Determination of reflectance and transmittance of multi-layer of InGaAs and theoretical methods for obtaining of optical constants.

Muñoz Zurita Ana Luz1, Campos Acosta Joaquín2, Marín Cárdenas J. Didier1, Larruquert Juan I2, Gómez Jiménez Ramon1

anamunozzurita@uadec.edu.mx

1Facultad de Ingeniería Mecánica y Eléctrica, U .Torreón
Universidad Autónoma de Coahuila (México)
2Instituto de Física Aplicada IFA-CETEF.
Consejo Superior de Investigaciones Científicas *(España)*

ABSTRACT

The theoretical concepts are necessary to obtain the optical constants of several materials in InGaAs Photodiode and are possible to obtain from experimental dates of reflectance and transmittance and several optical coverings can be designed. In this work we will show how to calculate the reflectance of photodiode for all the wavelengths (each 50 nm, according to the data of refractive index), as well as changing to the angle of incidence and polarization s and p, besides the calculation of the transmittance of a multi-layer ones of InGaAs. A multi-layer is constituted by a series of piled up laminae some on others and in this work we will suppose that they are homogenous, isotropic and plane-parallel, the structure is in the first case we have a transparent layer of NSi, late second layer of InP (Zn), soon a third layer of InGaAs and finally a later of InP (S). These multilayers are destined for optical applications, in our case will be case of study in the case of the photodiodes, the thicknesses of the layers will be of the order of the wavelength of incident radiation, which in the case of radiation IR/NIR is translated in thicknesses of approximately between 1y 100 nm. For the determination of optical constants they are possible to be done of different ways in our case we will concentrate in 1) Measured of reflectance in normal incidence. These measures only provide the value of n in the case of means transparents.2) Measured of reflectance in two angles of incidence. It allows to the use of natural light or polarized.3) Two measures of R p R s in two angles of incidence outside the normal one. 4) Rs and Rp in a single angle of incidence outside the normal one.

INTRODUCTION.

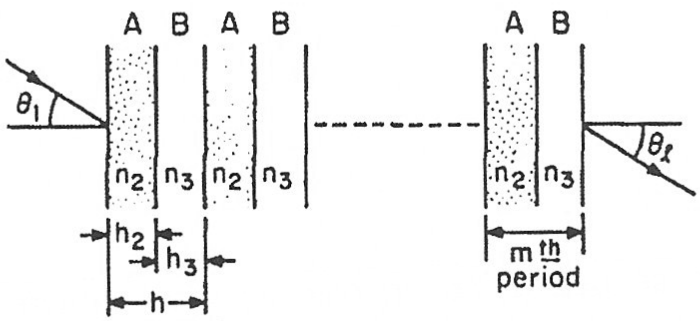

Figure 1. The Multiplain reflections is produced in slim layer of thickness deepness,

As far as the optical properties of multilayer stacks are concerned, most published treatments are based on the characteristic matrix technique originally developed by Abeles,5 Born and Wolf,6 and

Thelen.7 Another computational method, such as that developed by Berning and Berning, 8 is also possible, but alternate procedures tend to be more limited in scope.9 Most of such work is specific to certain given structures of a limited number of lossless dielectric layers, and the assumption that the stacking is ideal is invariably made. But the analysis of homogeneous, lossless layers adjoining perfectly with sharp boundaries often cannot describe many experimentally produced stacks adequately. Real stacks incorporate series of layers that differ in thickness within some limit of error, and layers.

THE BASIC EQUATIONS

The problem of studying the optical properties of layer structures reduces to the fact that each layer can be fully represented by a characteristic matrix,6 and that the entire structure can be expressed by a characteristic matrix T that is the product of m characteristic matrices representing the m individual layers. Omitting the interfacial layers for the moment, Fig. 1 illustrates the basic notation used. The scheme represents a layer structure *S* of m two-layer units. Each basic unit consists of two layers of different materials *A* and *B* of thicknesses h2 and *h3,* respectively.

ANALYSIS AND RESULTS

To do this analysis we used the following figure 2:

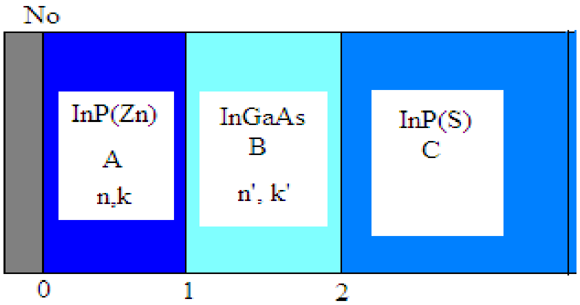

Figure 2.

