645
1.013	0.000036	3.654	13.354	0.00026	0.000448
1.014	0.000048	3.459	11.963	0.00033	0.00059
1.016	0.000051	3.624	13.134	0.00037	0.000626
1.017	0.000056	3.592	12.9	0.0004	0.000687
1.019	0.000061	3.155	9.957	0.00038	0.000752
1.021	0.000056	3.114	9.7	0.00035	0.000691
1.022	0.000038	3.131	9.803	0.00024	0.000469
1.024	0.000015	3.32	11.022	0.0001	0.000179
1.026	0.000014	3.354	11.246	0.0001	0.000175
1.027	0.000027	3.328	11.076	0.00018	0.000332
1.029	0.000023	3.328	11.079	0.00016	0.000285
1.03	0.000034	3.094	9.571	0.00021	0.000421
1.032	0.000058	3.12	9.733	0.00036	0.000707
1.034	0.000057	3.332	11.102	0.00038	0.000698
1.035	0.000049	3.41	11.625	0.00033	0.000593
1.037	0.000046	3.564	12.701	0.00033	0.000561
1.039	0.00005	3.407	11.604	0.00034	0.000608
1.04	0.000046	3.154	9.946	0.00029	0.000555
1.042	0.000039	3.376	11.401	0.00026	0.000472
1.044	0.000037	3.489	12.171	0.00026	0.000443
1.045	0.000036	3.331	11.094	0.00024	0.000438
1.047	0.000035	3.155	9.954	0.00022	0.000422
1.049	0.000037	3.101	9.617	0.00023	0.000439
1.05	0.000044	3.125	9.764	0.00027	0.000522
1.052	0.000044	3.211	10.308	0.00028	0.000524
1.054	0.000039	3.3	10.892	0.00026	0.000468
1.056	0.000035	3.27	10.696	0.00023	0.00042
1.057	0.00004	3.122	9.744	0.00025	0.000473
1.059	0.000046	3.02	9.121	0.00028	0.000548
1.061	0.000042	3.189	10.169	0.00027	0.0005
1.063	0.000035	3.379	11.417	0.00023	0.000408
1.064	0.000037	3.331	11.093	0.00025	0.000438
1.066	0.000038	3.123	9.75	0.00024	0.000444
1.068	0.000034	3.115	9.704	0.00021	0.0004
1.07	0.000038	3.076	9.459	0.00023	0.000442
1.071	0.000039	3.211	10.308	0.00025	0.00046
1.073	0.000042	3.447	11.883	0.00029	0.000494
1.075	0.000046	3.432	11.778	0.00031	0.000534
1.077	0.000045	3.492	12.191	0.00031	0.00052
1.078	0.000042	3.45	11.905	0.00029	0.000489
1.08	0.000043	3.352	11.236	0.00029	0.000502

1.082	0.000037	3.39	11.492	0.00025	0.000425
1.084	0.00003	3.276	10.735	0.0002	0.000347
1.086	0.000028	3.024	9.143	0.00017	0.000319
1.088	0.000024	3.042	9.251	0.00015	0.000277
1.089	0.000027	3.175	10.082	0.00017	0.000315
1.091	0.000031	3.171	10.056	0.0002	0.000363
1.093	0.00003	3.22	10.371	0.00019	0.000346
1.095	0.00003	3.301	10.897	0.0002	0.000342
1.097	0.000028	3.327	11.072	0.00019	0.000322
1.099	0.000031	3.345	11.191	0.00021	0.000357
1.1	0.000035	3.309	10.951	0.00023	0.000395
1.102	0.000035	3.313	10.974	0.00023	0.0004
1.104	0.000041	3.275	10.727	0.00027	0.000472
1.106	0.000044	3.218	10.355	0.00028	0.000497
1.108	0.000038	3.345	11.192	0.00025	0.000432
1.11	0.000032	3.367	11.336	0.00021	0.00036
1.112	0.000036	3.261	10.637	0.00023	0.000407
1.114	0.000041	3.216	10.342	0.00026	0.000459
1.116	0.000037	3.273	10.713	0.00024	0.000418
1.118	0.00003	3.34	11.154	0.0002	0.000333
1.12	0.000027	3.3	10.888	0.00018	0.000304
1.121	0.000028	3.338	11.145	0.00018	0.000309
1.123	0.000028	3.323	11.042	0.00019	0.000318
1.125	0.00003	3.25	10.562	0.00019	0.000335
1.127	0.000031	3.231	10.44	0.0002	0.000346
1.129	0.000034	3.193	10.195	0.00022	0.000383
1.131	0.000034	3.195	10.208	0.00022	0.000382
1.133	0.000029	3.289	10.816	0.00019	0.000321
1.135	0.000029	3.236	10.474	0.00019	0.000325
1.137	0.000038	3.098	9.597	0.00024	0.000424
1.139	0.000036	3.15	9.924	0.00022	0.000393
1.141	0.000031	3.185	10.143	0.0002	0.000338
1.143	0.000037	3.131	9.803	0.00023	0.000407
1.145	0.000035	3.163	10.003	0.00022	0.000388
1.147	0.000032	3.217	10.351	0.00021	0.000354
1.149	0.000032	3.266	10.664	0.00021	0.000346
1.151	0.000029	3.306	10.929	0.00019	0.000321
1.153	0.000028	3.362	11.304	0.00019	0.000301
1.155	0.000027	3.374	11.385	0.00018	0.000295
1.158	0.000031	3.263	10.644	0.0002	0.000338
1.16	0.000033	3.26	10.629	0.00021	0.000354
1.162	0.000033	3.296	10.864	0.00022	0.000357
1.164	0.000033	3.229	10.424	0.00021	0.000352
1.166	0.000027	3.21	10.303	0.00017	0.000288
1.168	0.000025	3.3	10.888	0.00017	0.000273
1.17	0.000032	3.276	10.734	0.00021	0.000347
1.172	0.000035	3.225	10.403	0.00023	0.000379
1.174	0.000033	3.242	10.512	0.00022	0.000357
1.176	0.000034	3.255	10.596	0.00022	0.00036
1.179	0.000034	3.312	10.972	0.00023	0.000366
1.181	0.000033	3.307	10.933	0.00022	0.00035

1.183	0.00003	3.271	10.7	0.0002	0.00032
1.185	0.000028	3.281	10.768	0.00018	0.000293
1.187	0.000028	3.271	10.7	0.00018	0.000297
1.189	0.00003	3.262	10.638	0.00019	0.000314
1.192	0.000031	3.271	10.697	0.0002	0.000328
1.194	0.000034	3.247	10.546	0.00022	0.000355
1.196	0.000036	3.242	10.51	0.00024	0.000384
1.198	0.000037	3.244	10.525	0.00024	0.000383
1.2	0.000034	3.242	10.508	0.00022	0.000356
1.203	0.000034	3.252	10.574	0.00022	0.00035
1.205	0.000034	3.229	10.425	0.00022	0.000355
1.207	0.000032	3.218	10.354	0.00021	0.000335
1.209	0.00003	3.251	10.567	0.00019	0.000309
1.212	0.000031	3.289	10.817	0.0002	0.000318
1.214	0.000031	3.353	11.24	0.00021	0.00032
1.216	0.00003	3.354	11.252	0.0002	0.000306
1.219	0.000031	3.318	11.006	0.0002	0.000317
1.221	0.000031	3.278	10.742	0.0002	0.000322
1.223	0.000032	3.241	10.503	0.00021	0.000329
1.225	0.000035	3.262	10.638	0.00023	0.000357
1.228	0.000036	3.233	10.449	0.00023	0.000364
1.23	0.000032	3.228	10.422	0.00021	0.00033
1.232	0.000032	3.24	10.496	0.0002	0.000322
1.235	0.000032	3.226	10.405	0.00021	0.000327
1.237	0.000032	3.233	10.453	0.00021	0.000327
1.24	0.000031	3.218	10.353	0.0002	0.000319
1.242	0.00003	3.201	10.244	0.00019	0.000304
1.244	0.000029	3.204	10.268	0.00019	0.000298
1.247	0.00003	3.217	10.352	0.00019	0.000301
1.249	0.000031	3.233	10.45	0.0002	0.000316
1.252	0.000034	3.227	10.417	0.00022	0.000339
1.254	0.000033	3.237	10.476	0.00021	0.000333
1.256	0.000031	3.255	10.592	0.0002	0.000309
1.259	0.000029	3.258	10.613	0.00019	0.000291
1.261	0.000027	3.263	10.646	0.00018	0.000273
1.264	0.000029	3.227	10.414	0.00018	0.000285
1.266	0.00003	3.205	10.269	0.00019	0.000302
1.269	0.000031	3.238	10.487	0.0002	0.000307
1.271	0.000032	3.26	10.629	0.00021	0.000313
1.274	0.000032	3.267	10.676	0.00021	0.000316
1.276	0.000032	3.263	10.65	0.00021	0.000311
1.279	0.000033	3.222	10.38	0.00021	0.000321
1.281	0.000032	3.209	10.298	0.0002	0.000311
1.284	0.000031	3.236	10.473	0.0002	0.000299
1.286	0.000031	3.243	10.514	0.0002	0.000302
1.289	0.00003	3.234	10.457	0.00019	0.000292
1.291	0.000032	3.219	10.361	0.0002	0.000309
1.294	0.000034	3.209	10.299	0.00022	0.000331
1.297	0.000031	3.226	10.405	0.0002	0.000304
1.299	0.00003	3.247	10.542	0.0002	0.000291
1.302	0.000033	3.23	10.432	0.00021	0.000317

1.304	0.000034	3.214	10.329	0.00022	0.000329
1.307	0.000033	3.222	10.382	0.00021	0.000319
1.31	0.000031	3.222	10.384	0.0002	0.000298
1.312	0.000029	3.231	10.437	0.00019	0.000281
1.315	0.000031	3.233	10.453	0.0002	0.000293
1.318	0.000033	3.231	10.436	0.00021	0.000317
1.32	0.000033	3.224	10.394	0.00021	0.000314
1.323	0.000032	3.226	10.406	0.0002	0.0003
1.326	0.000032	3.215	10.337	0.0002	0.000301
1.329	0.000032	3.213	10.325	0.0002	0.0003
1.331	0.000031	3.239	10.494	0.0002	0.000297
1.334	0.000032	3.233	10.453	0.0002	0.000297
1.337	0.000031	3.216	10.344	0.0002	0.000293
1.34	0.000031	3.21	10.301	0.0002	0.000295
1.342	0.000032	3.222	10.382	0.0002	0.000295
1.345	0.000032	3.243	10.518	0.0002	0.000295
1.348	0.000031	3.243	10.52	0.0002	0.000293
1.351	0.000032	3.226	10.408	0.00021	0.000302
1.354	0.000034	3.231	10.441	0.00022	0.000316
1.356	0.000034	3.249	10.557	0.00022	0.000312
1.359	0.000032	3.245	10.531	0.00021	0.000298
1.362	0.000033	3.233	10.451	0.00021	0.000301
1.365	0.000034	3.225	10.401	0.00022	0.000309
1.368	0.000034	3.231	10.442	0.00022	0.000309
1.371	0.000034	3.24	10.499	0.00022	0.000308
1.374	0.000033	3.232	10.448	0.00022	0.000306
1.377	0.000033	3.218	10.356	0.00021	0.000303
1.38	0.000032	3.218	10.355	0.00021	0.000291
1.382	0.000032	3.228	10.42	0.00021	0.000292
1.385	0.000033	3.238	10.487	0.00022	0.000301
1.388	0.000032	3.234	10.459	0.00021	0.000287
1.391	0.000031	3.221	10.372	0.0002	0.000283
1.394	0.000032	3.232	10.447	0.00021	0.000289
1.397	0.000032	3.236	10.471	0.0002	0.000284
1.4	0.000032	3.223	10.388	0.0002	0.000285
1.403	0.000032	3.232	10.447	0.00021	0.000288
1.406	0.000033	3.222	10.382	0.00021	0.000292
1.41	0.000033	3.202	10.252	0.00021	0.000292
1.413	0.000033	3.203	10.26	0.00021	0.00029
1.416	0.000032	3.226	10.404	0.00021	0.000285
1.419	0.000032	3.226	10.405	0.00021	0.000287
1.422	0.000033	3.218	10.355	0.00021	0.000288
1.425	0.000032	3.22	10.367	0.00021	0.000283
1.428	0.000033	3.23	10.433	0.00021	0.000287
1.431	0.000033	3.246	10.535	0.00021	0.000287
1.435	0.000032	3.24	10.498	0.00021	0.000284
1.438	0.000033	3.238	10.488	0.00021	0.000284
1.441	0.000032	3.222	10.381	0.00021	0.000283
1.444	0.000032	3.21	10.306	0.0002	0.000276
1.447	0.000031	3.229	10.423	0.0002	0.000266
1.451	0.000031	3.229	10.423	0.0002	0.000269

1.454	0.000032	3.222	10.383	0.00021	0.000276
1.457	0.000032	3.226	10.41	0.00021	0.000279
1.46	0.000032	3.226	10.407	0.00021	0.000278
1.464	0.000032	3.23	10.434	0.0002	0.000272
1.467	0.000032	3.233	10.451	0.0002	0.000272
1.47	0.000032	3.222	10.38	0.00021	0.000272
1.474	0.000032	3.212	10.32	0.00021	0.000277
1.477	0.000032	3.215	10.336	0.0002	0.000271
1.48	0.000031	3.223	10.388	0.0002	0.000261
1.484	0.000031	3.226	10.407	0.0002	0.000263
1.487	0.000031	3.228	10.419	0.0002	0.000264
1.491	0.000031	3.235	10.466	0.0002	0.000263
1.494	0.000032	3.233	10.453	0.00021	0.000269
1.498	0.000031	3.237	10.476	0.0002	0.000264
1.501	0.000031	3.234	10.46	0.0002	0.00026
1.505	0.000032	3.222	10.384	0.00021	0.000267
1.508	0.000032	3.225	10.402	0.0002	0.000265
1.512	0.000031	3.233	10.455	0.0002	0.000256
1.515	0.00003	3.235	10.463	0.0002	0.000253
1.519	0.000031	3.229	10.423	0.0002	0.000254
1.522	0.000032	3.226	10.409	0.0002	0.000262
1.526	0.000033	3.223	10.388	0.00021	0.000269
1.529	0.000033	3.219	10.364	0.00021	0.000268
1.533	0.000032	3.223	10.391	0.0002	0.00026
1.537	0.000031	3.229	10.424	0.0002	0.000257
1.54	0.000032	3.232	10.444	0.00021	0.000259
1.544	0.000031	3.226	10.408	0.0002	0.000254
1.548	0.000031	3.225	10.4	0.0002	0.000254
1.551	0.000031	3.224	10.396	0.0002	0.000253
1.555	0.000031	3.221	10.372	0.0002	0.000251
1.559	0.000031	3.227	10.416	0.0002	0.00025
1.563	0.000031	3.229	10.424	0.0002	0.000253
1.566	0.000031	3.223	10.391	0.0002	0.000252
1.57	0.000031	3.224	10.393	0.0002	0.000248
1.574	0.000031	3.223	10.385	0.0002	0.000248
1.578	0.00003	3.22	10.371	0.0002	0.000241
1.582	0.00003	3.215	10.335	0.00019	0.000239
1.586	0.000031	3.211	10.308	0.0002	0.000242
1.589	0.000031	3.205	10.269	0.0002	0.000246
1.593	0.000031	3.198	10.226	0.0002	0.000243
1.597	0.00003	3.211	10.313	0.0002	0.00024
1.601	0.00003	3.21	10.303	0.00019	0.000238
1.605	0.00003	3.198	10.229	0.00019	0.000237
1.609	0.000031	3.201	10.245	0.0002	0.000239
1.613	0.00003	3.203	10.26	0.00019	0.000235
1.617	0.000029	3.211	10.31	0.00019	0.000229
1.621	0.00003	3.207	10.283	0.00019	0.00023
1.625	0.00003	3.21	10.303	0.00019	0.000232
1.629	0.000029	3.217	10.352	0.00019	0.000227
1.634	0.000029	3.202	10.251	0.00019	0.000226
1.638	0.00003	3.2	10.243	0.00019	0.00023

1.642	0.00003	3.204	10.263	0.00019	0.000233
1.646	0.000029	3.209	10.295	0.00019	0.000221
1.65	0.000027	3.213	10.32	0.00018	0.000208
1.654	0.000029	3.197	10.221	0.00019	0.00022
1.659	0.00003	3.202	10.254	0.00019	0.000226
1.663	0.00003	3.223	10.385	0.0002	0.00023
1.667	0.000031	3.213	10.327	0.0002	0.000235
1.672	0.000029	3.206	10.278	0.00019	0.000218
1.676	0.000029	3.195	10.21	0.00018	0.000216
1.68	0.00003	3.195	10.207	0.00019	0.000226
1.685	0.00003	3.2	10.239	0.00019	0.000227
1.689	0.000032	3.185	10.144	0.0002	0.000238
1.693	0.000031	3.203	10.259	0.0002	0.000227
1.698	0.000028	3.201	10.246	0.00018	0.000211
1.702	0.000028	3.178	10.101	0.00018	0.000206
1.707	0.000028	3.173	10.068	0.00018	0.000206
1.711	0.00003	3.189	10.167	0.00019	0.000222
1.716	0.000032	3.233	10.453	0.00021	0.000237
1.72	0.000032	3.242	10.508	0.00021	0.000234
1.725	0.000027	3.184	10.14	0.00017	0.000197
1.73	0.000027	3.131	9.803	0.00017	0.000199
1.734	0.000029	3.13	9.796	0.00018	0.000209
1.739	0.00003	3.152	9.932	0.00019	0.000216
1.744	0.000032	3.145	9.891	0.0002	0.000234
1.748	0.000029	3.169	10.04	0.00018	0.000208
1.753	0.000026	3.216	10.34	0.00017	0.000185
1.758	0.000024	3.2	10.242	0.00015	0.000171
1.763	0.000025	3.161	9.989	0.00016	0.000175
1.767	0.000026	3.139	9.855	0.00016	0.000183
1.772	0.000025	3.163	10.004	0.00016	0.000176
1.777	0.000024	3.193	10.197	0.00015	0.000167
1.782	0.000025	3.171	10.053	0.00016	0.000174
1.787	0.000027	3.161	9.991	0.00017	0.000189
1.792	0.000029	3.191	10.181	0.00018	0.000203
1.797	0.000031	3.177	10.096	0.0002	0.000219
1.802	0.000032	3.187	10.159	0.00021	0.000226
1.807	0.000028	3.163	10.001	0.00017	0.000192
1.812	0.000027	3.105	9.64	0.00017	0.000185
1.817	0.000032	3.142	9.873	0.0002	0.000221
1.822	0.000031	3.144	9.882	0.00019	0.000213
1.827	0.000029	3.096	9.585	0.00018	0.000199
1.832	0.000032	3.096	9.584	0.0002	0.000218
1.838	0.000033	3.126	9.773	0.00021	0.000226
1.843	0.00003	3.154	9.947	0.00019	0.000208
1.848	0.000027	3.181	10.116	0.00017	0.000185
1.853	0.000026	3.145	9.894	0.00017	0.000178
1.859	0.000026	3.136	9.835	0.00016	0.000174
1.864	0.000025	3.139	9.852	0.00016	0.00017
1.869	0.000027	3.114	9.698	0.00017	0.000183
1.875	0.000027	3.142	9.869	0.00017	0.000182
1.88	0.000027	3.162	10	0.00017	0.000179

1.886	0.000026	3.177	10.095	0.00017	0.000174
1.891	0.000026	3.155	9.956	0.00016	0.000173
1.897	0.000027	3.161	9.993	0.00017	0.000181
1.902	0.00003	3.154	9.951	0.00019	0.000196
1.908	0.00003	3.108	9.661	0.00018	0.000195
1.914	0.000028	3.124	9.76	0.00017	0.000183
1.919	0.000028	3.155	9.957	0.00017	0.00018
1.925	0.000026	3.178	10.1	0.00016	0.000167
1.931	0.000025	3.163	10.003	0.00016	0.000161
1.936	0.000027	3.132	9.812	0.00017	0.000174
1.942	0.000028	3.141	9.863	0.00018	0.000184
1.948	0.000029	3.171	10.057	0.00018	0.000186
1.954	0.000029	3.164	10.009	0.00018	0.000185
1.96	0.000029	3.143	9.876	0.00018	0.000187
1.966	0.000027	3.16	9.989	0.00017	0.000174
1.972	0.000029	3.148	9.907	0.00018	0.000182
1.978	0.00003	3.121	9.742	0.00019	0.00019
1.984	0.000028	3.127	9.775	0.00017	0.000176
1.99	0.000027	3.147	9.905	0.00017	0.000172
1.996	0.000028	3.153	9.941	0.00018	0.000178
2.002	0.000029	3.142	9.87	0.00018	0.000183
2.009	0.000029	3.154	9.945	0.00018	0.000182
2.015	0.000028	3.159	9.978	0.00018	0.000176
2.021	0.000027	3.156	9.96	0.00017	0.000168
2.027	0.000029	3.149	9.915	0.00018	0.00018
2.034	0.00003	3.156	9.962	0.00019	0.000188
2.04	0.00003	3.166	10.022	0.00019	0.000187
2.047	0.000029	3.143	9.88	0.00018	0.00018
2.053	0.000029	3.127	9.781	0.00018	0.000176
2.06	0.000031	3.123	9.755	0.00019	0.000186
2.066	0.000031	3.14	9.86	0.00019	0.000187
2.073	0.00003	3.153	9.943	0.00019	0.000183
2.08	0.000031	3.131	9.801	0.00019	0.000186
2.086	0.000029	3.125	9.765	0.00018	0.000174
2.093	0.000028	3.138	9.848	0.00018	0.00017
2.1	0.00003	3.151	9.928	0.00019	0.000181
2.107	0.000031	3.162	10.001	0.0002	0.000184
2.113	0.000031	3.142	9.872	0.0002	0.000187
2.12	0.000033	3.13	9.794	0.0002	0.000193
2.127	0.000032	3.13	9.8	0.0002	0.00019
2.134	0.000031	3.143	9.875	0.00019	0.000182
2.141	0.00003	3.161	9.991	0.00019	0.000178
2.149	0.00003	3.142	9.872	0.00019	0.000177
2.156	0.000032	3.106	9.647	0.0002	0.000185
2.163	0.000033	3.104	9.635	0.00021	0.000193
2.17	0.000032	3.137	9.84	0.0002	0.000183
2.177	0.00003	3.154	9.948	0.00019	0.000174
2.185	0.00003	3.162	9.998	0.00019	0.000175
2.192	0.000032	3.16	9.988	0.0002	0.000181
2.2	0.000031	3.142	9.874	0.00019	0.000177
2.207	0.000029	3.134	9.82	0.00018	0.000166