Therefore the number of photons absorbed in A is:

$$S_1^A = N_0 \int_0^T \alpha e^{-\alpha x} dx \tag{1}$$

Where α is the absorption coefficient, N_0 is the index of refraction in the (aire), T is the length of the first layer. Then in the first layer the photons are:

$$W_1 = N_0 - N_0 \int_0^T \alpha e^{-\alpha x} dx = N_0 - \left(1 - e^{\alpha T}\right) N_0 \tag{2}$$

$$W_1 = N_o e^{-\alpha T} \tag{3}$$

In the first layer is reflected:

$$A_1 = P_1 \left[N_0 \left(1 - \int_0^T \alpha e^{-\alpha x} dx \right) \right] \tag{4}$$

$$A_1 = P_1 N_0 e^{-\alpha T} \tag{5}$$

In the region A will be absorbed into the 2nd pass:

$$S_2^A = P_1 N_0 \left(1 - \int_0^T \alpha e^{-\alpha x} dx \right) \int_0^T \alpha e^{-\alpha x} dx \tag{6}$$

$$S_2^A = P_1 N_0 \left(e^{-\alpha T} - e^{2\alpha T} \right) \tag{7}$$

If we summarize the absorption in both layers:

$$\varepsilon_A(\lambda) = \frac{S_1^A + S_2^A}{N_0} \tag{8}$$

$$\varepsilon_A(\lambda) = \left(1 - e^{-\alpha T}\right)\left(1 + P_1 e^{-\alpha T}\right) \tag{9}$$

In the zone B, at the beginning of the area

$$L = N_0 \left(1 - \int_{=}^{T} \alpha e^{-\alpha x} dx \right) - P_1 N_0 \left(1 - \int_0^T \alpha e^{-\alpha x} dx \right) \tag{10}$$

$$L = N_0 e^{-\alpha T} - P_1 N_0 e^{-\alpha T} \tag{11}$$

The photons absorbed in the second layer:

$$S_1^B = L\left[1 - e^{-\alpha' D}\right] \tag{12}$$

And the photons in the second layer are:

$$\gamma = L - S_1^B = L e^{-\alpha' D} \tag{13}$$

The photons are reflected: $R = P_2 \left(L e^{-\alpha' D} \right)$ (14)

The photons are absorbed: $AA = S_2^B = P_2 L e^{-\alpha' D} \left[\left(1 - e^{-\alpha' D} \right) \right]$ (15)

If we summarize the absorption in the second layer:

$$\varepsilon_B(\lambda) = \frac{S_1^B + S_2^B}{N_0} \tag{16}$$

$$\varepsilon_B(\lambda) \equiv \frac{L - L e^{-\alpha' D} + P_2 L e^{-\alpha' D} - P_2 L e^{-2\alpha' D}}{N_0} \tag{17}$$

In the case if the third layer the absorption is:

$$S_1^C \equiv L e^{-\alpha' D} \left(1 - P_2 \right) \left[1 - e^{-\alpha' H} \right] \tag{18}$$

Results and discussion.

All these calculations were obtained the following results:

Wavelength	InP		InGaAs		alpha1	alpha2
	n	K	Index of Refraction	k		
0.8	4.58E+00	0.2100	3.65	0.235	3.29867229	3.69137137
0.85	4.38E+00	0.1571	3.623	0.194	2.32256097	2.86808929
0.9	4.22E+00	0.1057	3.5942	0.153	1.47585042	2.136283
0.95	4.08E+00	0.0553	3.553	0.1414	0.7317596	1.87040506
1	3.97E+00	0.0040	3.5235	0.111	0.05026548	1.39486714
1.05	3.87E+00	0.0037	3.5	0.088	0.0442815	1.05318154
1.1	3.78E+00	0.0032	3.4705	0.0707	0.03655671	0.80767491
1.15	3.70E+00	0.0027	3.4587	0.0589	0.02950365	0.64361672
1.2	3.63E+00	0.0027	3.441	0.0471	0.02827433	0.49323005
1.25	3.58E+00	0.0027	3.4292	0.02948	0.02714336	0.29636528
1.3	3.52E+00	0.0020	3.4175	0.02945	0.01933288	0.28467663
1.35	3.48E+00	0.0016	3.417	0.02941	0.01489348	0.27376071
1.4	3.43E+00	0.0011	3.399	0.0177	0.00987358	0.15887483
1.45	3.40E+00	0.00006	3.388	0.01767	0.00055465	0.15313639
1.5	3.36E+00	0.00006	3.388	0.00589	0.00053617	0.04934395
1.55	3.33E+00	0.00000	3.388	0.00589	0	0.04775221
1.6	3.30E+00	0.00000	3.3762	0.00589	0	0.04625995

Table 1. Index of Refraction, absorption coefficients.

In the table 1, we have the different parameters by calculation of the absorption, transmittance and reflection in different layers.

S1c	s1a+s2a	s1a+s2a+s1b+s2b	s1a+s2a+s1b+s2b+s1c
0.001226	0.963519	0.986657551	0.987883822
0.008396	0.902774	0.982889548	0.991285303
0.035249	0.772548	0.954523987	0.989773403
0.089793	0.520142	0.889747406	0.979540384
0.232664	0.049186	0.686265533	0.918929182
0.266913	0.043417	0.58674694	0.853660062
0.278941	0.035959	0.493957434	0.772898547
0.274724	0.029105	0.419379626	0.694103449
0.254704	0.027899	0.344605541	0.599309387
0.196753	0.02679	0.232126919	0.428879749
0.193417	0.019152	0.218874563	0.412291681
0.18951	0.014784	0.208547173	0.39805749
0.128086	0.009825	0.128003644	0.256089761
0.125546	0.000555	0.115792519	0.241338286
0.046257	0.000536	0.039220927	0.085477628
0.044876	0	0.037478741	0.082354897
0.043554	0	0.036327401	0.079881316

Table 2. Results of the absorption in different layers.

In the next graphics is possible to observe the different behavior of the absorption by wavelength of 800 nm to 1600 nm.