2.215	0.000032	3.127	9.777	0.0002	0.000179
2.222	0.000033	3.126	9.769	0.00021	0.000187
2.23	0.000034	3.138	9.847	0.00021	0.00019
2.238	0.000034	3.146	9.895	0.00021	0.000189
2.245	0.000032	3.135	9.829	0.0002	0.000179
2.253	0.000031	3.129	9.789	0.0002	0.000174
2.261	0.000032	3.135	9.828	0.0002	0.000176
2.269	0.000033	3.126	9.769	0.00021	0.000183
2.277	0.000034	3.121	9.741	0.00021	0.000189
2.285	0.000034	3.124	9.76	0.00021	0.000185
2.293	0.000033	3.132	9.807	0.00021	0.000181
2.301	0.000034	3.134	9.823	0.00022	0.000188
2.309	0.000034	3.13	9.798	0.00021	0.000187
2.318	0.000033	3.126	9.774	0.00021	0.00018
2.326	0.000035	3.11	9.675	0.00022	0.000191
2.334	0.000036	3.12	9.737	0.00023	0.000196
2.343	0.000035	3.135	9.831	0.00022	0.00019
2.351	0.000035	3.123	9.754	0.00022	0.000189
2.36	0.000035	3.121	9.74	0.00022	0.000187
2.369	0.000035	3.119	9.727	0.00022	0.000187
2.377	0.000036	3.121	9.74	0.00023	0.000192
2.386	0.000036	3.13	9.795	0.00023	0.000192
2.395	0.000036	3.122	9.748	0.00022	0.000188
2.404	0.000036	3.118	9.723	0.00022	0.000187
2.413	0.000036	3.119	9.73	0.00022	0.000187
2.422	0.000037	3.112	9.687	0.00023	0.000192
2.431	0.000037	3.116	9.707	0.00023	0.000191
2.44	0.000036	3.128	9.787	0.00023	0.000185
2.449	0.000036	3.131	9.801	0.00022	0.000184
2.459	0.000037	3.121	9.742	0.00023	0.000189
2.468	0.000038	3.119	9.731	0.00024	0.000192
2.477	0.000037	3.12	9.732	0.00023	0.00019
2.487	0.000038	3.112	9.686	0.00023	0.00019
2.496	0.000037	3.116	9.707	0.00023	0.000188
2.506	0.000038	3.115	9.703	0.00023	0.000189
2.516	0.000038	3.112	9.683	0.00024	0.000192
2.526	0.000038	3.109	9.668	0.00024	0.000191
2.535	0.000039	3.112	9.686	0.00024	0.000193
2.546	0.00004	3.12	9.733	0.00025	0.000196
2.556	0.000043	3.128	9.783	0.00027	0.00021
2.566	0.000044	3.127	9.777	0.00027	0.000215
2.576	0.000044	3.121	9.739	0.00028	0.000216
2.586	0.000045	3.115	9.705	0.00028	0.000219
2.597	0.000045	3.113	9.688	0.00028	0.000216
2.607	0.000045	3.108	9.659	0.00028	0.000219
2.618	0.000045	3.108	9.663	0.00028	0.000217
2.628	0.000044	3.115	9.702	0.00027	0.00021
2.639	0.000044	3.109	9.665	0.00027	0.00021
2.65	0.000045	3.107	9.655	0.00028	0.000215
2.661	0.00005	3.103	9.627	0.00031	0.000238
2.672	0.00005	3.11	9.669	0.00031	0.000233

2.683	0.000047	3.113	9.689	0.0003	0.000223
2.694	0.000047	3.111	9.678	0.00029	0.000219
2.705	0.000046	3.112	9.686	0.00029	0.000215
2.716	0.000047	3.115	9.704	0.00029	0.000218
2.728	0.000047	3.114	9.697	0.0003	0.000218
2.739	0.000047	3.107	9.653	0.00029	0.000214
2.751	0.000046	3.102	9.62	0.00029	0.00021
2.763	0.000047	3.097	9.589	0.00029	0.000216
2.775	0.000047	3.098	9.601	0.00029	0.000213
2.786	0.000046	3.096	9.585	0.00028	0.000206
2.799	0.000044	3.108	9.657	0.00027	0.000198
2.811	0.000044	3.121	9.738	0.00027	0.000195
2.823	0.000044	3.117	9.717	0.00027	0.000195
2.835	0.000044	3.111	9.681	0.00027	0.000196
2.848	0.000044	3.111	9.678	0.00028	0.000196
2.86	0.000044	3.118	9.725	0.00028	0.000195
2.873	0.000044	3.119	9.728	0.00028	0.000193
2.886	0.000043	3.12	9.732	0.00027	0.000188
2.899	0.000044	3.12	9.732	0.00027	0.000189
2.912	0.000045	3.117	9.715	0.00028	0.000193
2.925	0.000045	3.112	9.684	0.00028	0.000194
2.938	0.000046	3.113	9.688	0.00029	0.000196
2.952	0.000046	3.111	9.676	0.00029	0.000196
2.965	0.000045	3.112	9.684	0.00028	0.000191
2.979	0.000044	3.115	9.703	0.00028	0.000187
2.992	0.000045	3.108	9.659	0.00028	0.000188
3.006	0.000046	3.12	9.737	0.00029	0.000191
3.02	0.000045	3.119	9.728	0.00028	0.000188
3.035	0.000045	3.113	9.69	0.00028	0.000185
3.049	0.000045	3.12	9.732	0.00028	0.000185
3.063	0.000045	3.114	9.696	0.00028	0.000186
3.078	0.000047	3.114	9.695	0.0003	0.000194
3.093	0.000048	3.116	9.707	0.0003	0.000195
3.107	0.000047	3.119	9.729	0.00029	0.00019
3.122	0.000047	3.126	9.773	0.00029	0.00019
3.138	0.000047	3.122	9.748	0.00029	0.000188
3.153	0.000046	3.118	9.724	0.00029	0.000184
3.168	0.000046	3.123	9.751	0.00029	0.000184
3.184	0.000046	3.128	9.787	0.00029	0.000183
3.2	0.000047	3.124	9.757	0.00029	0.000183
3.215	0.000048	3.11	9.673	0.0003	0.000187
3.232	0.000048	3.111	9.678	0.0003	0.000186
3.248	0.000049	3.11	9.675	0.00031	0.00019
3.264	0.00005	3.104	9.637	0.00031	0.000193
3.281	0.000049	3.111	9.679	0.0003	0.000188
3.297	0.000049	3.105	9.644	0.00031	0.000187
3.314	0.00005	3.096	9.584	0.00031	0.000188
3.331	0.000049	3.101	9.613	0.00031	0.000186
3.349	0.00005	3.098	9.596	0.00031	0.000186
3.366	0.000051	3.096	9.585	0.00031	0.000189
3.383	0.000052	3.098	9.599	0.00032	0.000192

3.401	0.000053	3.095	9.577	0.00033	0.000196
3.419	0.000054	3.092	9.558	0.00034	0.0002
3.437	0.000052	3.094	9.576	0.00032	0.000192
3.456	0.000051	3.096	9.588	0.00032	0.000186
3.474	0.000053	3.092	9.562	0.00033	0.000191
3.493	0.000054	3.091	9.554	0.00033	0.000193
3.512	0.000053	3.098	9.596	0.00033	0.000189
3.531	0.000052	3.097	9.59	0.00032	0.000186
3.55	0.000053	3.093	9.566	0.00033	0.000187
3.57	0.000052	3.101	9.613	0.00032	0.000183
3.59	0.000052	3.102	9.62	0.00032	0.000182
3.61	0.000052	3.096	9.588	0.00033	0.000183
3.63	0.000053	3.094	9.576	0.00033	0.000182
3.651	0.000053	3.094	9.576	0.00033	0.000183
3.671	0.000053	3.097	9.591	0.00033	0.000183
3.692	0.000053	3.097	9.59	0.00033	0.00018
3.713	0.000053	3.09	9.551	0.00033	0.000178
3.735	0.000053	3.086	9.524	0.00033	0.00018
3.756	0.000054	3.092	9.562	0.00033	0.000181
3.778	0.000055	3.091	9.552	0.00034	0.000182
3.801	0.000054	3.09	9.546	0.00033	0.000179
3.823	0.000053	3.092	9.561	0.00033	0.000175
3.846	0.000054	3.092	9.558	0.00033	0.000176
3.869	0.000055	3.092	9.563	0.00034	0.000178
3.892	0.000055	3.09	9.551	0.00034	0.000179
3.915	0.000055	3.093	9.57	0.00034	0.000177
3.939	0.000055	3.093	9.567	0.00034	0.000176
3.963	0.000056	3.092	9.558	0.00034	0.000177
3.988	0.000056	3.09	9.545	0.00035	0.000177
4.013	0.000055	3.088	9.534	0.00034	0.000174
4.037	0.000055	3.094	9.571	0.00034	0.000172
4.063	0.000056	3.098	9.597	0.00035	0.000173
4.088	0.000057	3.091	9.553	0.00035	0.000174
4.114	0.000056	3.086	9.525	0.00035	0.000172
4.141	0.000056	3.089	9.54	0.00034	0.000169
4.167	0.000055	3.087	9.527	0.00034	0.000165
4.194	0.00005	3.081	9.493	0.00031	0.000148
4.222	0.000036	3.056	9.341	0.00022	0.000108
4.25	0.000034	3.04	9.239	0.0002	0.000099
4.278	0.000039	3.05	9.3	0.00024	0.000114
4.306	0.000047	3.063	9.383	0.00029	0.000136
4.335	0.000053	3.075	9.454	0.00032	0.000152
4.364	0.000056	3.078	9.475	0.00035	0.000162
4.394	0.000058	3.079	9.483	0.00036	0.000166
4.424	0.000058	3.087	9.528	0.00036	0.000166
4.454	0.000059	3.085	9.515	0.00036	0.000166
4.485	0.000059	3.085	9.516	0.00036	0.000165
4.516	0.00006	3.088	9.535	0.00037	0.000167
4.548	0.00006	3.089	9.543	0.00037	0.000167
4.58	0.000059	3.089	9.542	0.00037	0.000163
4.613	0.00006	3.083	9.508	0.00037	0.000163

4.646	0.00006	3.083	9.503	0.00037	0.000163
4.679	0.000061	3.083	9.508	0.00038	0.000164
4.713	0.000061	3.079	9.483	0.00038	0.000164
4.748	0.000062	3.079	9.481	0.00038	0.000164
4.783	0.000062	3.083	9.503	0.00038	0.000164
4.819	0.000062	3.084	9.51	0.00039	0.000163
4.855	0.000063	3.082	9.496	0.00039	0.000163
4.891	0.000064	3.078	9.473	0.00039	0.000164
4.929	0.000065	3.077	9.468	0.0004	0.000165
4.966	0.000065	3.078	9.476	0.0004	0.000164
5.005	0.000065	3.082	9.496	0.0004	0.000164
5.044	0.000066	3.083	9.505	0.00041	0.000164
5.084	0.000066	3.083	9.504	0.00041	0.000164
5.124	0.000067	3.081	9.491	0.00041	0.000164
5.165	0.000067	3.076	9.464	0.00041	0.000162
5.206	0.000067	3.076	9.461	0.00041	0.000162
5.248	0.000068	3.075	9.456	0.00042	0.000163
5.291	0.00007	3.068	9.415	0.00043	0.000166
5.335	0.000071	3.068	9.411	0.00044	0.000168
5.379	0.000071	3.073	9.444	0.00044	0.000167
5.424	0.000072	3.075	9.455	0.00044	0.000168
5.47	0.000072	3.078	9.471	0.00044	0.000165
5.517	0.000073	3.075	9.454	0.00045	0.000167
5.564	0.000076	3.07	9.425	0.00046	0.000171
5.612	0.000076	3.075	9.457	0.00047	0.00017
5.661	0.00008	3.075	9.454	0.00049	0.000178
5.711	0.000083	3.071	9.432	0.00051	0.000183
5.762	0.000081	3.072	9.434	0.0005	0.000178
5.814	0.000084	3.07	9.426	0.00052	0.000182
5.866	0.000088	3.07	9.427	0.00054	0.000189
5.92	0.000088	3.067	9.406	0.00054	0.000187
5.975	0.000089	3.053	9.319	0.00054	0.000187
6.03	0.000089	3.056	9.34	0.00054	0.000186
6.087	0.000089	3.066	9.4	0.00054	0.000183
6.145	0.000088	3.055	9.336	0.00054	0.00018
6.204	0.000084	3.052	9.313	0.00051	0.00017
6.264	0.000083	3.058	9.351	0.00051	0.000166
6.325	0.000088	3.061	9.371	0.00054	0.000176
6.387	0.000099	3.053	9.318	0.0006	0.000194
6.451	0.000102	3.046	9.279	0.00062	0.000199
6.516	0.000104	3.044	9.268	0.00063	0.0002
6.582	0.000105	3.04	9.242	0.00064	0.0002
6.65	0.000097	3.046	9.277	0.00059	0.000184
6.719	0.000092	3.048	9.289	0.00056	0.000171
6.789	0.000091	3.044	9.263	0.00055	0.000169
6.861	0.000091	3.042	9.256	0.00055	0.000167
6.935	0.000092	3.037	9.224	0.00056	0.000167
7.01	0.000093	3.034	9.207	0.00056	0.000166
7.087	0.000091	3.035	9.21	0.00055	0.000161
7.165	0.000089	3.038	9.228	0.00054	0.000157
7.245	0.000088	3.04	9.24	0.00053	0.000152

7.327	0.000087	3.038	9.227	0.00053	0.000149
7.411	0.000087	3.036	9.216	0.00053	0.000147
7.497	0.000086	3.033	9.201	0.00052	0.000145
7.584	0.000087	3.03	9.183	0.00053	0.000144
7.675	0.000087	3.034	9.205	0.00053	0.000142
7.766	0.000086	3.042	9.257	0.00052	0.000138
7.86	0.000083	3.047	9.287	0.00051	0.000133
7.957	0.000078	3.058	9.35	0.00048	0.000124
8.056	0.000077	3.067	9.404	0.00047	0.00012
8.158	0.000077	3.068	9.413	0.00047	0.000118
8.262	0.000078	3.067	9.407	0.00048	0.000119
8.369	0.000084	3.061	9.369	0.00052	0.000127
8.478	0.000085	3.062	9.374	0.00052	0.000126
8.591	0.000082	3.063	9.381	0.0005	0.000121
8.706	0.000081	3.064	9.386	0.0005	0.000117
8.825	0.000083	3.056	9.336	0.00051	0.000118
8.947	0.000091	3.044	9.265	0.00055	0.000127
9.072	0.000096	3.051	9.31	0.00058	0.000132
9.201	0.000098	3.054	9.325	0.0006	0.000133
9.334	0.000098	3.047	9.286	0.0006	0.000132
9.471	0.000102	3.035	9.211	0.00062	0.000136
9.611	0.000112	3.02	9.122	0.00068	0.000147
9.756	0.000121	3.017	9.101	0.00073	0.000156
9.905	0.000136	3.007	9.04	0.00082	0.000172
10.058	0.00015	2.989	8.934	0.0009	0.000187
10.217	0.000173	2.978	8.867	0.00103	0.000213
10.381	0.000185	2.969	8.813	0.0011	0.000224
10.55	0.000196	2.959	8.757	0.00116	0.000234
10.725	0.000191	2.968	8.808	0.00113	0.000223
10.905	0.000152	2.989	8.936	0.00091	0.000175
11.092	0.000135	2.999	8.995	0.00081	0.000153
11.285	0.00013	2.998	8.988	0.00078	0.000145
11.486	0.000135	2.992	8.954	0.00081	0.000148
11.693	0.000154	2.991	8.944	0.00092	0.000166
11.908	0.000174	2.973	8.836	0.00104	0.000184
12.131	0.000216	2.942	8.657	0.00127	0.000224
12.363	0.000262	2.928	8.571	0.00153	0.000266
12.604	0.000302	2.918	8.517	0.00176	0.000301
12.854	0.000324	2.902	8.422	0.00188	0.000317
13.114	0.000329	2.888	8.341	0.0019	0.000315
13.385	0.000363	2.878	8.283	0.00209	0.000341
13.668	0.000425	2.875	8.266	0.00245	0.000391
13.962	0.000494	2.888	8.342	0.00286	0.000445
14.27	0.00085	2.928	8.572	0.00498	0.000749
14.592	0.001567	2.967	8.803	0.0093	0.00135
14.928	0.002548	3.044	9.266	0.01551	0.002146
15.28	0.002895	3.061	9.367	0.01772	0.002382
15.65	0.003137	3.027	9.164	0.01899	0.00252
16.037	0.002786	3.012	9.07	0.01678	0.002184
16.445	0.001276	2.876	8.273	0.00734	0.000976
16.873	0.000798	2.788	7.772	0.00445	0.000594

17.324	0.000736	2.806	7.875	0.00413	0.000534
17.801	0.00073	2.797	7.825	0.00408	0.000515
18.304	0.000767	2.78	7.73	0.00427	0.000527
18.837	0.000798	2.767	7.658	0.00442	0.000533
19.401	0.001479	2.758	7.605	0.00816	0.000959
20	0.002814	3.013	9.08	0.01696	0.001769

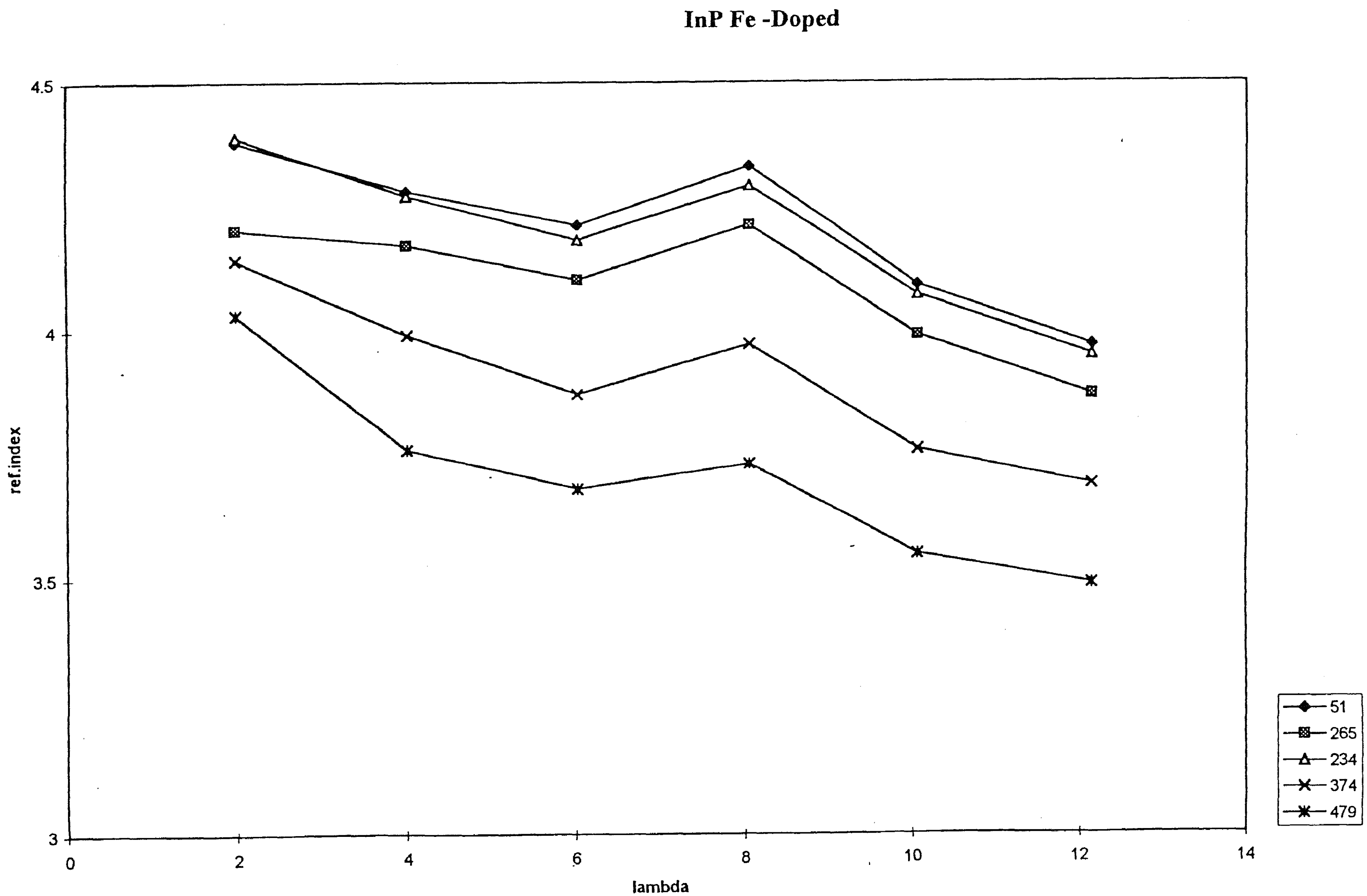


Fig.A2.1 Refractive index Vs Wavelength plot of InP, Fe-doped at different temperatures

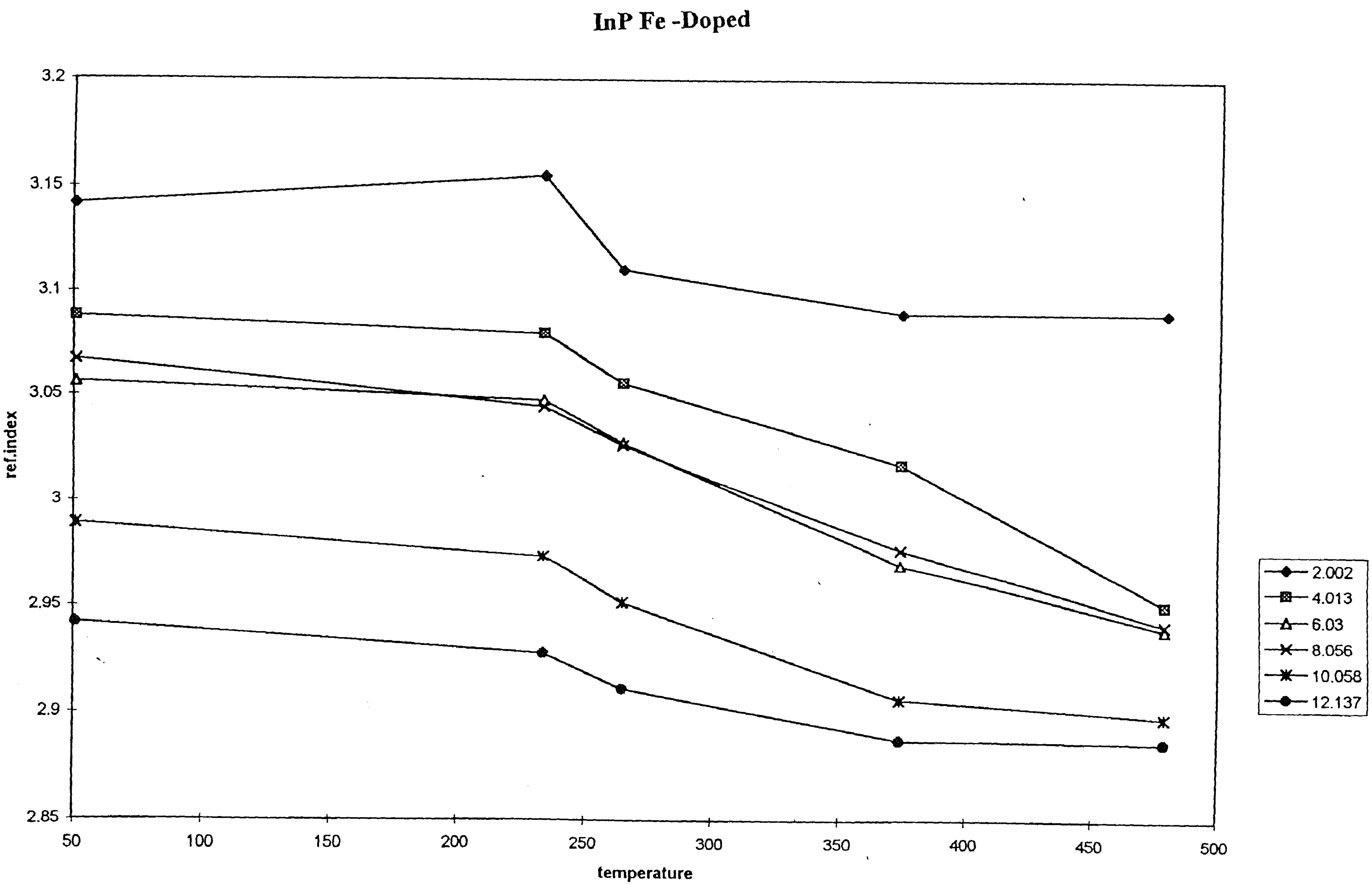


Fig.A2.2 Refractive index Vs Temperature plot of InP, Fe -doped at different wavelengths

InP Fe -Doped

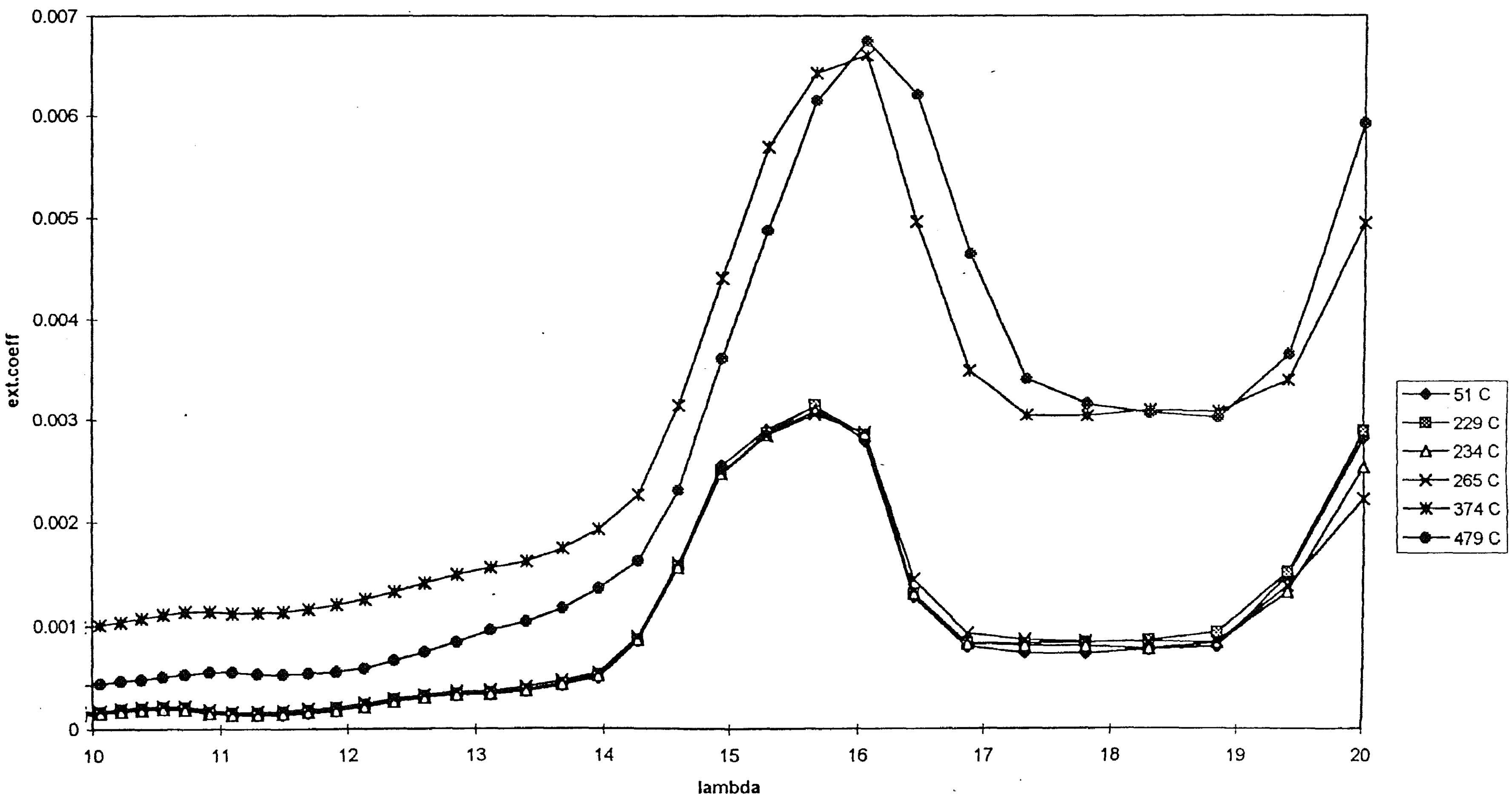


Fig.A2.3 Extinction coefficient Vs Wavelength plot of InP, Fe -doped at different temperatures

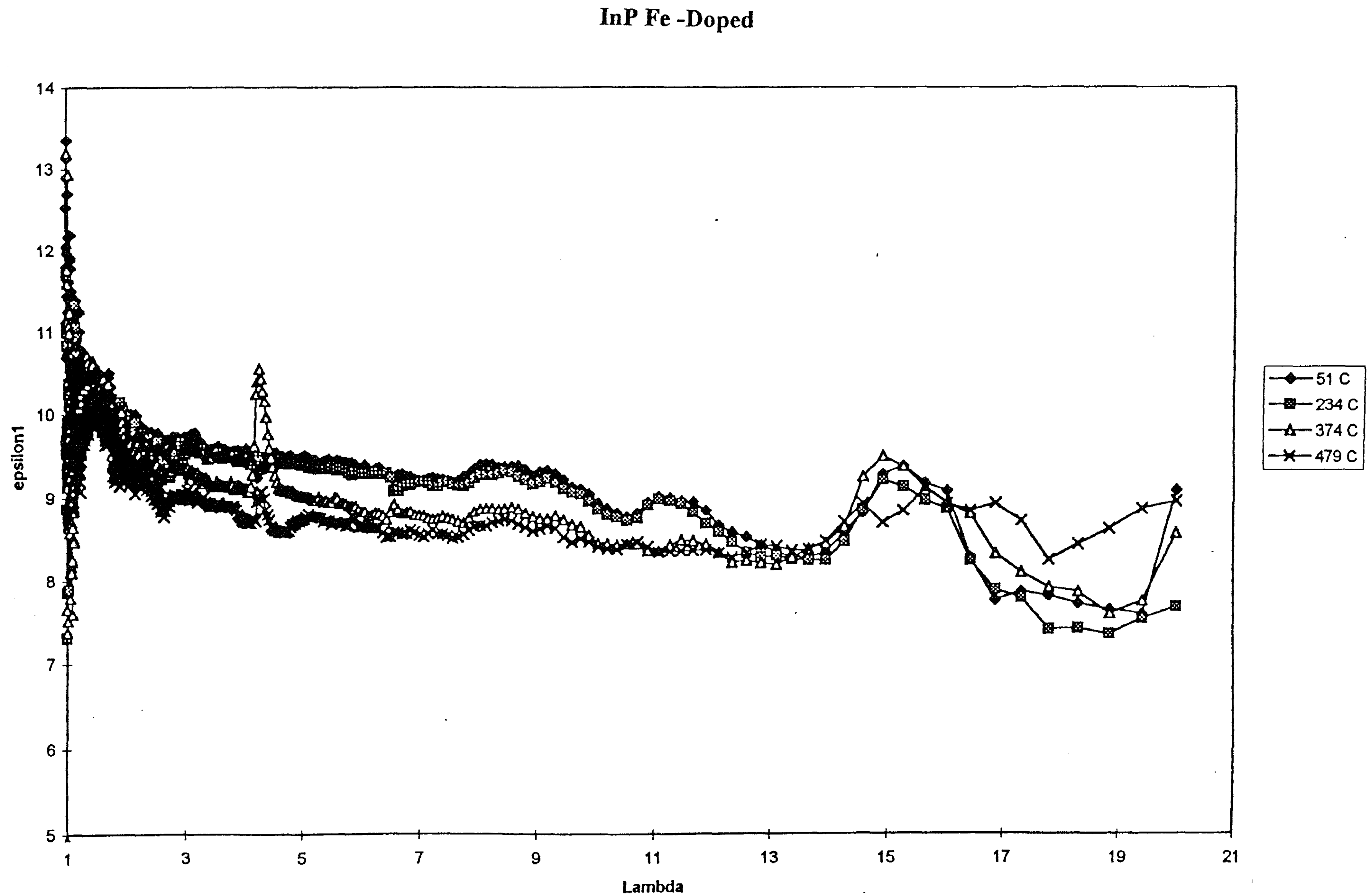


Fig.A2.4 Real part of Complex dielectric constant Vs Wavelength plot of InP, Fe - doped at different temperatures

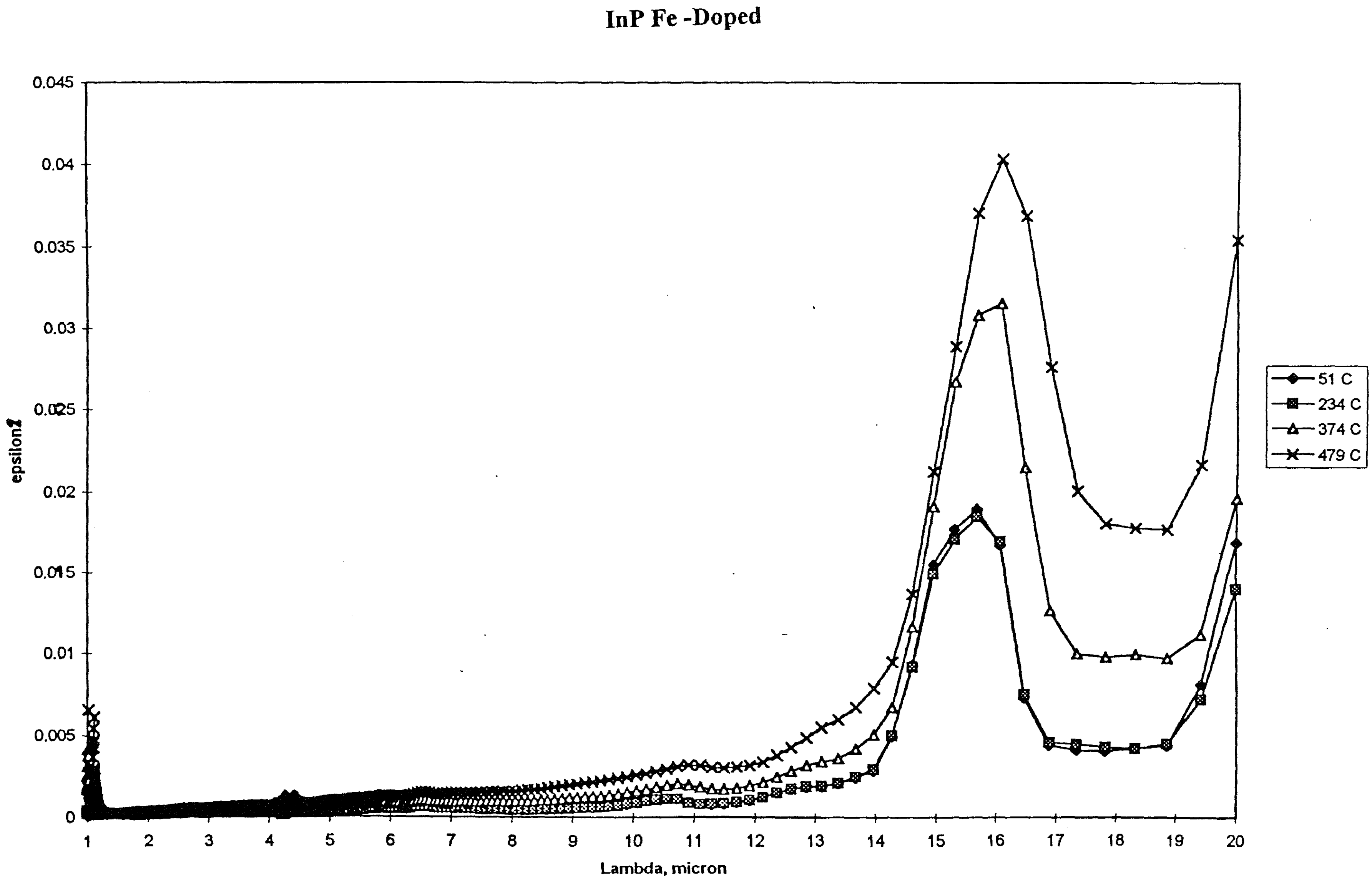


Fig.A2.5 Imaginary part of Complex dielectric constant index Vs Wavelength plot of InP, Fe -doped at different temperatures

InP Fe -Doped

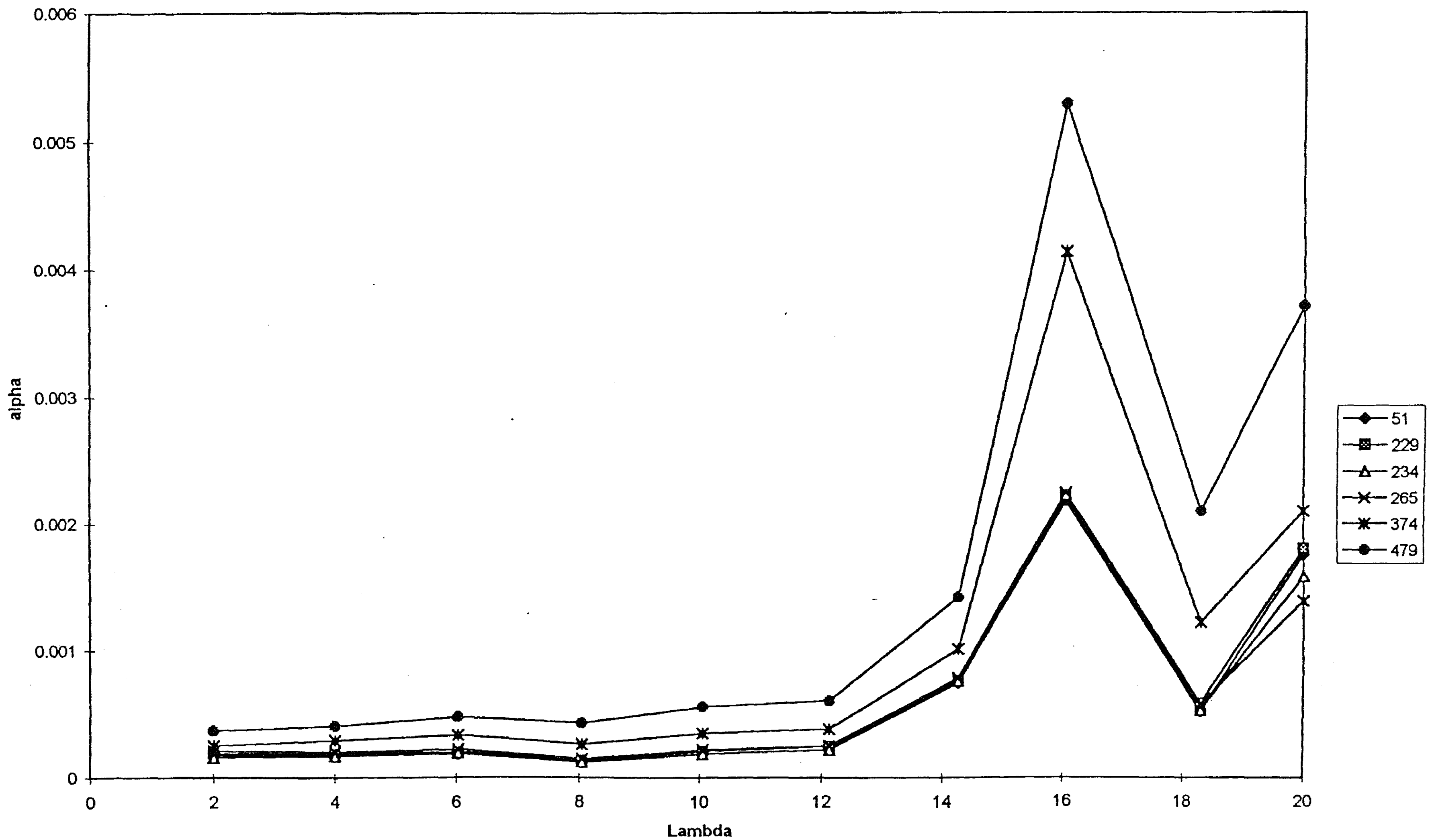


Fig.A2.6 Absorption coefficient Vs Wavelength plot of InP, Fe -doped at different temperatures

APPENDIX B: AlN OPTICAL CONSTANTS DATA AT 161 °C

LAMBDA	EXTCOEF	REFINDEX	SILON1	EPSILON2	ALPHA
1	0.000506	1.856	3.445	0.00188	0.006357
1.002	0.000468	1.798	3.232	0.00168	0.005879
1.003	0.000392	2.272	5.161	0.00178	0.004911
1.005	0.000396	2.102	4.42	0.00167	0.004957
1.006	0.00043	1.722	2.966	0.00148	0.005375
1.01	0.00123	2.182	4.762	0.00537	0.015315
1.011	0.000316	2.198	4.833	0.00139	0.003924
1.013	0.000304	2.284	5.216	0.00139	0.003776
1.014	0.000441	2.073	4.297	0.00183	0.00546
1.016	0.000473	2.023	4.094	0.00191	0.00585
1.027	0.00059	2.01	4.04	0.00237	0.007226
1.029	0.000495	1.989	3.955	0.00197	0.006047
1.03	0.000566	1.697	2.879	0.00192	0.006901
1.035	0.000782	2.221	4.932	0.00348	0.0095
1.039	0.000495	2.338	5.466	0.00231	0.005986
1.04	0.000466	2.122	4.501	0.00198	0.005625
1.042	0.001073	1.882	3.542	0.00404	0.01295
1.044	0.000821	1.964	3.857	0.00323	0.009891
1.045	0.000519	2.166	4.69	0.00225	0.006236
1.047	0.000473	2.115	4.474	0.002	0.005677
1.049	0.000552	1.975	3.902	0.00218	0.006621
1.05	0.000877	1.835	3.369	0.00322	0.01049
1.052	0.000771	1.905	3.631	0.00294	0.009213
1.054	0.00058	1.898	3.603	0.0022	0.006924
1.056	0.000562	2.009	4.037	0.00226	0.006698
1.057	0.000573	2.33	5.428	0.00267	0.006814
1.059	0.000628	2.117	4.482	0.00266	0.007454
1.061	0.000596	1.948	3.793	0.00232	0.007064
1.063	0.000609	2.152	4.631	0.00262	0.007209
1.064	0.00074	2.161	4.671	0.0032	0.008743
1.066	0.000728	2.128	4.529	0.0031	0.008585
1.068	0.000661	2.149	4.617	0.00284	0.007787
1.07	0.000606	2.172	4.716	0.00263	0.007124
1.071	0.000812	2.175	4.729	0.00353	0.009526
1.077	0.000789	2.085	4.345	0.00329	0.009213
1.078	0.000541	2.073	4.299	0.00224	0.006309
1.08	0.00053	2.008	4.033	0.00213	0.006171
1.082	0.000668	2.026	4.106	0.00271	0.007763
1.084	0.000726	1.991	3.964	0.00289	0.008421
1.086	0.000601	2.004	4.018	0.00241	0.006955
1.088	0.000537	2.129	4.533	0.00229	0.006205
1.089	0.000547	2.167	4.695	0.00237	0.006311
1.091	0.000712	1.997	3.99	0.00285	0.008205
1.093	0.000723	2.006	4.024	0.0029	0.008317
1.095	0.000628	2.171	4.714	0.00273	0.007205
1.097	0.000551	2.213	4.897	0.00244	0.00631
1.099	0.000536	2.262	5.118	0.00243	0.006135
1.1	0.000555	2.128	4.529	0.00236	0.006339
1.102	0.000542	2.091	4.372	0.00227	0.006182
1.104	0.000551	2.169	4.703	0.00239	0.006276

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1.106	0.000546	2.139	4.573	0.00234	0.006206
1.108	0.000543	2.159	4.662	0.00234	0.006158
1.11	0.000609	2.197	4.825	0.00267	0.006896
1.112	0.000596	2.206	4.867	0.00263	0.006738
1.114	0.000614	2.162	4.676	0.00266	0.006935
1.116	0.0006	2.226	4.957	0.00267	0.006762
1.118	0.000598	2.124	4.512	0.00254	0.006723
1.12	0.000732	2.05	4.204	0.003	0.008219
1.121	0.000591	2.118	4.486	0.00251	0.00663
1.123	0.000494	2.074	4.3	0.00205	0.005527
1.125	0.000551	2.052	4.209	0.00226	0.006155
1.127	0.000654	1.994	3.977	0.00261	0.007293
1.129	0.000563	2.038	4.152	0.00229	0.006267
1.131	0.000485	2.138	4.569	0.00208	0.005395
1.133	0.00052	2.164	4.683	0.00225	0.005769
1.135	0.00057	2.131	4.539	0.00243	0.006315
1.137	0.000568	2.107	4.44	0.00239	0.006274
1.139	0.000512	2.128	4.53	0.00218	0.005654
1.141	0.000516	2.085	4.349	0.00215	0.005688
1.143	0.000521	2.061	4.25	0.00215	0.005732
1.145	0.000527	2.094	4.383	0.00221	0.005782
1.147	0.000585	2.084	4.344	0.00244	0.006405
1.149	0.000625	2.053	4.216	0.00256	0.006832
1.151	0.00059	2.055	4.223	0.00243	0.006444
1.153	0.000566	2.083	4.34	0.00236	0.006174
1.155	0.00057	2.068	4.277	0.00236	0.006205
1.158	0.000598	2.057	4.232	0.00246	0.006491
1.16	0.000607	2.069	4.279	0.00251	0.006578
1.162	0.000577	2.123	4.509	0.00245	0.006243
1.164	0.00062	2.101	4.412	0.0026	0.006693
1.166	0.000601	2.048	4.196	0.00246	0.00648
1.168	0.000572	2.076	4.312	0.00238	0.006158
1.17	0.000639	2.06	4.243	0.00263	0.00686
1.172	0.000656	2.031	4.125	0.00267	0.007038
1.174	0.000631	2.062	4.25	0.0026	0.00676
1.176	0.000569	2.115	4.475	0.00241	0.006084
1.179	0.000571	2.122	4.501	0.00242	0.00609
1.181	0.000592	2.129	4.531	0.00252	0.006307
1.183	0.000576	2.153	4.636	0.00248	0.006121
1.185	0.000649	2.173	4.72	0.00282	0.006889
1.187	0.000642	2.14	4.579	0.00275	0.0068
1.189	0.000608	2.077	4.314	0.00253	0.006427
1.192	0.000669	2.136	4.561	0.00286	0.007059
1.194	0.000743	2.133	4.552	0.00317	0.007825
1.196	0.000674	2.123	4.506	0.00286	0.007085
1.198	0.000605	2.153	4.637	0.00261	0.006347
1.2	0.000632	2.149	4.618	0.00272	0.006618
1.203	0.000631	2.124	4.513	0.00268	0.0066
1.205	0.000621	2.144	4.598	0.00266	0.006476
1.207	0.000662	2.129	4.534	0.00282	0.006899
1.209	0.00068	2.096	4.392	0.00285	0.007069
1.212	0.000655	2.114	4.469	0.00277	0.0068

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1.214	0.000604	2.132	4.547	0.00258	0.006259
1.216	0.000629	2.142	4.587	0.0027	0.006505
1.219	0.000657	2.133	4.549	0.0028	0.00678
1.221	0.000658	2.125	4.517	0.0028	0.006777
1.223	0.00065	2.109	4.447	0.00274	0.006682
1.225	0.000658	2.111	4.458	0.00278	0.006747
1.228	0.000637	2.115	4.473	0.00269	0.00652
1.23	0.000628	2.102	4.417	0.00264	0.006415
1.232	0.00064	2.14	4.579	0.00274	0.006528
1.235	0.000634	2.163	4.678	0.00274	0.006453
1.237	0.000626	2.161	4.672	0.00271	0.006366
1.24	0.000623	2.144	4.596	0.00267	0.00632
1.242	0.000621	2.121	4.497	0.00263	0.006288
1.244	0.00062	2.101	4.414	0.0026	0.006263
1.247	0.000607	2.089	4.365	0.00254	0.00612
1.249	0.000602	2.108	4.442	0.00254	0.00606
1.252	0.000595	2.13	4.537	0.00254	0.00598
1.254	0.000594	2.138	4.573	0.00254	0.005954
1.256	0.000612	2.144	4.595	0.00263	0.006128
1.259	0.000614	2.163	4.68	0.00266	0.006131
1.261	0.00061	2.165	4.686	0.00264	0.006075
1.264	0.000603	2.131	4.541	0.00257	0.006003
1.266	0.000634	2.112	4.459	0.00268	0.006292
1.269	0.000648	2.105	4.432	0.00273	0.006417
1.271	0.000626	2.103	4.421	0.00263	0.006188
1.274	0.000617	2.114	4.47	0.00261	0.00609
1.276	0.000615	2.13	4.536	0.00262	0.006061
1.279	0.00061	2.126	4.518	0.00259	0.005995
1.281	0.000618	2.104	4.426	0.0026	0.006061
1.284	0.000628	2.112	4.462	0.00265	0.00615
1.286	0.000639	2.111	4.456	0.0027	0.006247
1.289	0.000637	2.128	4.529	0.00271	0.006217
1.291	0.000626	2.14	4.578	0.00268	0.006096
1.294	0.000629	2.123	4.505	0.00267	0.006107
1.297	0.000629	2.135	4.557	0.00268	0.006095
1.299	0.000626	2.146	4.605	0.00269	0.006057
1.302	0.00064	2.132	4.547	0.00273	0.006183
1.304	0.000627	2.142	4.589	0.00269	0.00604
1.307	0.000608	2.146	4.604	0.00261	0.005844
1.31	0.000619	2.111	4.458	0.00262	0.005944
1.312	0.000618	2.111	4.458	0.00261	0.005921
1.315	0.00063	2.113	4.466	0.00266	0.006027
1.318	0.000639	2.105	4.431	0.00269	0.0061
1.32	0.000636	2.113	4.465	0.00269	0.006057
1.323	0.000626	2.13	4.539	0.00267	0.005949
1.326	0.000623	2.145	4.603	0.00267	0.005906
1.329	0.000642	2.148	4.615	0.00276	0.00607
1.331	0.000642	2.144	4.598	0.00275	0.006064
1.334	0.000638	2.133	4.55	0.00272	0.006012
1.337	0.000627	2.125	4.514	0.00266	0.005898
1.34	0.000628	2.102	4.417	0.00264	0.00589
1.342	0.000641	2.115	4.473	0.00271	0.006006

ALNAB161

1.345	0.000641	2.135	4.557	0.00274	0.005995
1.348	0.000636	2.136	4.563	0.00272	0.005928
1.351	0.000627	2.13	4.537	0.00267	0.005836
1.354	0.00063	2.1	4.411	0.00265	0.005851
1.356	0.000631	2.106	4.436	0.00266	0.005847
1.359	0.000634	2.128	4.527	0.0027	0.00586
1.362	0.000644	2.14	4.578	0.00275	0.005941
1.365	0.000644	2.148	4.615	0.00277	0.00593
1.368	0.000652	2.134	4.553	0.00278	0.005995
1.371	0.000646	2.131	4.542	0.00275	0.005924
1.374	0.000647	2.148	4.614	0.00278	0.005917
1.377	0.000641	2.152	4.633	0.00276	0.005857
1.38	0.000635	2.144	4.596	0.00272	0.005784
1.382	0.000647	2.133	4.549	0.00276	0.005886
1.385	0.000654	2.123	4.505	0.00278	0.005937
1.388	0.000648	2.129	4.533	0.00276	0.005872
1.391	0.000636	2.133	4.55	0.00271	0.005749
1.394	0.000634	2.129	4.533	0.0027	0.005715
1.397	0.000633	2.127	4.524	0.00269	0.005695
1.4	0.00065	2.117	4.483	0.00275	0.005837
1.403	0.000659	2.118	4.486	0.00279	0.005903
1.406	0.000653	2.116	4.479	0.00277	0.00584
1.41	0.000656	2.138	4.572	0.0028	0.005849
1.413	0.000649	2.143	4.592	0.00278	0.005773
1.416	0.000644	2.118	4.485	0.00273	0.005718
1.419	0.000646	2.112	4.462	0.00273	0.005727
1.422	0.000639	2.132	4.547	0.00273	0.005651
1.425	0.000641	2.136	4.563	0.00274	0.005657
1.428	0.00065	2.139	4.577	0.00278	0.005717
1.431	0.000645	2.129	4.532	0.00275	0.005665
1.435	0.000656	2.119	4.492	0.00278	0.005746
1.438	0.000665	2.119	4.492	0.00282	0.005815
1.441	0.000647	2.118	4.486	0.00274	0.005642
1.444	0.000644	2.133	4.549	0.00275	0.005605
1.447	0.000661	2.13	4.535	0.00281	0.005737
1.451	0.000669	2.111	4.455	0.00282	0.005795
1.454	0.000681	2.109	4.447	0.00287	0.005891
1.457	0.000679	2.13	4.539	0.00289	0.005861
1.46	0.000673	2.135	4.56	0.00287	0.005792
1.464	0.00068	2.127	4.524	0.00289	0.005843
1.467	0.000679	2.126	4.521	0.00289	0.005819
1.47	0.000676	2.121	4.498	0.00287	0.005784
1.474	0.000689	2.115	4.474	0.00291	0.005876
1.477	0.000695	2.109	4.447	0.00293	0.005912
1.48	0.000692	2.114	4.471	0.00293	0.005878
1.484	0.0007	2.123	4.509	0.00297	0.005934
1.487	0.000708	2.119	4.491	0.003	0.005987
1.491	0.000705	2.117	4.481	0.00298	0.005946
1.494	0.000701	2.116	4.477	0.00297	0.005898
1.498	0.000697	2.116	4.476	0.00295	0.005851
1.501	0.000694	2.112	4.461	0.00293	0.005809
1.505	0.000703	2.113	4.463	0.00297	0.005874

ALNAB161

1.508	0.000715	2.115	4.475	0.00303	0.005964
1.512	0.000735	2.113	4.464	0.0031	0.006111
1.515	0.000725	2.107	4.439	0.00306	0.006017
1.519	0.000699	2.116	4.477	0.00296	0.005784
1.522	0.0007	2.116	4.476	0.00296	0.005778
1.526	0.0007	2.106	4.436	0.00295	0.005766
1.529	0.000698	2.115	4.473	0.00295	0.005734
1.533	0.000701	2.116	4.478	0.00297	0.005746
1.537	0.000699	2.111	4.455	0.00295	0.005719
1.54	0.000695	2.107	4.441	0.00293	0.00567
1.544	0.000702	2.109	4.448	0.00296	0.005712
1.548	0.000709	2.117	4.481	0.003	0.005762
1.551	0.000701	2.125	4.514	0.00298	0.005678
1.555	0.000689	2.134	4.554	0.00294	0.005572
1.559	0.000693	2.136	4.562	0.00296	0.005592
1.563	0.000694	2.127	4.524	0.00295	0.005581
1.566	0.000688	2.122	4.505	0.00292	0.005524
1.57	0.000691	2.125	4.515	0.00293	0.005529
1.574	0.000691	2.135	4.559	0.00295	0.005523
1.578	0.00069	2.138	4.572	0.00295	0.005494
1.582	0.000682	2.135	4.558	0.00291	0.005421
1.586	0.000679	2.142	4.59	0.00291	0.005383
1.589	0.000674	2.134	4.556	0.00288	0.005332
1.593	0.000673	2.119	4.491	0.00285	0.005313
1.597	0.000684	2.118	4.485	0.0029	0.005382
1.601	0.000689	2.122	4.503	0.00292	0.005406
1.605	0.000693	2.131	4.54	0.00295	0.005428
1.609	0.000691	2.135	4.56	0.00295	0.005401
1.613	0.000676	2.142	4.587	0.0029	0.005268
1.617	0.000672	2.132	4.545	0.00287	0.005226
1.621	0.000675	2.121	4.497	0.00286	0.005236
1.625	0.000673	2.135	4.56	0.00287	0.005204
1.629	0.000668	2.146	4.603	0.00287	0.005156
1.634	0.000677	2.134	4.554	0.00289	0.005209
1.638	0.000699	2.112	4.462	0.00295	0.005366
1.642	0.000694	2.129	4.531	0.00295	0.005312
1.646	0.000688	2.147	4.609	0.00295	0.005252
1.65	0.000692	2.129	4.534	0.00295	0.00527
1.654	0.000687	2.129	4.533	0.00293	0.00522
1.659	0.000702	2.12	4.494	0.00298	0.005324
1.663	0.000699	2.127	4.522	0.00297	0.005281
1.667	0.000682	2.149	4.618	0.00293	0.005142
1.672	0.000687	2.126	4.52	0.00292	0.005166
1.676	0.000692	2.091	4.37	0.00289	0.005188
1.68	0.000679	2.102	4.417	0.00286	0.005084
1.685	0.000677	2.126	4.521	0.00288	0.005049
1.689	0.00068	2.143	4.591	0.00291	0.005061
1.693	0.000682	2.163	4.68	0.00295	0.00506
1.698	0.00067	2.159	4.662	0.00289	0.004963
1.702	0.000664	2.181	4.756	0.00289	0.0049
1.707	0.000661	2.187	4.784	0.00289	0.004869
1.711	0.000668	2.15	4.623	0.00287	0.004909

ALNAB161

1.716	0.000669	2.123	4.508	0.00284	0.0049
1.72	0.00066	2.147	4.611	0.00284	0.004824
1.725	0.000688	2.146	4.606	0.00295	0.005012
1.73	0.000703	2.143	4.59	0.00301	0.005112
1.734	0.000685	2.172	4.716	0.00297	0.004962
1.739	0.000688	2.157	4.652	0.00297	0.004975
1.744	0.000686	2.134	4.556	0.00293	0.004946
1.748	0.000689	2.15	4.625	0.00296	0.004953
1.753	0.000707	2.168	4.701	0.00306	0.005069
1.758	0.000704	2.152	4.631	0.00303	0.005034
1.763	0.000704	2.147	4.608	0.00302	0.005022
1.767	0.000684	2.129	4.533	0.00291	0.004863
1.772	0.000666	2.141	4.583	0.00285	0.004725
1.777	0.000684	2.169	4.706	0.00297	0.004838
1.782	0.000695	2.158	4.655	0.003	0.004902
1.787	0.000682	2.125	4.515	0.0029	0.004798
1.792	0.000676	2.116	4.478	0.00286	0.004745
1.797	0.000682	2.125	4.515	0.0029	0.00477
1.802	0.000688	2.115	4.472	0.00291	0.004798
1.807	0.000679	2.137	4.569	0.0029	0.004722
1.812	0.000654	2.168	4.702	0.00284	0.004538
1.817	0.000649	2.169	4.704	0.00282	0.004492
1.822	0.000675	2.177	4.741	0.00294	0.004655
1.827	0.000696	2.151	4.627	0.00299	0.004789
1.832	0.000662	2.145	4.6	0.00284	0.004542
1.838	0.000649	2.177	4.739	0.00283	0.004442
1.843	0.000682	2.189	4.79	0.00298	0.004652
1.848	0.000677	2.172	4.716	0.00294	0.004607
1.853	0.000683	2.146	4.605	0.00293	0.004636
1.859	0.000711	2.124	4.51	0.00302	0.004811
1.864	0.000702	2.12	4.493	0.00298	0.004734
1.869	0.000703	2.139	4.573	0.00301	0.004726
1.875	0.00072	2.154	4.639	0.0031	0.00483
1.88	0.000688	2.167	4.696	0.00298	0.004598
1.886	0.00068	2.166	4.693	0.00295	0.004534
1.891	0.000688	2.166	4.69	0.00298	0.004572
1.897	0.000692	2.175	4.731	0.00301	0.004584
1.902	0.0007	2.167	4.694	0.00303	0.004627
1.908	0.000679	2.134	4.553	0.0029	0.004473
1.914	0.000691	2.138	4.571	0.00296	0.004541
1.919	0.000703	2.169	4.705	0.00305	0.004608
1.925	0.000698	2.162	4.674	0.00302	0.004561
1.931	0.000697	2.154	4.64	0.003	0.004538
1.936	0.000691	2.134	4.555	0.00295	0.004486
1.942	0.000696	2.123	4.508	0.00296	0.004506
1.948	0.000703	2.129	4.532	0.00299	0.004534
1.954	0.000699	2.128	4.53	0.00298	0.004499
1.96	0.000687	2.114	4.471	0.0029	0.004406
1.966	0.000681	2.126	4.518	0.00289	0.004354
1.972	0.000678	2.155	4.645	0.00292	0.004322
1.978	0.000682	2.142	4.588	0.00292	0.004335
1.984	0.000694	2.138	4.573	0.00297	0.004397

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1.99	0.000703	2.145	4.6	0.00302	0.004442
1.996	0.000703	2.137	4.566	0.00301	0.00443
2.002	0.000697	2.136	4.563	0.00298	0.004374
2.009	0.000699	2.151	4.626	0.00301	0.004376
2.015	0.000701	2.162	4.673	0.00303	0.004372
2.021	0.000687	2.145	4.599	0.00295	0.004273
2.027	0.000684	2.152	4.631	0.00294	0.004242
2.034	0.000689	2.155	4.644	0.00297	0.004258
2.04	0.000691	2.155	4.646	0.00298	0.004255
2.047	0.000701	2.152	4.632	0.00302	0.004305
2.053	0.000708	2.147	4.61	0.00304	0.004337
2.06	0.000703	2.162	4.673	0.00304	0.004289
2.066	0.000702	2.165	4.689	0.00304	0.004272
2.073	0.000691	2.16	4.664	0.00299	0.004192
2.08	0.000682	2.142	4.587	0.00292	0.004125
2.086	0.000693	2.133	4.55	0.00296	0.004178
2.093	0.000702	2.141	4.586	0.00301	0.004215
2.1	0.00069	2.162	4.674	0.00298	0.004129
2.107	0.000684	2.163	4.678	0.00296	0.004083
2.113	0.000692	2.158	4.657	0.00299	0.004115
2.12	0.000692	2.158	4.657	0.00298	0.0041
2.127	0.000697	2.138	4.572	0.00298	0.004119
2.134	0.00071	2.146	4.605	0.00305	0.004181
2.141	0.000707	2.149	4.617	0.00304	0.00415
2.149	0.000699	2.148	4.615	0.003	0.004092
2.156	0.000698	2.156	4.649	0.00301	0.004068
2.163	0.000696	2.145	4.602	0.00299	0.004045
2.17	0.000697	2.139	4.573	0.00298	0.004038
2.177	0.000695	2.14	4.58	0.00298	0.004014
2.185	0.0007	2.139	4.575	0.00299	0.004028
2.192	0.000699	2.135	4.559	0.00298	0.004008
2.2	0.000694	2.133	4.548	0.00296	0.003966
2.207	0.000701	2.134	4.555	0.00299	0.00399
2.215	0.000693	2.134	4.555	0.00296	0.003936
2.222	0.000694	2.14	4.581	0.00297	0.003924
2.23	0.00071	2.158	4.658	0.00307	0.004005
2.238	0.000713	2.159	4.66	0.00308	0.004008
2.245	0.000701	2.148	4.613	0.00301	0.003927
2.253	0.000698	2.143	4.593	0.00299	0.003893
2.261	0.000712	2.131	4.543	0.00303	0.003956
2.269	0.000715	2.126	4.521	0.00304	0.00396
2.277	0.000709	2.136	4.563	0.00303	0.003913
2.285	0.000711	2.137	4.568	0.00304	0.003913
2.293	0.000708	2.136	4.565	0.00303	0.003884
2.301	0.0007	2.14	4.582	0.003	0.003825
2.309	0.000699	2.143	4.591	0.003	0.003807
2.318	0.000705	2.137	4.565	0.00301	0.003825
2.326	0.000708	2.134	4.554	0.00302	0.003829
2.334	0.000704	2.143	4.594	0.00302	0.00379
2.343	0.000702	2.148	4.615	0.00302	0.003769
2.351	0.000707	2.14	4.579	0.00303	0.003782
2.36	0.000709	2.135	4.557	0.00303	0.003778

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2.369	0.00071	2.137	4.568	0.00303	0.003768
2.377	0.000712	2.144	4.597	0.00305	0.003766
2.386	0.000707	2.153	4.637	0.00304	0.003723
2.395	0.000707	2.149	4.617	0.00304	0.00371
2.404	0.000707	2.147	4.609	0.00304	0.003699
2.413	0.000712	2.148	4.614	0.00306	0.003707
2.422	0.000715	2.153	4.633	0.00308	0.003713
2.431	0.000714	2.152	4.631	0.00307	0.003692
2.44	0.000712	2.147	4.609	0.00306	0.003669
2.449	0.000711	2.147	4.609	0.00305	0.003651
2.459	0.000709	2.143	4.593	0.00304	0.003626
2.468	0.000703	2.142	4.59	0.00301	0.003583
2.477	0.000704	2.141	4.585	0.00301	0.003571
2.487	0.000706	2.149	4.619	0.00303	0.003569
2.496	0.00071	2.155	4.645	0.00306	0.003573
2.506	0.000713	2.145	4.602	0.00306	0.003576
2.516	0.00071	2.139	4.577	0.00304	0.003546
2.526	0.000702	2.141	4.583	0.00301	0.003494
2.535	0.000702	2.142	4.587	0.00301	0.003482
2.546	0.000707	2.141	4.585	0.00303	0.00349
2.556	0.000709	2.144	4.595	0.00304	0.003486
2.566	0.000712	2.152	4.633	0.00307	0.003491
2.576	0.000712	2.152	4.629	0.00306	0.003474
2.586	0.000708	2.142	4.588	0.00303	0.003441
2.597	0.000707	2.142	4.589	0.00303	0.003422
2.607	0.000707	2.151	4.626	0.00304	0.003407
2.618	0.000707	2.145	4.602	0.00303	0.003396
2.628	0.000716	2.134	4.556	0.00305	0.003423
2.639	0.000715	2.137	4.569	0.00306	0.003408
2.65	0.000712	2.141	4.585	0.00305	0.00338
2.661	0.000706	2.143	4.593	0.00303	0.003336
2.672	0.000702	2.158	4.657	0.00303	0.003303
2.683	0.00071	2.163	4.678	0.00307	0.003328
2.694	0.000715	2.159	4.66	0.00309	0.003339
2.705	0.000715	2.158	4.658	0.00309	0.003322
2.716	0.000718	2.154	4.638	0.00309	0.003324
2.728	0.000715	2.156	4.648	0.00308	0.003297
2.739	0.000711	2.153	4.636	0.00306	0.003261
2.751	0.00071	2.161	4.668	0.00307	0.003245
2.763	0.000715	2.165	4.689	0.0031	0.003254
2.775	0.00072	2.16	4.665	0.00311	0.003261
2.786	0.000715	2.165	4.687	0.0031	0.003228
2.799	0.000712	2.171	4.713	0.00309	0.0032
2.811	0.000712	2.167	4.697	0.00309	0.003186
2.823	0.000714	2.161	4.668	0.00308	0.003179
2.835	0.000713	2.161	4.67	0.00308	0.003161
2.848	0.000714	2.167	4.697	0.00309	0.00315
2.86	0.000716	2.168	4.701	0.0031	0.003145
2.873	0.000716	2.162	4.674	0.0031	0.003133
2.886	0.000718	2.16	4.664	0.0031	0.003129
2.899	0.000718	2.157	4.651	0.0031	0.003112
2.912	0.000714	2.161	4.67	0.00309	0.003085

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2.925	0.000714	2.166	4.693	0.00309	0.00307
2.938	0.000716	2.167	4.695	0.0031	0.003064
2.952	0.000717	2.165	4.687	0.0031	0.003054
2.965	0.000716	2.159	4.659	0.00309	0.003038
2.979	0.000716	2.159	4.661	0.00309	0.003023
2.992	0.000714	2.158	4.658	0.00308	0.003001
3.006	0.000717	2.16	4.667	0.0031	0.002997
3.02	0.000718	2.163	4.68	0.0031	0.002987
3.035	0.000717	2.161	4.671	0.0031	0.002972
3.049	0.000717	2.161	4.668	0.0031	0.002958
3.063	0.000714	2.16	4.665	0.00308	0.00293
3.078	0.000716	2.155	4.645	0.00309	0.002926
3.093	0.000722	2.155	4.645	0.00311	0.002933
3.107	0.000721	2.155	4.644	0.00311	0.002916
3.122	0.00072	2.152	4.633	0.0031	0.0029
3.138	0.000721	2.158	4.655	0.00311	0.002888
3.153	0.000719	2.159	4.663	0.00311	0.002869
3.168	0.00072	2.161	4.671	0.00311	0.002856
3.184	0.00072	2.162	4.675	0.00311	0.002843
3.2	0.000718	2.16	4.666	0.0031	0.00282
3.215	0.000716	2.16	4.666	0.00309	0.002799
3.232	0.000717	2.163	4.678	0.0031	0.002791
3.248	0.000719	2.163	4.679	0.00311	0.002782
3.264	0.000714	2.162	4.676	0.00309	0.002749
3.281	0.000712	2.163	4.677	0.00308	0.00273
3.297	0.000717	2.153	4.634	0.00309	0.002732
3.314	0.000718	2.149	4.62	0.00309	0.002723
3.331	0.000715	2.157	4.653	0.00309	0.0027
3.349	0.000714	2.154	4.639	0.00308	0.002682
3.366	0.000714	2.158	4.656	0.00308	0.002666
3.383	0.000714	2.166	4.694	0.00309	0.002651
3.401	0.000712	2.165	4.686	0.00308	0.002632
3.419	0.000712	2.164	4.681	0.00308	0.002618
3.437	0.000714	2.165	4.686	0.00309	0.002612
3.456	0.000714	2.162	4.673	0.00309	0.002598
3.474	0.000715	2.161	4.671	0.00309	0.002587
3.493	0.000716	2.164	4.683	0.0031	0.002575
3.512	0.000714	2.162	4.675	0.00309	0.002557
3.531	0.000713	2.155	4.646	0.00307	0.002539
3.55	0.000714	2.159	4.66	0.00308	0.002529
3.57	0.000715	2.163	4.678	0.00309	0.002518
3.59	0.000713	2.159	4.663	0.00308	0.002497
3.61	0.000711	2.157	4.654	0.00307	0.002476
3.63	0.000711	2.156	4.648	0.00307	0.002462
3.651	0.00071	2.155	4.646	0.00306	0.002445
3.671	0.000711	2.153	4.637	0.00306	0.002435
3.692	0.000714	2.158	4.656	0.00308	0.002432
3.713	0.000715	2.158	4.658	0.00309	0.00242
3.735	0.000715	2.158	4.658	0.00309	0.002407
3.756	0.000711	2.162	4.674	0.00307	0.002379
3.778	0.000707	2.159	4.661	0.00305	0.002351
3.801	0.000708	2.159	4.663	0.00306	0.002342

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3.823	0.000707	2.159	4.659	0.00305	0.002326
3.846	0.000706	2.155	4.645	0.00304	0.002307
3.869	0.000706	2.155	4.646	0.00304	0.002293
3.892	0.000706	2.156	4.649	0.00305	0.002281
3.915	0.000705	2.161	4.668	0.00305	0.002264
3.939	0.000705	2.16	4.664	0.00304	0.00225
3.963	0.000707	2.149	4.619	0.00304	0.002243
3.988	0.000707	2.149	4.619	0.00304	0.002229
4.013	0.000706	2.151	4.627	0.00304	0.002213
4.037	0.000705	2.148	4.612	0.00303	0.002196
4.063	0.000703	2.149	4.617	0.00302	0.002176
4.088	0.000702	2.15	4.621	0.00302	0.002158
4.114	0.000702	2.151	4.626	0.00302	0.002145
4.141	0.0007	2.153	4.636	0.00301	0.002126
4.167	0.000704	2.149	4.619	0.00303	0.002125
4.194	0.000719	2.145	4.602	0.00308	0.002155
4.222	0.000735	2.138	4.57	0.00314	0.002188
4.25	0.000732	2.131	4.54	0.00312	0.002165
4.278	0.000718	2.141	4.586	0.00307	0.00211
4.306	0.000708	2.138	4.573	0.00303	0.002068
4.335	0.000704	2.136	4.564	0.00301	0.002042
4.364	0.000705	2.137	4.567	0.00301	0.00203
4.394	0.000706	2.132	4.546	0.00301	0.002019
4.424	0.000705	2.13	4.537	0.003	0.002004
4.454	0.000707	2.132	4.547	0.00301	0.001995
4.485	0.000709	2.13	4.539	0.00302	0.001989
4.516	0.000713	2.123	4.509	0.00303	0.001986
4.548	0.000718	2.116	4.477	0.00304	0.001985
4.58	0.000723	2.11	4.451	0.00305	0.001985
4.613	0.000728	2.105	4.433	0.00307	0.001985
4.646	0.000734	2.103	4.422	0.00308	0.001985
4.679	0.000739	2.097	4.398	0.0031	0.001986
4.713	0.000747	2.092	4.376	0.00313	0.001993
4.748	0.000754	2.091	4.374	0.00315	0.001995
4.783	0.00076	2.084	4.343	0.00317	0.001997
4.819	0.00077	2.077	4.312	0.0032	0.00201
4.855	0.000781	2.071	4.29	0.00324	0.002022
4.891	0.000792	2.063	4.258	0.00327	0.002036
4.929	0.000812	2.058	4.235	0.00334	0.002071
4.966	0.000831	2.05	4.202	0.00341	0.002105
5.005	0.000851	2.038	4.155	0.00347	0.002138
5.044	0.000867	2.032	4.128	0.00352	0.00216
5.084	0.000858	2.034	4.138	0.00349	0.002123
5.124	0.000838	2.036	4.146	0.00341	0.002057
5.165	0.000823	2.037	4.147	0.00335	0.002003
5.206	0.000817	2.039	4.156	0.00333	0.001973
5.248	0.000822	2.036	4.146	0.00335	0.001969
5.291	0.000834	2.025	4.1	0.00338	0.001981
5.335	0.000849	2.013	4.052	0.00342	0.002001
5.379	0.000861	2.011	4.042	0.00346	0.002012
5.424	0.00087	2.008	4.033	0.00349	0.002016
5.47	0.000879	2.001	4.003	0.00352	0.002021

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5.517	0.000892	1.996	3.982	0.00356	0.002032
5.564	0.000909	1.99	3.959	0.00362	0.002053
5.612	0.000925	1.979	3.915	0.00366	0.002071
5.661	0.00094	1.974	3.898	0.00371	0.002088
5.711	0.000958	1.97	3.881	0.00378	0.002109
5.762	0.000981	1.956	3.826	0.00384	0.002139
5.814	0.00101	1.948	3.795	0.00394	0.002184
5.866	0.001035	1.945	3.784	0.00402	0.002217
5.92	0.001056	1.942	3.77	0.0041	0.002241
5.975	0.001092	1.934	3.74	0.00423	0.002298
6.03	0.001147	1.923	3.696	0.00441	0.002392
6.087	0.00122	1.905	3.631	0.00465	0.002519
6.145	0.0013	1.894	3.587	0.00492	0.002659
6.204	0.001397	1.886	3.558	0.00527	0.002831
6.264	0.001511	1.879	3.529	0.00568	0.003033
6.325	0.00174	1.866	3.483	0.0065	0.003459
6.387	0.002162	1.849	3.42	0.008	0.004256
6.451	0.002628	1.832	3.355	0.00963	0.005122
6.516	0.003091	1.819	3.31	0.01125	0.005963
6.582	0.003675	1.805	3.258	0.01326	0.007018
6.65	0.004147	1.794	3.218	0.01488	0.00784
6.719	0.004518	1.785	3.187	0.01613	0.008454
6.789	0.004872	1.775	3.152	0.0173	0.009022
6.861	0.005255	1.772	3.14	0.01862	0.009628
6.935	0.005556	1.765	3.114	0.01961	0.010072
7.01	0.005559	1.753	3.073	0.01949	0.00997
7.087	0.005739	1.742	3.036	0.02	0.010181
7.165	0.006034	1.738	3.022	0.02098	0.010587
7.245	0.005801	1.736	3.014	0.02014	0.010065
7.327	0.006073	1.725	2.977	0.02096	0.01042
7.411	0.006769	1.715	2.942	0.02322	0.011482
7.497	0.007052	1.717	2.949	0.02422	0.011825
7.584	0.006866	1.716	2.944	0.02356	0.01138
7.675	0.006908	1.703	2.9	0.02353	0.011315
7.766	0.006867	1.692	2.864	0.02324	0.011116
7.86	0.007047	1.684	2.835	0.02373	0.011271
7.957	0.007331	1.676	2.808	0.02457	0.011583
8.056	0.007361	1.669	2.785	0.02457	0.011487
8.158	0.007511	1.656	2.744	0.02488	0.011574
8.262	0.007437	1.642	2.696	0.02442	0.011317
8.369	0.007645	1.624	2.639	0.02484	0.011484
8.478	0.00757	1.613	2.601	0.02442	0.011224
8.591	0.007076	1.606	2.579	0.02273	0.010355
8.706	0.007194	1.591	2.531	0.02289	0.010388
8.825	0.007526	1.579	2.493	0.02376	0.010721
8.947	0.008154	1.562	2.44	0.02547	0.011457
9.072	0.0084	1.527	2.331	0.02565	0.01164
9.201	0.007915	1.493	2.228	0.02363	0.010814
9.334	0.007772	1.466	2.149	0.02279	0.010469
9.471	0.007975	1.434	2.057	0.02288	0.010586
9.611	0.008704	1.407	1.979	0.02449	0.011386
9.756	0.009236	1.392	1.937	0.02571	0.011901

9.905	0.009472	1.378	1.9	0.02611	0.012022
10.058	0.009714	1.369	1.873	0.02659	0.012141
10.217	0.009057	1.387	1.923	0.02512	0.011144
10.381	0.008984	1.469	2.159	0.0264	0.010879
10.55	0.009457	1.636	2.677	0.03094	0.011268
10.725	0.009247	2.072	4.294	0.03832	0.010839
10.905	0.009269	3.193	10.195	0.05919	0.010686
11.092	0.010026	5.349	28.614	0.10726	0.011363
11.285	0.007484	8.326	69.32	0.12462	0.008336
11.486	0.006444	10.949	119.875	0.1411	0.007053
11.693	0.006268	12.622	159.304	0.15821	0.006738
11.908	0.005749	14.113	199.164	0.16225	0.006069
12.131	0.008231	16.268	264.649	0.26782	0.00853
12.363	0.004287	19.783	391.37	0.16962	0.004359

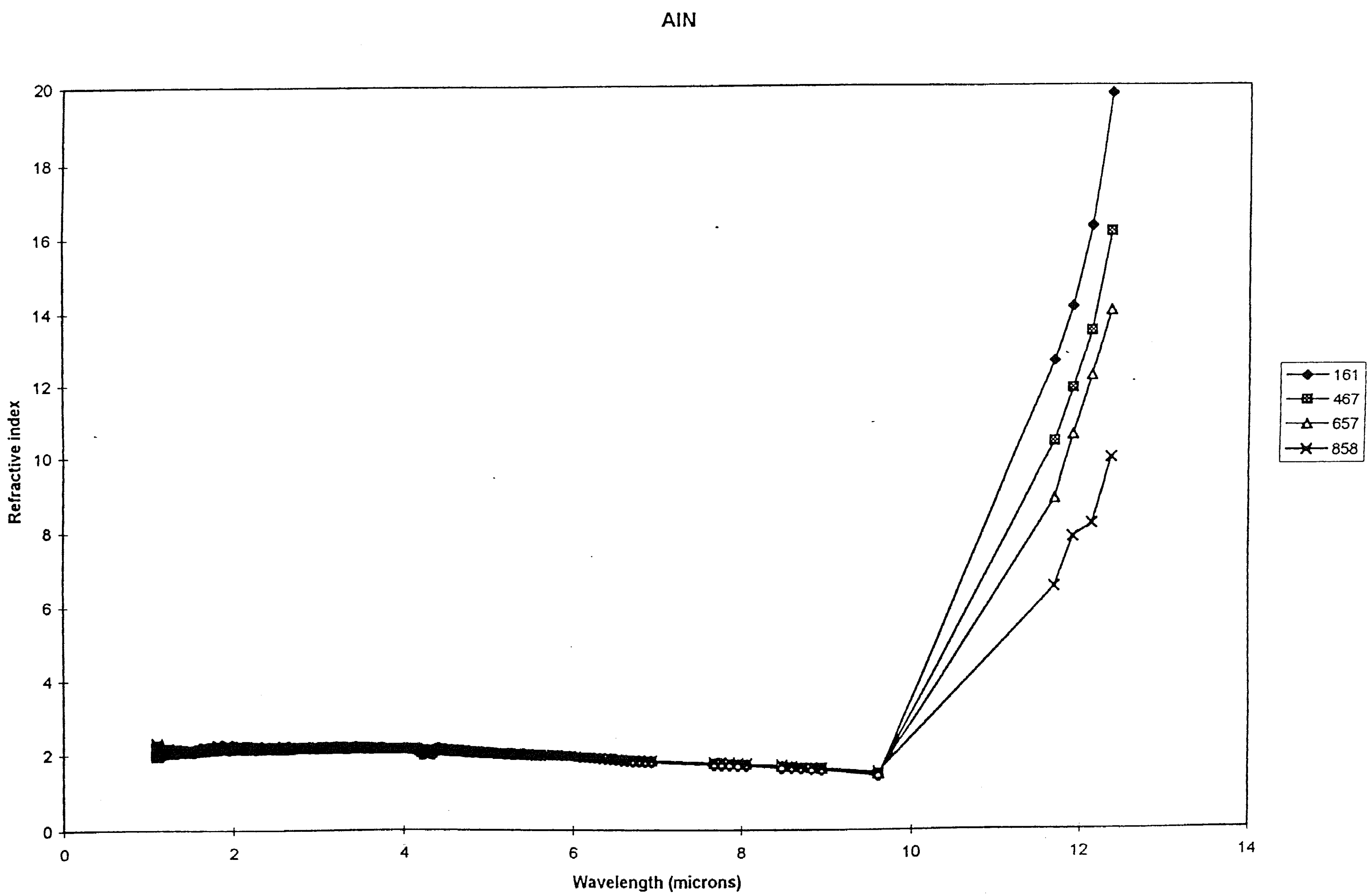

Fig.B-1 Refractive index Vs Wavelength plot of AlN at different temperatures

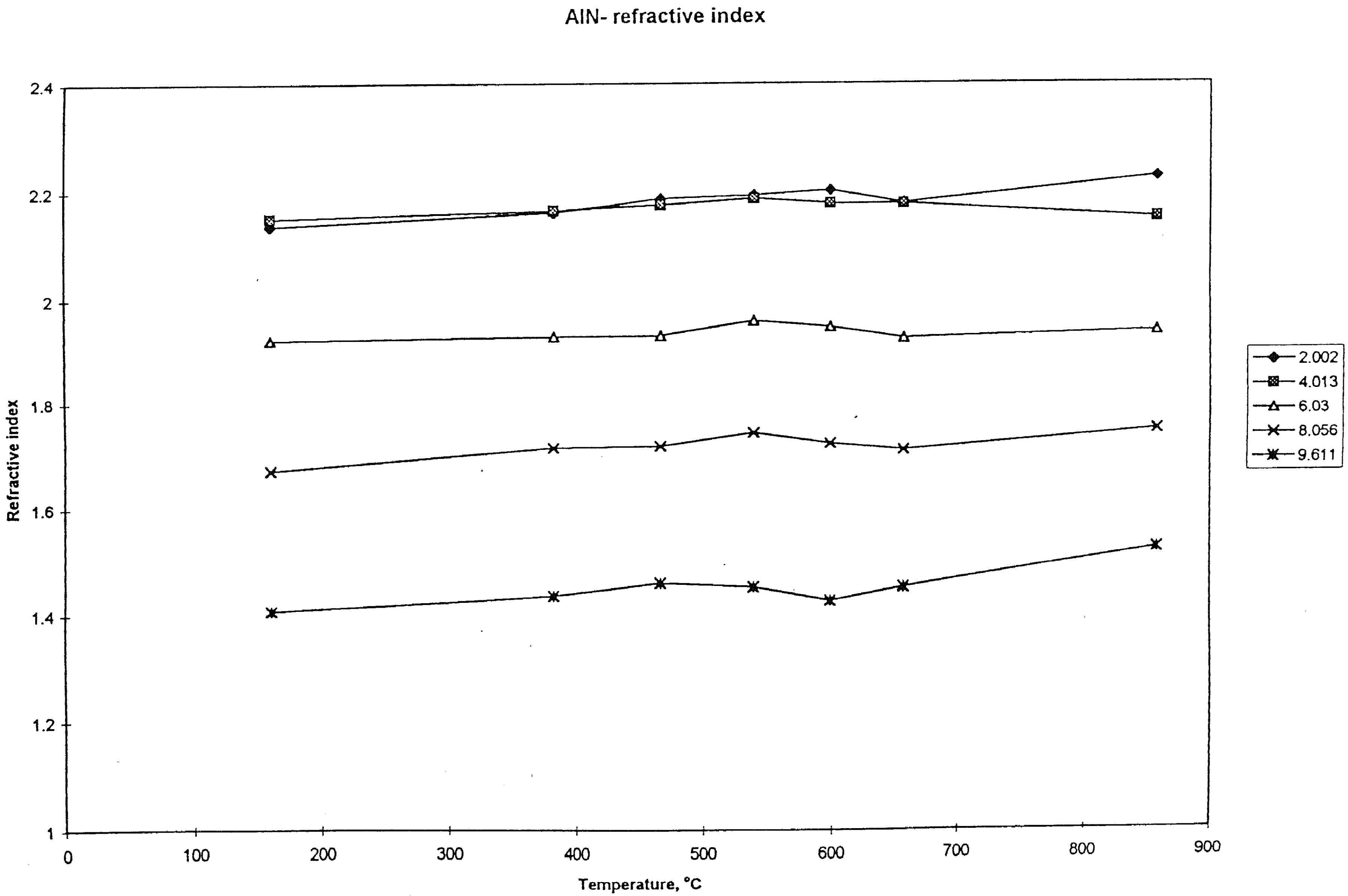

Fig.B-2 Refractive index Vs Temperature plot of AlN at different wavelengths

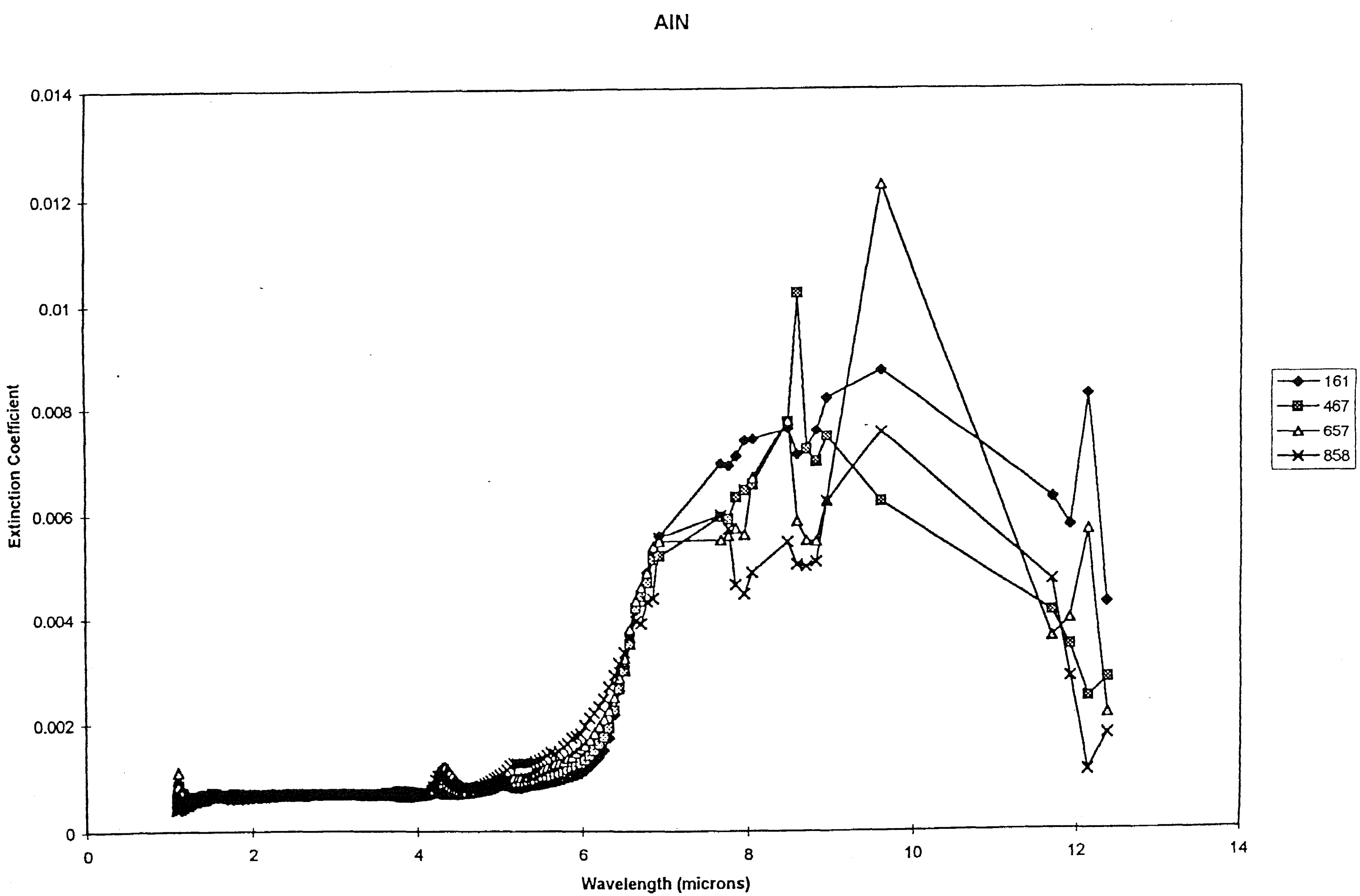

Fig.B-3 Extinction coefficient Vs Wavelength plot of AlN at different temperatures

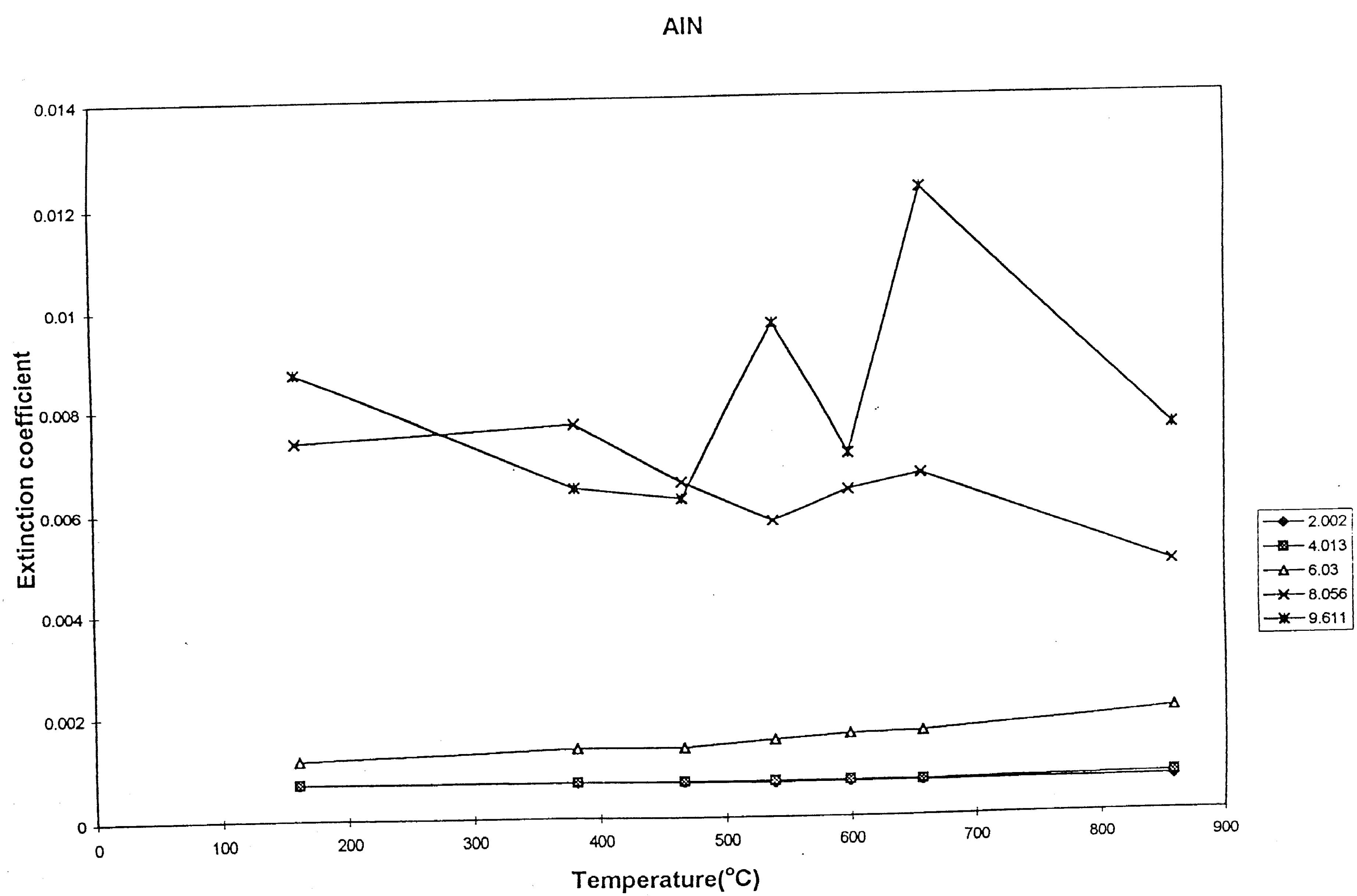

Fig.B-4 Extinction coefficient Vs Temperature plot of AlN at different wavelengths

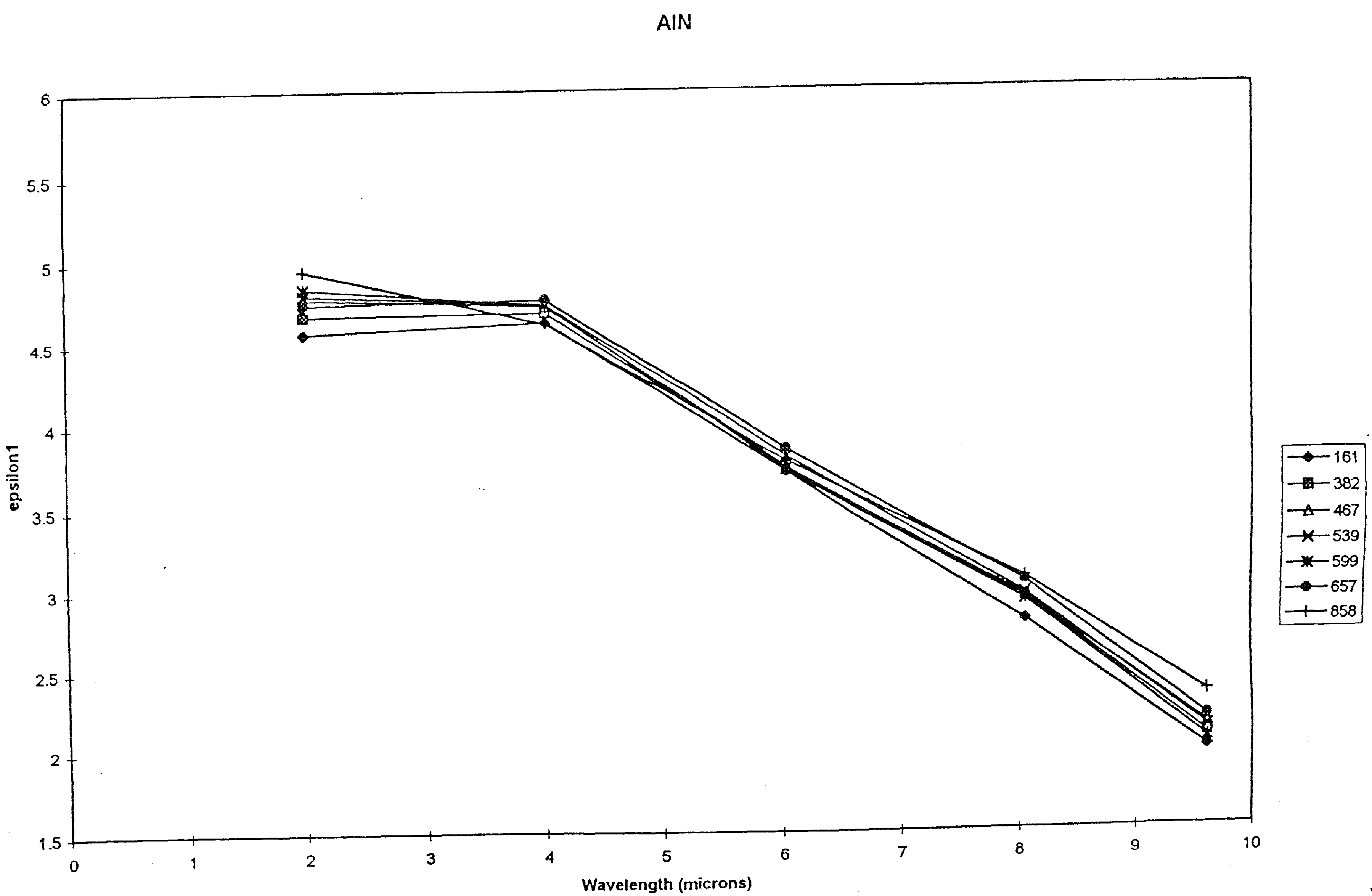

Fig.B-5 Real part of Complex dielectric constant Vs Wavelength plot of AlN at different temperatures

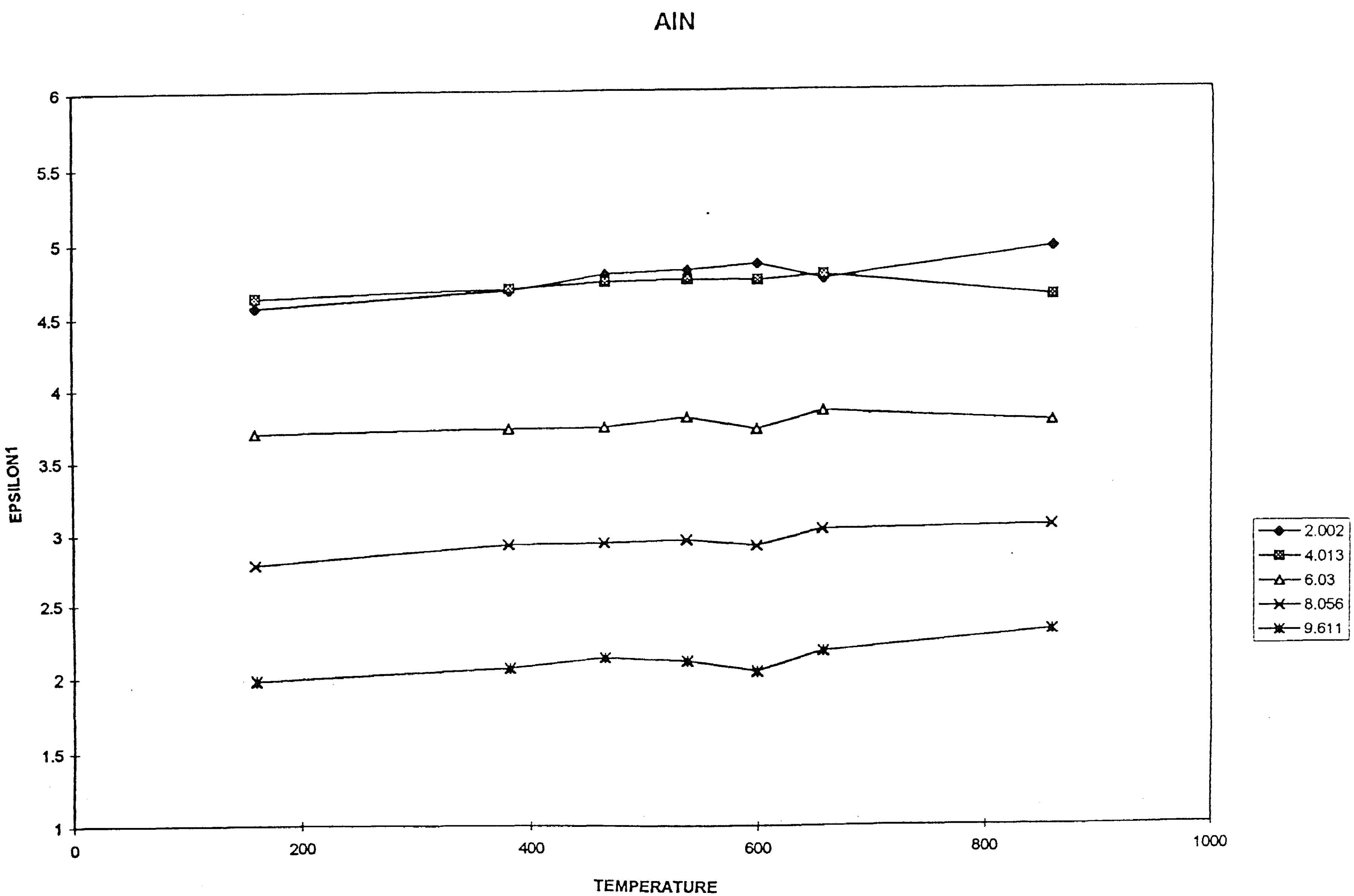

Fig.B-6 Real part of Complex dielectric constant Vs Temperature plot of AlN at different wavelengths

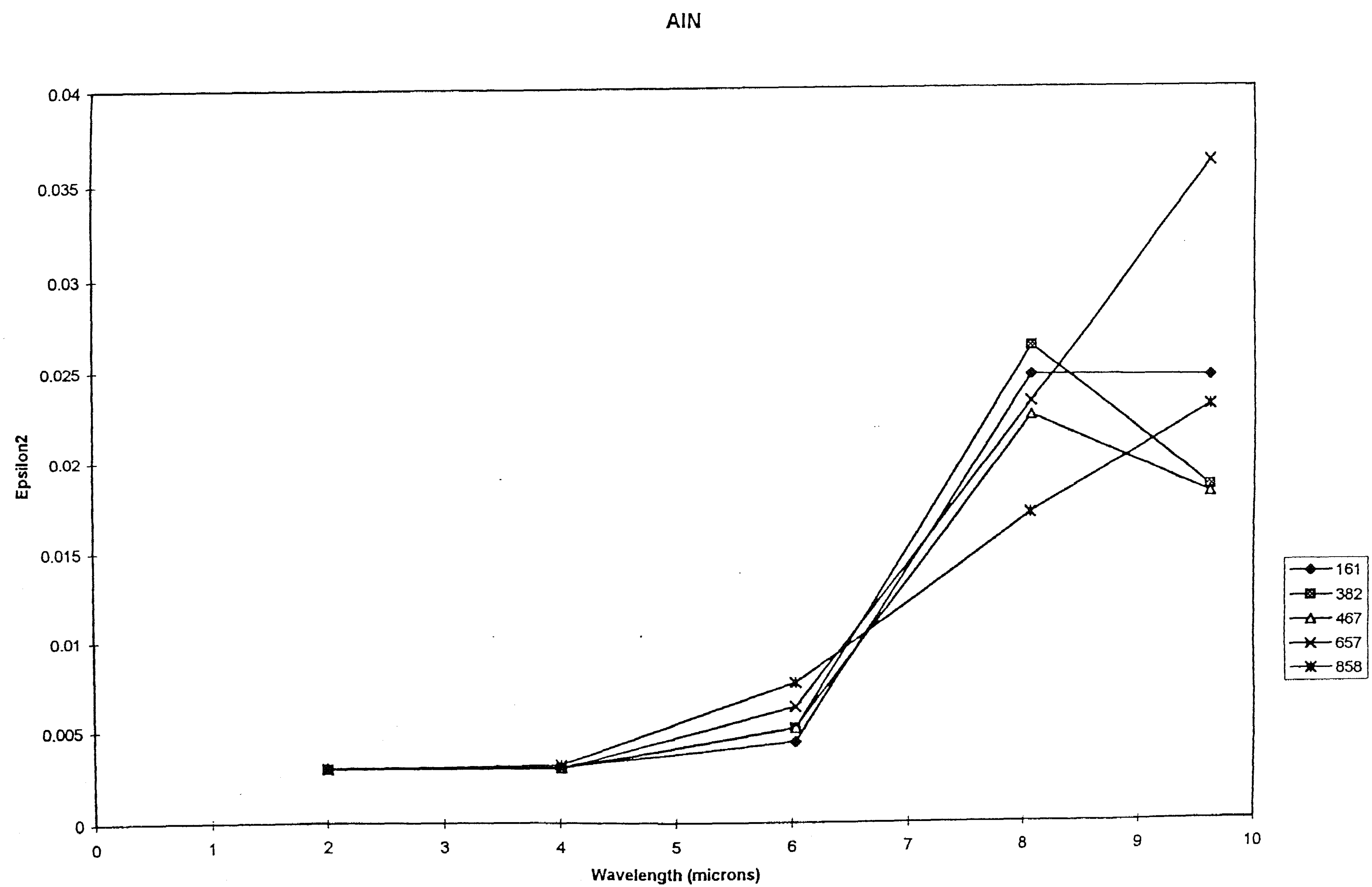

Fig.B-7 Imaginary part of Complex dielectric constant index Vs Wavelength plot of AlN at different temperatures

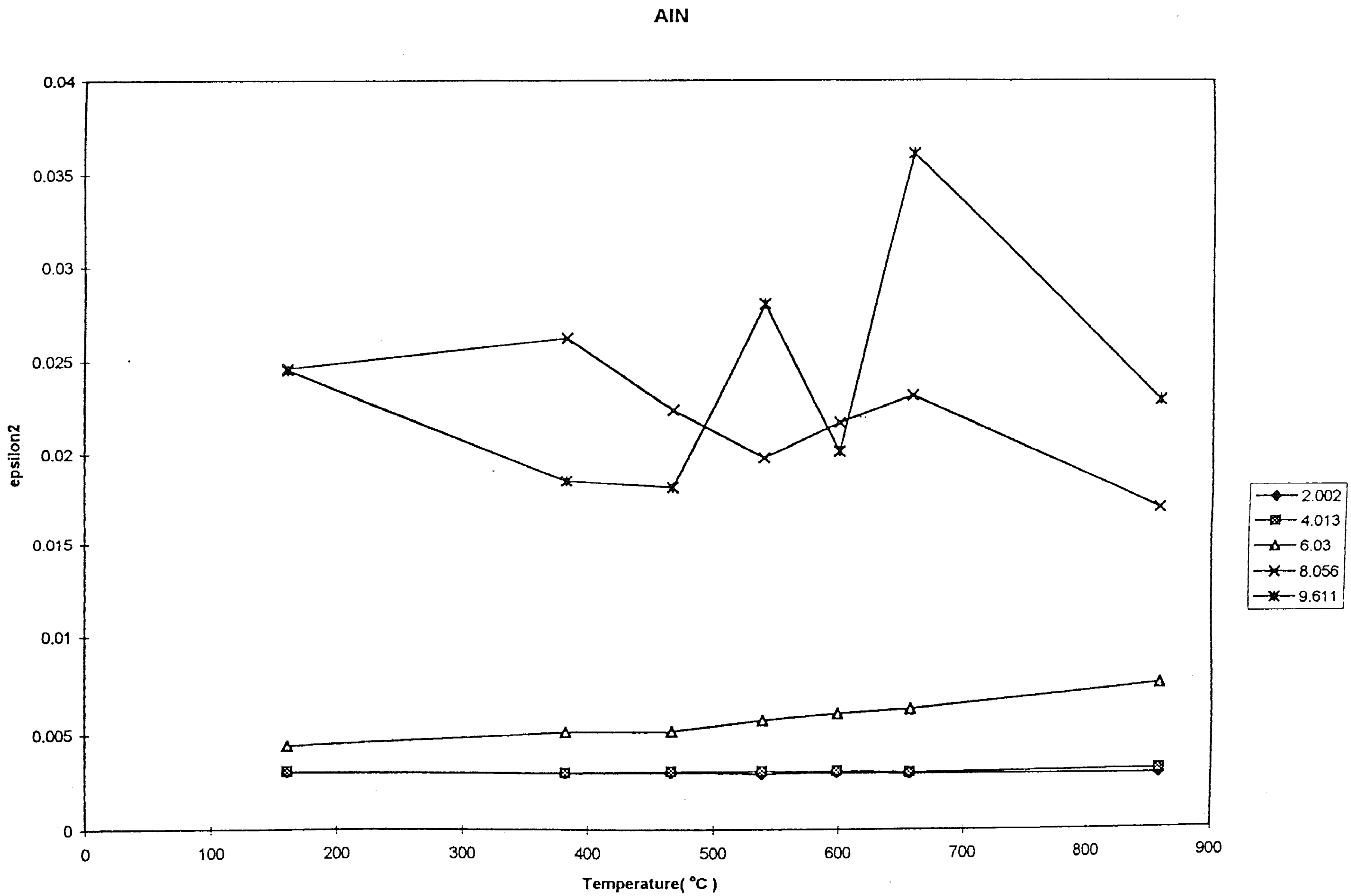

Fig.B-8 Imaginary part of Complex dielectric constant Vs Temperature plot of AlN at different wavelengths

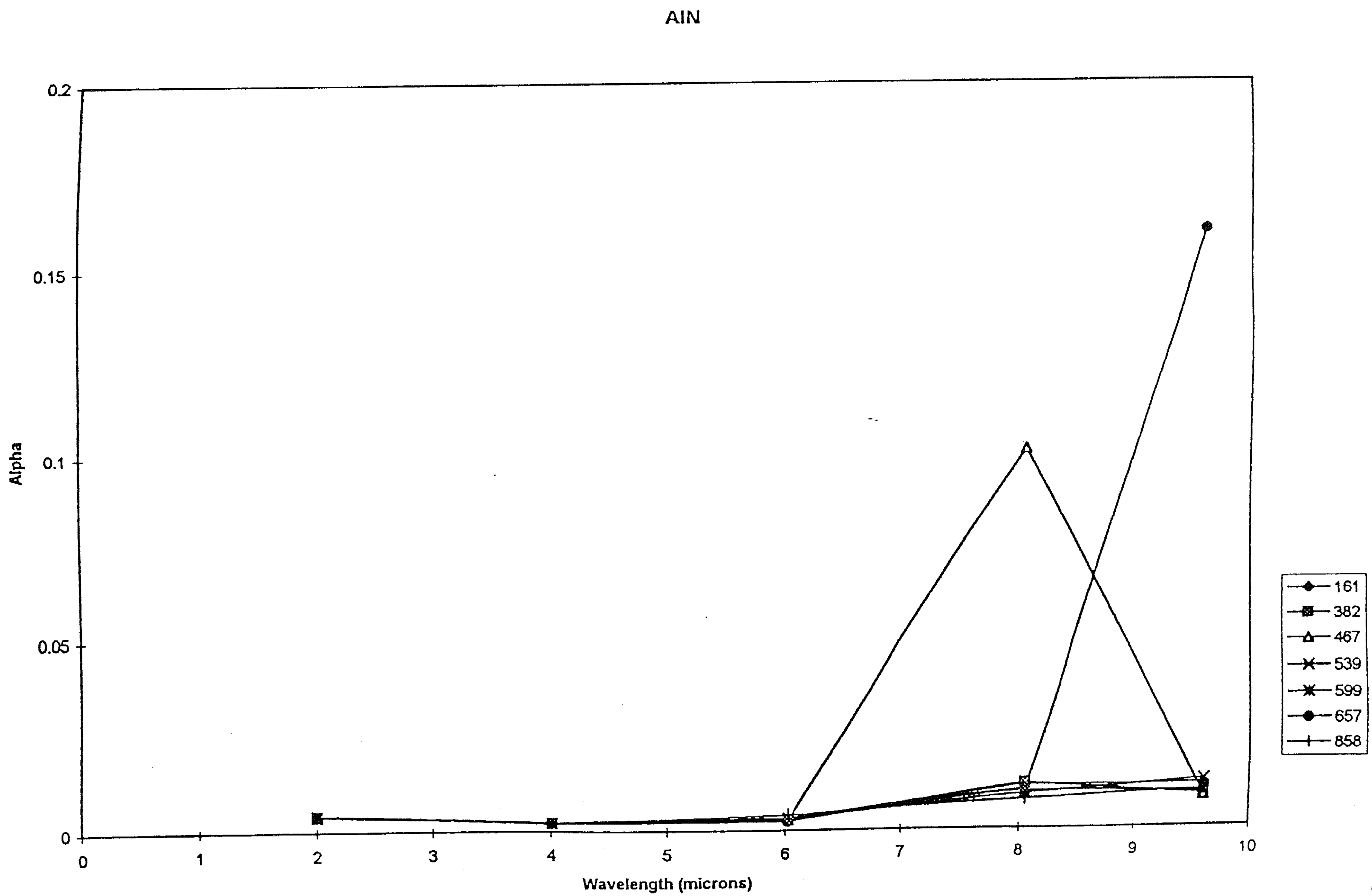

Fig.B-9 Absorption coefficient Vs Wavelength plot of AlN at different temperatures

APPENDIX C: SAPPHIRE OPTICAL CONSTANTS DATA AT 67 ^{o}C

LAMBDA	EXTCOEF	REFINDEX	EPSILON1	EPSILON2	ALPHA
1	0.000005	1.602	2.565	0.00002	0.000069
1.002	0.000005	1.604	2.572	0.00001	0.000058
1.003	0.00002	1.688	2.848	0.00007	0.000247
1.008	0.000002	1.64	2.69	0.00001	0.000021
1.01	0.000021	1.472	2.167	0.00006	0.000267
1.011	0.000003	1.699	2.886	0.00001	0.000036
1.013	0.000012	1.707	2.914	0.00004	0.000153
1.014	0.000023	1.53	2.341	0.00007	0.000287
1.016	0.00004	1.45	2.103	0.00012	0.000498
1.022	0.000003	1.735	3.011	0.00001	0.000042
1.024	0.000023	1.562	2.441	0.00007	0.000288
1.026	0.00002	1.414	1.999	0.00006	0.000246
1.044	0.000017	1.668	2.782	0.00006	0.000199
1.045	0.000026	1.596	2.548	0.00008	0.000308
1.047	0.000011	1.74	3.028	0.00004	0.000127
1.049	0.000027	1.749	3.059	0.0001	0.000327
1.05	0.000016	1.829	3.344	0.00006	0.000192
1.057	0.000013	1.689	2.853	0.00004	0.000154
1.059	0.000019	1.71	2.925	0.00007	0.000228
1.061	0.000014	1.765	3.116	0.00005	0.000164
1.063	0.000014	1.758	3.091	0.00005	0.00017
1.064	0.000021	1.613	2.602	0.00007	0.000242
1.066	0.00002	1.629	2.652	0.00006	0.000234
1.071	0.000003	1.788	3.197	0.00001	0.000036
1.073	0.000005	1.782	3.177	0.00002	0.00006
1.075	0.000002	1.719	2.956	0.00001	0.000027
1.077	0.000002	1.692	2.863	0.00001	0.000018
1.078	0.000009	1.779	3.163	0.00003	0.000099
1.08	0.000013	1.793	3.215	0.00005	0.000149
1.082	0.000002	1.801	3.245	0.00001	0.00002
1.089	0.000015	1.707	2.914	0.00005	0.00017
1.091	0.000011	1.736	3.012	0.00004	0.000127
1.093	0.000005	1.76	3.097	0.00002	0.000055
1.097	0.000002	1.736	3.015	0.00001	0.000019
1.099	0.000002	1.694	2.869	0.00001	0.000019
1.1	0.000016	1.661	2.758	0.00005	0.000183
1.102	0.000023	1.66	2.757	0.00008	0.000264
1.104	0.000009	1.755	3.081	0.00003	0.000098
1.106	0.000012	1.781	3.173	0.00004	0.000136
1.108	0.000011	1.731	2.997	0.00004	0.00012
1.118	0.000005	1.735	3.011	0.00002	0.00006
1.12	0.000011	1.717	2.947	0.00004	0.000119
1.121	0.000005	1.705	2.907	0.00002	0.000056
1.123	0.000005	1.723	2.968	0.00002	0.00006
1.129	0.000007	1.755	3.079	0.00003	0.00008
1.131	0.000012	1.725	2.975	0.00004	0.000132
1.133	0.000011	1.755	3.08	0.00004	0.000117
1.135	0.000011	1.727	2.984	0.00004	0.00012
1.137	0.000012	1.704	2.905	0.00004	0.00013

1.139	0.00001	1.729	2.991	0.00003	0.000111
1.141	0.000004	1.725	2.977	0.00001	0.000045
1.143	0.000008	1.712	2.932	0.00003	0.000088
1.145	0.000006	1.761	3.101	0.00002	0.000069
1.151	0.000006	1.73	2.994	0.00002	0.00007
1.153	0.000011	1.699	2.885	0.00004	0.000117
1.155	0.000006	1.686	2.843	0.00002	0.00006
1.158	0.000006	1.716	2.944	0.00002	0.000067
1.16	0.000005	1.772	3.139	0.00002	0.000056
1.168	0.000006	1.744	3.041	0.00002	0.00007
1.17	0.000011	1.731	2.998	0.00004	0.000119
1.172	0.00001	1.73	2.994	0.00004	0.000112
1.174	0.000003	1.737	3.018	0.00001	0.000037
1.176	0.000003	1.74	3.029	0.00001	0.000028
1.179	0.000003	1.733	3.003	0.00001	0.000033
1.183	0.000005	1.713	2.936	0.00002	0.000054
1.185	0.000003	1.691	2.86	0.00001	0.000032
1.187	0.000003	1.702	2.897	0.00001	0.000032
1.189	0.000005	1.695	2.872	0.00002	0.00005
1.192	0.000006	1.698	2.884	0.00002	0.000067
1.194	0.000007	1.732	2.999	0.00002	0.000072
1.196	0.000006	1.744	3.041	0.00002	0.00006
1.198	0.000003	1.76	3.099	0.00001	0.000035
1.2	0.000003	1.751	3.067	0.00001	0.000033
1.203	0.000005	1.753	3.073	0.00002	0.000052
1.205	0.000006	1.759	3.095	0.00002	0.000064
1.207	0.000007	1.73	2.994	0.00002	0.00007
1.209	0.000004	1.719	2.954	0.00001	0.00004
1.221	0.000004	1.765	3.117	0.00001	0.000037
1.223	0.00001	1.737	3.017	0.00003	0.000103
1.225	0.000009	1.73	2.994	0.00003	0.000093
1.228	0.000004	1.742	3.035	0.00001	0.000038
1.23	0.000002	1.745	3.045	0.00001	0.00002
1.232	0.000005	1.743	3.037	0.00002	0.000053
1.235	0.000005	1.745	3.046	0.00002	0.000056
1.237	0.000003	1.759	3.093	0.00001	0.000029
1.242	0.000002	1.761	3.101	0.00001	0.000022
1.244	0.000002	1.757	3.086	0.00001	0.000022
1.249	0.000002	1.754	3.076	0.00001	0.000025
1.252	0.000002	1.751	3.067	0.00001	0.000018
1.254	0.000002	1.747	3.054	0.00001	0.000021
1.256	0.000003	1.745	3.045	0.00001	0.000029
1.259	0.000003	1.725	2.975	0.00001	0.000033
1.261	0.000004	1.715	2.94	0.00001	0.000043
1.264	0.000004	1.741	3.03	0.00001	0.000036
1.274	0.000003	1.748	3.054	0.00001	0.000032
1.276	0.000005	1.727	2.981	0.00002	0.000052
1.279	0.000005	1.725	2.977	0.00002	0.000053
1.281	0.000003	1.739	3.025	0.00001	0.000031
1.284	0.000002	1.742	3.035	0.00001	0.000016
1.291	0.000004	1.736	3.013	0.00001	0.000037

1.294	0.000003	1.739	3.023	0.00001	0.000031
1.297	0.000002	1.741	3.032	0.00001	0.000022
1.299	0.000003	1.742	3.034	0.00001	0.000029
1.31	0.000004	1.728	2.986	0.00001	0.000039
1.312	0.000004	1.742	3.034	0.00001	0.00004
1.315	0.000006	1.738	3.022	0.00002	0.000054
1.318	0.000005	1.734	3.008	0.00002	0.000048
1.32	0.000002	1.741	3.03	0.00001	0.000022
1.323	0.000003	1.745	3.045	0.00001	0.00003
1.326	0.000004	1.741	3.031	0.00002	0.000041
1.329	0.000006	1.737	3.017	0.00002	0.000058
1.331	0.000005	1.733	3.005	0.00002	0.000047
1.334	0.000002	1.73	2.994	0.00001	0.000015
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1.34	0.000003	1.734	3.008	0.00001	0.000027
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1.351	0.000002	1.744	3.04	0.00001	0.000021
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4.855	0.00001	1.625	2.64	0.00003	0.000025
4.891	0.000013	1.62	2.626	0.00004	0.000034
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4.966	0.000023	1.617	2.614	0.00007	0.000057
5.005	0.000027	1.616	2.61	0.00009	0.000069
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5.084	0.000034	1.609	2.589	0.00011	0.000083
5.124	0.000038	1.608	2.585	0.00012	0.000093
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5.248	0.000056	1.601	2.564	0.00018	0.000133
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5.335	0.000073	1.597	2.55	0.00023	0.000172
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6.789	0.002235	1.481	2.192	0.00662	0.004139
6.861	0.002751	1.476	2.179	0.00812	0.005041
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7.165	0.004497	1.44	2.074	0.01296	0.007891
7.245	0.005176	1.427	2.037	0.01477	0.008982
7.327	0.005906	1.415	2.002	0.01671	0.010133
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7.497	0.007092	1.394	1.944	0.01978	0.011893
7.584	0.007329	1.389	1.93	0.02036	0.012147
7.675	0.007702	1.383	1.912	0.0213	0.012616
7.766	0.008065	1.384	1.914	0.02232	0.013055
7.86	0.008211	1.375	1.892	0.02259	0.013132
7.957	0.008276	1.356	1.838	0.02244	0.013075
8.056	0.008133	1.337	1.789	0.02176	0.012692
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8.262	0.008714	1.318	1.737	0.02297	0.01326
8.369	0.009168	1.308	1.71	0.02398	0.013772
8.478	0.009677	1.283	1.647	0.02483	0.014349
8.591	0.01001	1.254	1.574	0.02512	0.014648
8.706	0.010239	1.236	1.528	0.02532	0.014785
8.825	0.010461	1.223	1.495	0.02558	0.014902
8.947	0.010758	1.221	1.491	0.02628	0.015116
9.072	0.010826	1.216	1.479	0.02633	0.015002
9.201	0.010863	1.21	1.464	0.02629	0.014842
9.334	0.011049	1.204	1.449	0.0266	0.014882
9.471	0.011094	1.209	1.461	0.02682	0.014727
9.611	0.011165	1.226	1.502	0.02737	0.014604
9.756	0.011088	1.252	1.568	0.02777	0.014288
9.905	0.011135	1.292	1.669	0.02877	0.014132
10.058	0.01141	1.374	1.887	0.03135	0.014261
10.217	0.011646	1.501	2.253	0.03496	0.014329
10.381	0.011641	1.694	2.87	0.03944	0.014098
10.55	0.011523	2.041	4.165	0.04703	0.013731

10.725	0.011105	2.82	7.95	0.06262	0.013017
10.905	0.010347	4.632	21.459	0.09586	0.011928
11.092	0.00936	7.538	56.819	0.14111	0.010609
11.285	0.00846	10.707	114.647	0.18117	0.009424
11.486	0.008286	14.872	221.177	0.24646	0.009069
11.693	0.00742	19.443	378.026	0.28854	0.007977
11.908	0.005871	23.721	562.677	0.27851	0.006198
12.131	0.004746	28.08	788.5	0.26655	0.004918
12.363	0.00512	31.405	986.304	0.32159	0.005206
12.604	0.006351	34.915	1219.076	0.44349	0.006335
12.854	0.00499	39.51	1561.024	0.39429	0.00488
13.114	0.006454	44.85	2011.526	0.57892	0.006187
13.385	0.008268	52.204	2725.258	0.86325	0.007765
13.668	0.003773	57.407	3295.615	0.43323	0.003471
13.962	0.002327	60.488	3658.77	0.28145	0.002095
14.27	0.001955	63.704	4058.214	0.24903	0.001722
14.592	0.002443	62.038	3848.722	0.30315	0.002105
14.928	0.001371	63.25	4000.516	0.17339	0.001154
15.28	0.007214	42.814	1833.068	0.61771	0.005935
15.65	0.01429	20.558	422.649	0.58755	0.011479
16.037	0.018527	25.053	627.638	0.92833	0.014524
17.324	0.0112	23.223	539.319	0.52022	0.008128
17.801	0.019856	10.55	111.293	0.41895	0.014023
18.304	0.026742	6.695	44.817	0.35805	0.018367
18.837	0.018043	5.217	27.213	0.18825	0.012042
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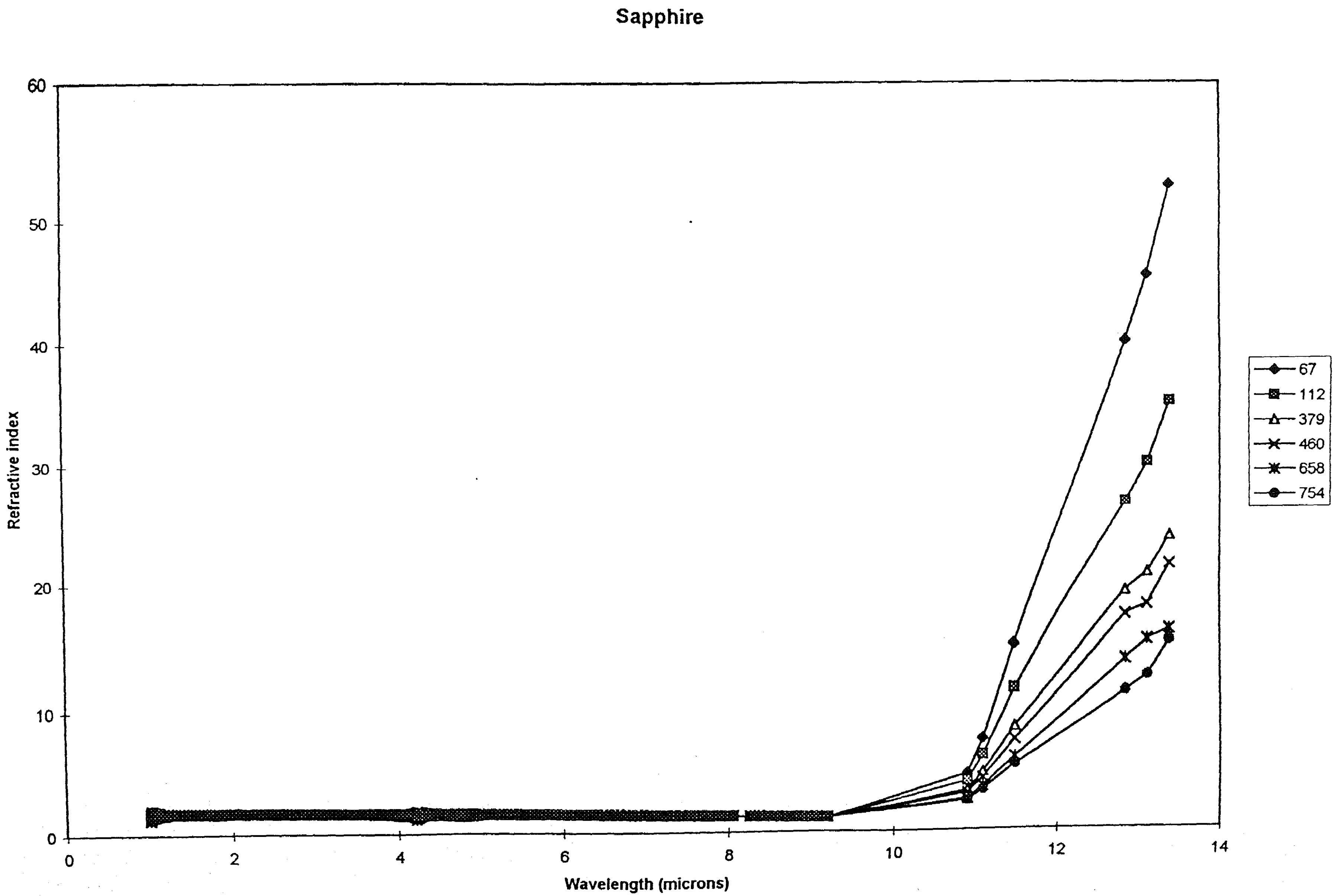

Fig.C-1 Refractive index Vs Wavelength plot of Sapphire at different temperatures

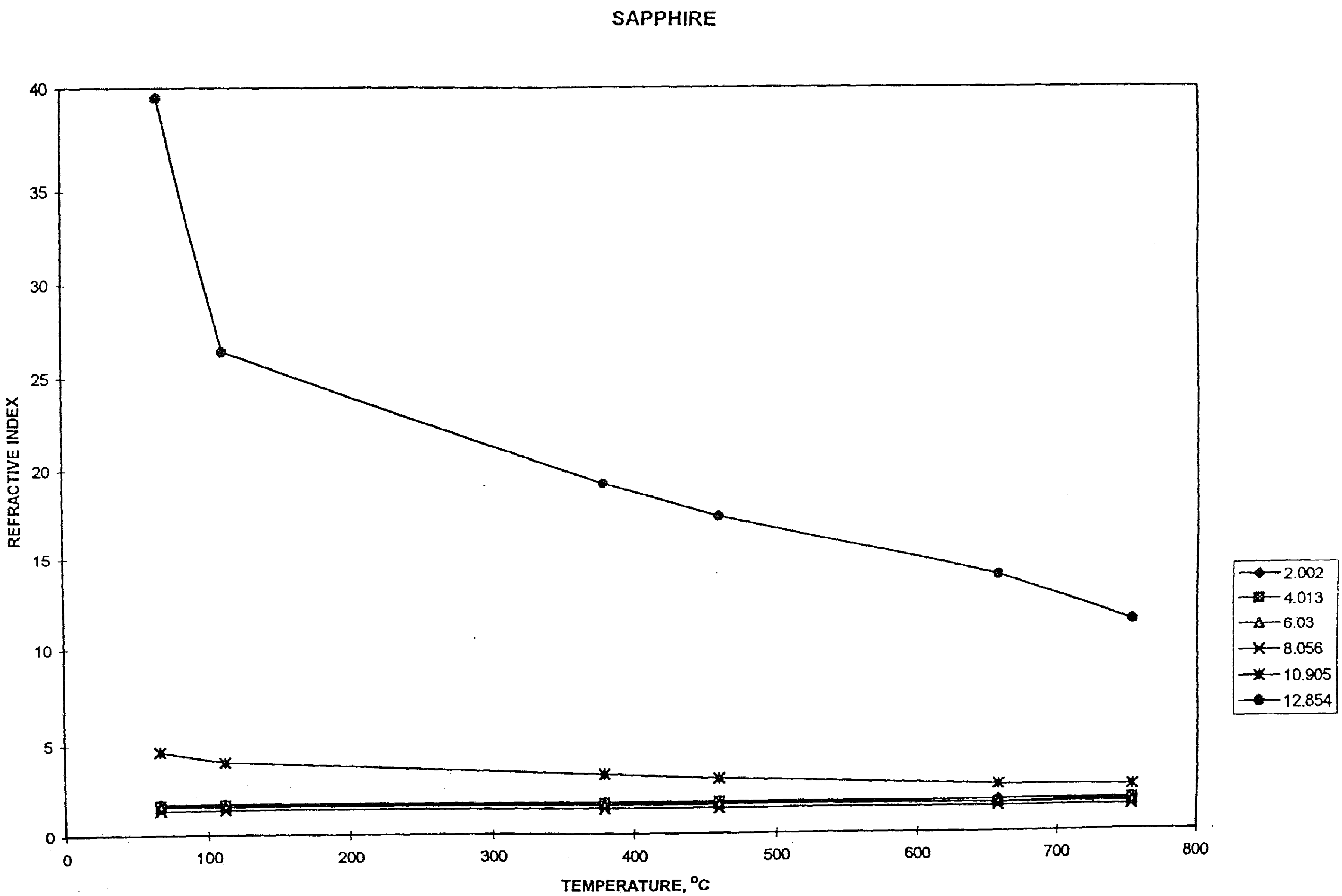

Fig.C-2 Refractive index Vs Temperature plot of Sapphire at different wavelengths

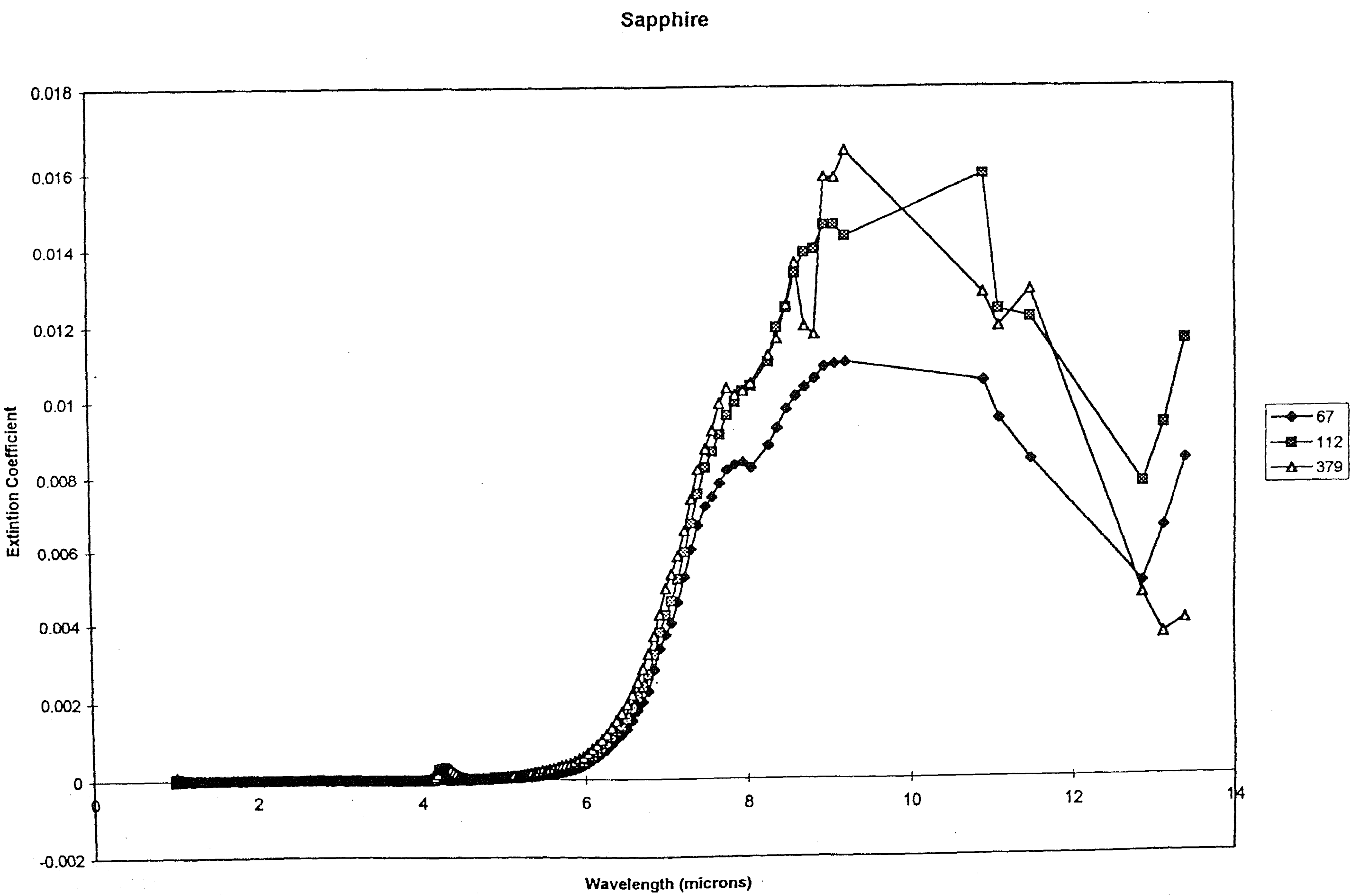

Fig.C-3 Extinction Coefficient Vs Wavelength plot of Sapphire at different temperatures

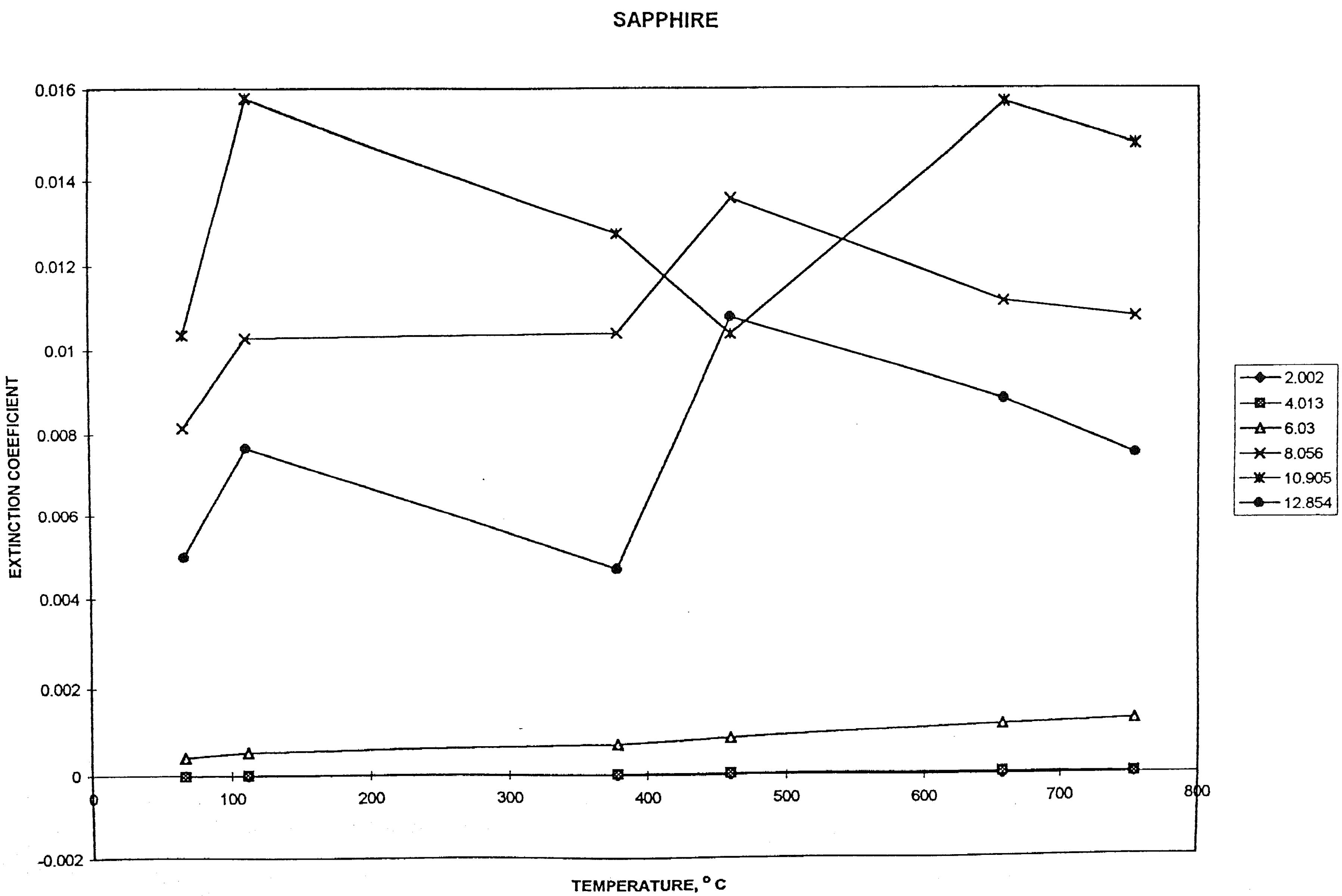

Fig.C-4 Extinction Coefficient Vs Temperature plot of Sapphire at different wavelengths

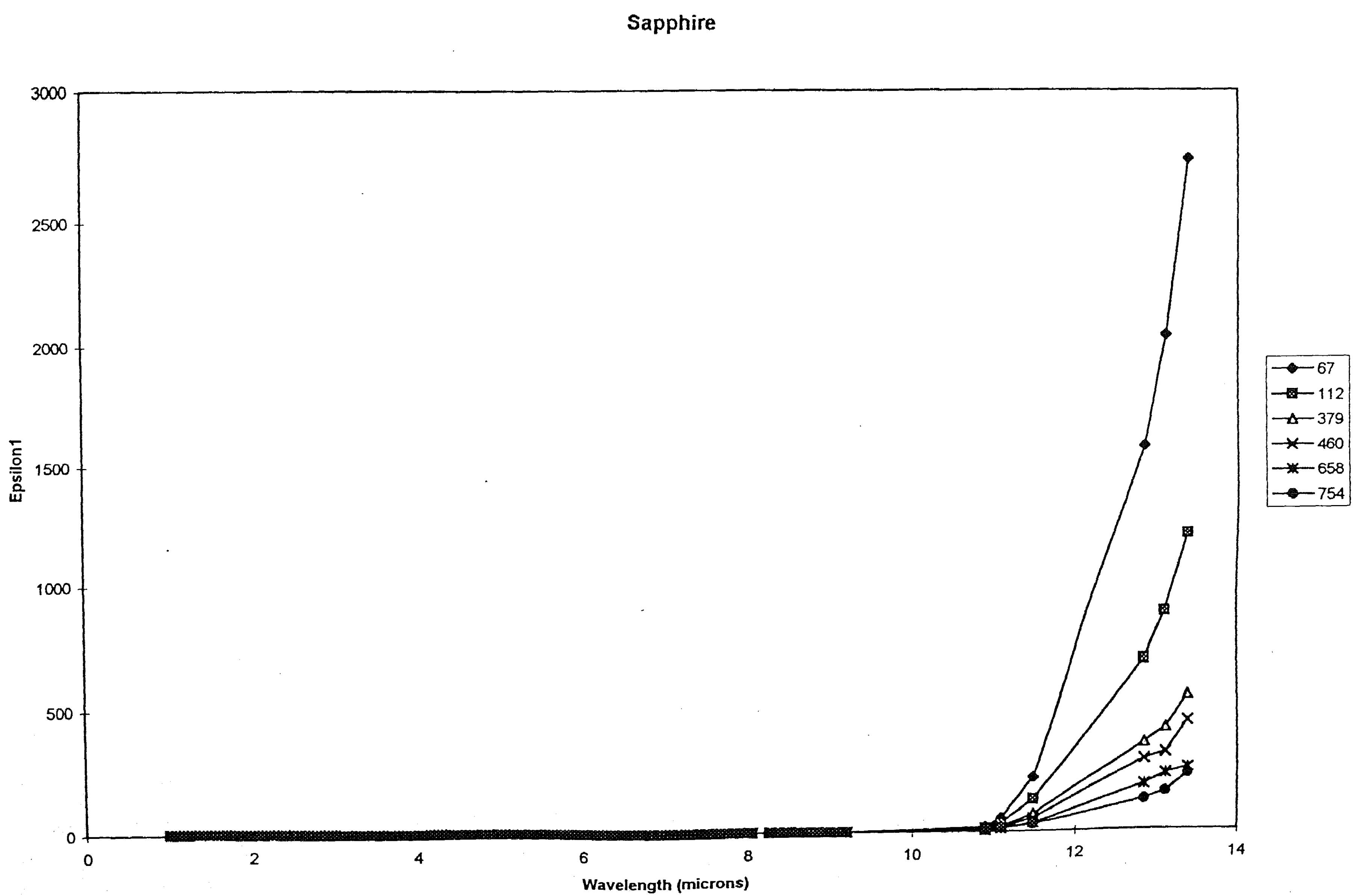

Fig.C-5 Real part of Complex dielectric constant Vs Wavelength plot of Sapphire at different temperatures

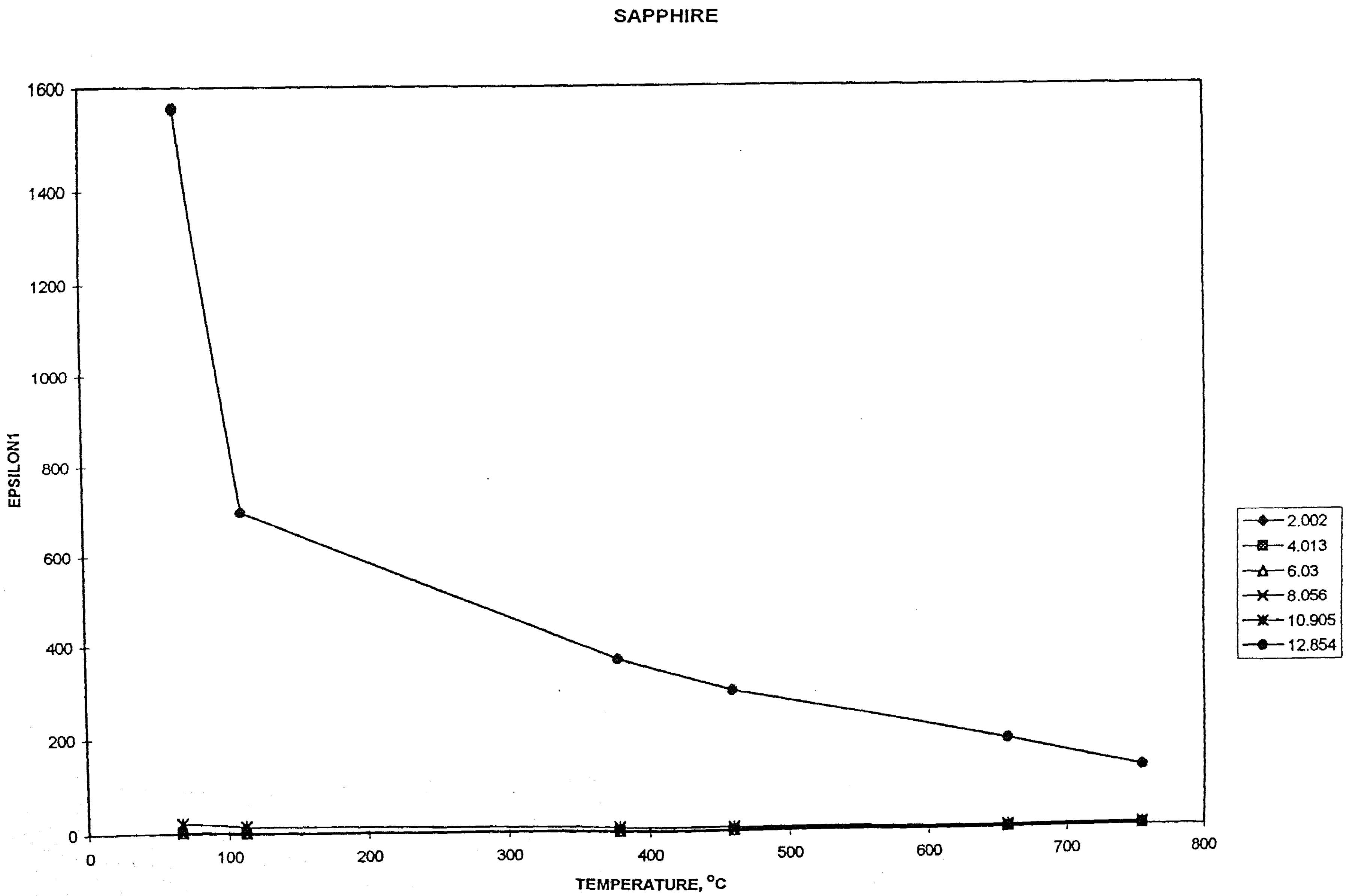

Fig.C-6 Real part of Complex dielectric constant Vs Temperature plot of Sapphire at different wavelengths

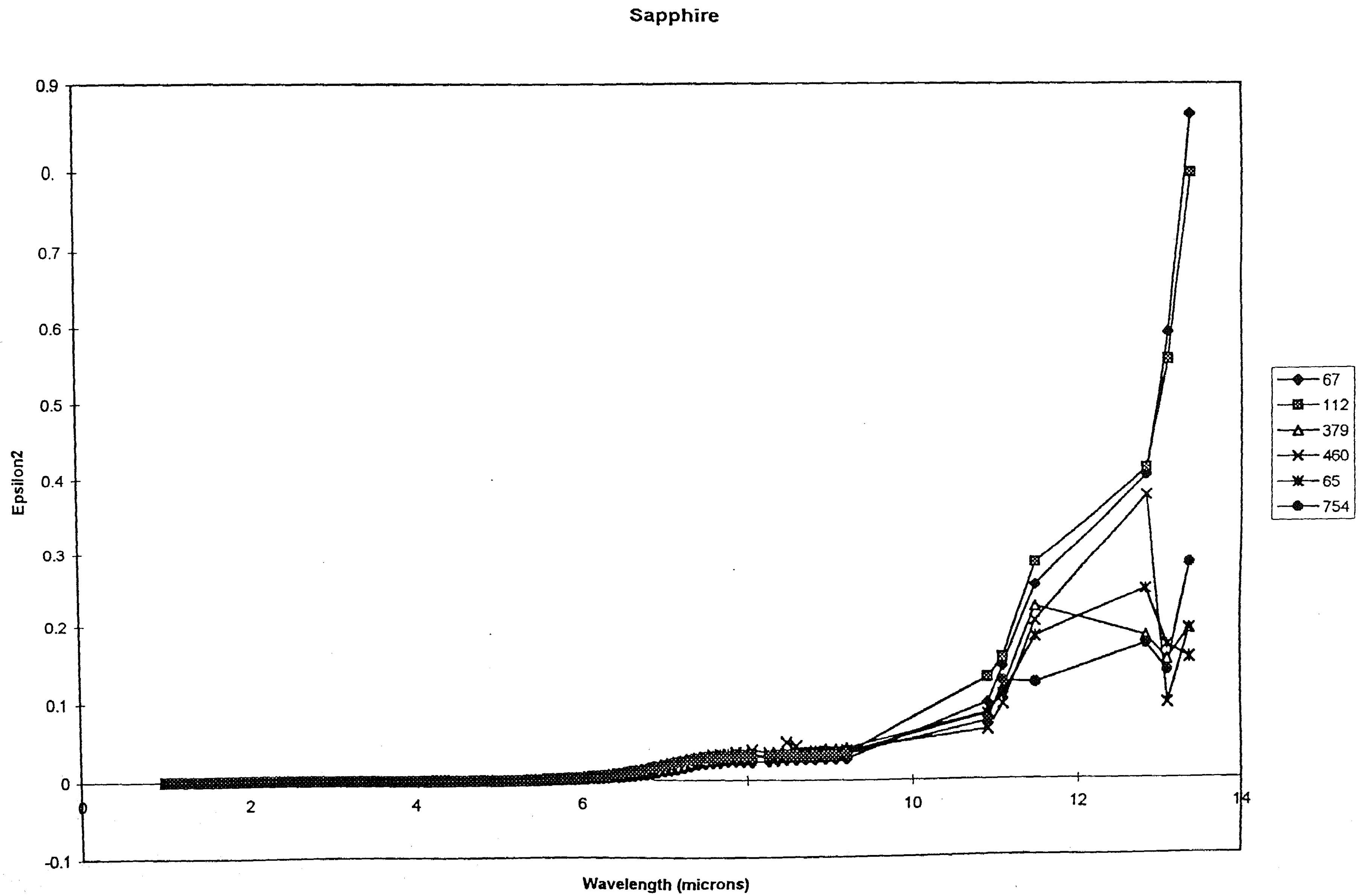

Fig.C-7 Imaginary part of Complex dielectric constant Vs Wavelength plot of Sapphire at different temperatures

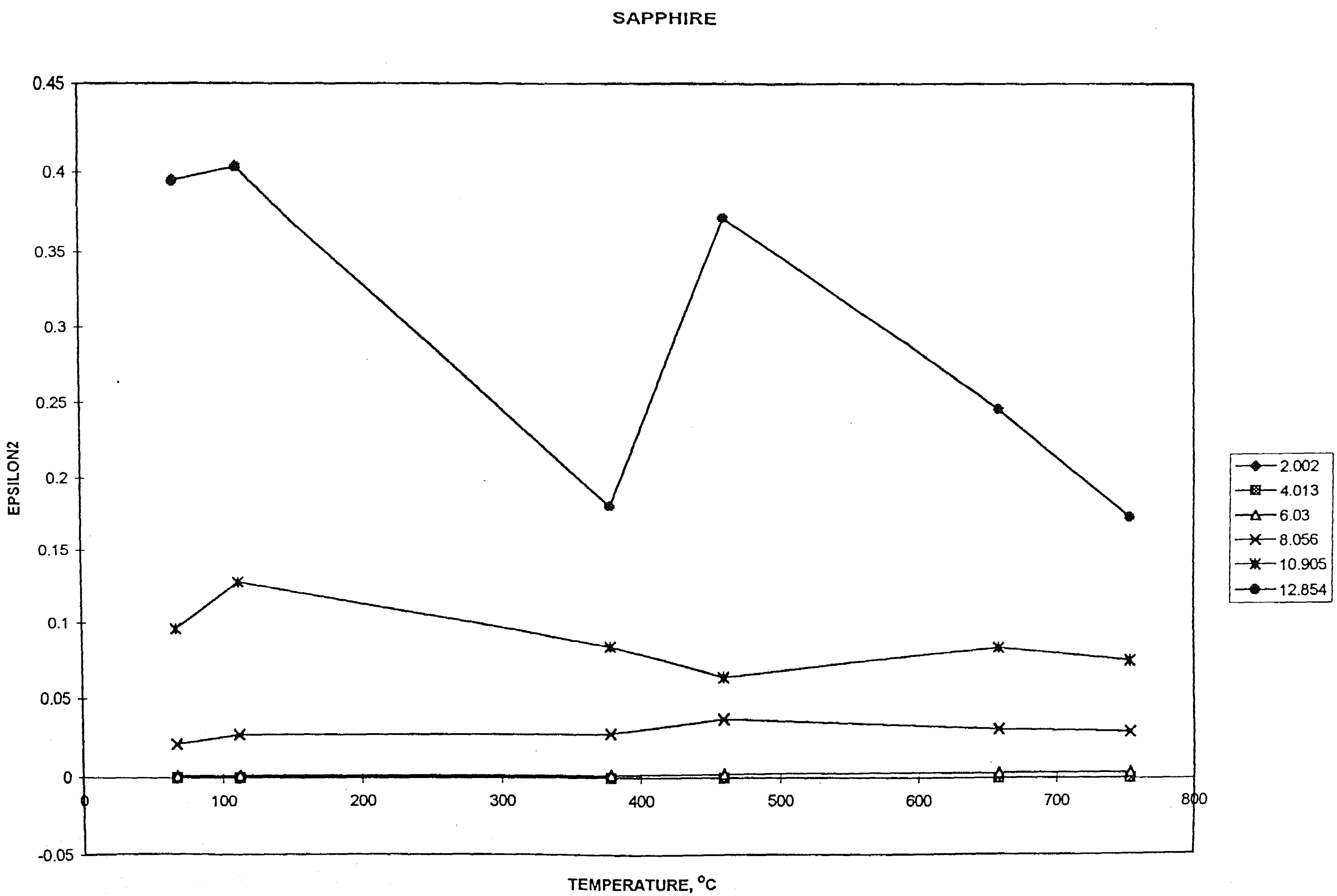

Fig.C-8 Imaginary part of Complex dielectric constant Vs Temperature plot of Sapphire at different wavelengths

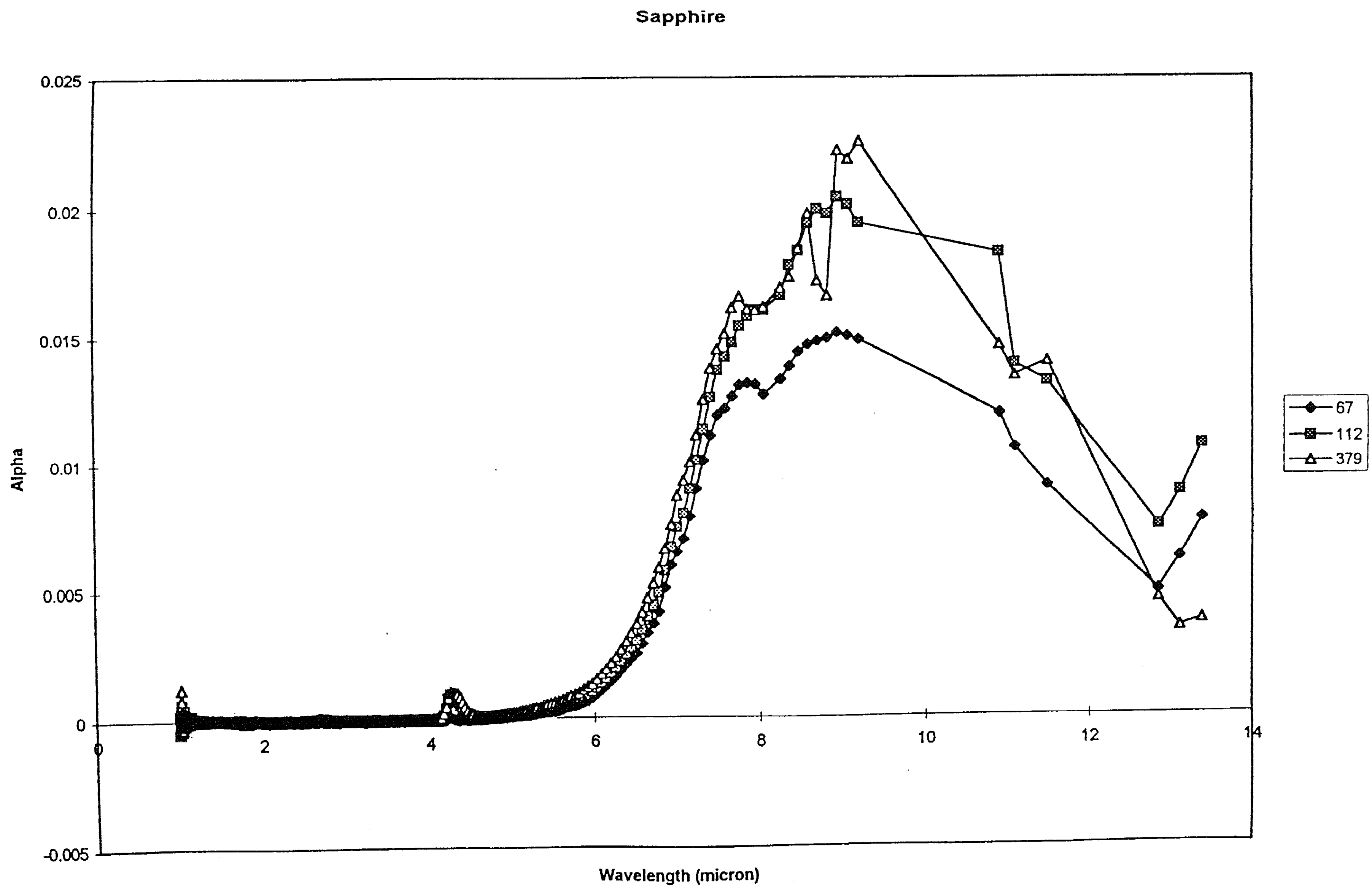

Fig.C-9 Absorption coefficient Vs Wavelength plot of Sapphire at different temperatures

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