A STUDY OF THIN FILM VACUUM DEPOSITED JUNCTIONS

Annual Status Report

on

NASA Grant NsG-340

Submitted by:

Dr. Robert L. Ramey

Professor of Electrical Engineering

Research Laboratories for the Engineering Sciences

University of Virginia

Charlottesville

Report No. EE-4012-107-67U

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SECTION I
REPORT COVERAGE

This annual report covers the period from December 5, 1965 to December 5, 1966. This research program is currently entering its fifth year of operation.

SECTION II
INTRODUCTION

The development of thin film devices in all laboratories throughout the world has been disappointingly slow during the past five years. Probably the principal reason for this slow pace has been the realization of how little we know about the thin film solid state. In our laboratory, as in many other laboratories, we have found ourselves devoting most of our effort to adding to the basic knowledge of the physical behavior of thin films in order to prepare for the device design stage. As a consequence of this, we have made significant contributions to the physics of thin films through published papers on our research.

Obviously, the important question is when can we and others begin to develop thin film devices? The answer is probably within the next three years. Major steps are being made throughout the country toward taking the alchemy out of the production and processing of thin films. This field of research has definitely passed through its era of infancy and entered an era of sophistication. Answers to basic questions are appearing quite rapidly. We and others will soon be sufficiently armed with basic information to enter into the device design stage.

From an applied viewpoint the question of thin film vs. microminiature device must still be resolved. During the past five or so years that research in thin film solid state electronics has been pursued at an intensified level throughout the world, the production of reliable microminiature transistor chips and associated circuitry has become a reality. The engineering and economic value of further pursuit of a thin film transistor is open to question. However the possible applications of thin film devices, both passive and active, to microwaves, specialized instrumentation problems, and miniature computer design demand that research in applied thin film electronics continues.

SECTION III
STATUS OF THEORETICAL RESEARCH

The problems encountered in the design of field effect active thin film devices has led us into a detailed study of the mechanisms of charge transport phenomena in thin polycrystalline films. As a result of a long study of the properties of polycrystalline germanium films we have just recently [1] been able to show that the reciprocal hole mobility, as a function of temperature, is given by

$$\frac{1}{\mu_H} = \frac{1}{\mu_L} + \frac{1}{\mu_I} + \frac{1}{\mu_D} + \frac{1}{\mu_F} \qquad (1)$$

volt-seconds/cm^2. The first three mobility terms are based upon single crystal theory and the fourth term accounts for the thinness of the film.

The single crystal bulk lattice scattering mobility, μ_L, for holes in germanium has been given by Morin [2] as

$$\mu_L = 1.05 \times 10^9 \, T^{-2.33} \qquad (2)$$

cm^2/volt-second.

The impurity scattering mobility, μ_I, for nondegenerate bulk/germanium as given by Shockley [3] is

$$\mu_I = \frac{8.52 \times 10^{13}}{N_I(1 + X^2)} T^{3/2} \qquad (3)$$

cm^2/volt-second, where

$$X = 2.86 \times 10^4 \, T \, N_I^{-1/3} \, . \qquad (4)$$

By use of Eqs. (2), (3) and (4) it is possible to place Eq. (1) in the form

$$\frac{1}{\mu_H} - \left(\frac{1}{\mu_L} + \frac{1}{\mu_I} \right) = F(a, T) \quad (5)$$

where a is the film thickness. The terms on the left-hand side of Eq. (5) are known as functions of temperature. Therefore $F(a, T)$ may be plotted by use of a computer and may be expressed in empirical form as

$$F(a, T) = \alpha_D T^{-1} + A \log_{10} \frac{B}{a} . \quad (6)$$

The first term in Eq. (6) is exactly that obtained by Dexter and Seitz [4] for dislocation scattering. They defined a dislocation scattering term, μ_D, given by

$$\frac{1}{\mu_D} = \alpha_D T^{-1} \quad (7)$$

where the coefficient

$$\alpha_D = 1.1 \times 10^{-11} N \frac{m^*}{m} \quad (8)$$

(volt-seconds-°K)/cm^2. The ratio of the effective mass is m^*/m and the N is the density of dislocation lines per unit surface area.

Our Ge films were deposited at a mean rate of 7.5 Å/second on an amorphous substrate at 500°C. The experimentally determined values for the parameters are

A	=	0.0219	volt-seconds/cm^2
B	=	8,000*	Angstrom units
α_D	=	1.4	(volt-seconds-°K)/cm^2
N	=	5×10^{11}	per unit area** .

The deposition and processing of the film will appear as variations in these parameters. The film dimensions and surface scattering conditions will manifest themselves through the film mobility term

$$\frac{1}{\mu_F} = A \log_{10} \frac{B}{a} \quad (9)$$

Future plans include the application of the above theory to polycrystalline films of other materials such as Si and CdSe.

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* Note that film thickness, a, is measured in Angstrom units.

** For $m^*/m = 0.25$.

SECTION IV
EXPERIMENTAL RESEARCH

The current experimental research program falls into four general categories:

(1) Special Films. At the moment CdSe films are being prepared by the codeposition of Cd and Se from separate crucibles. The solid state physical electronic properties of these films are being investigated. The theory reviewed in Section III of this report will be applied to these films.

(2) Thin Film Junctions. The electronic properties of junctions between thin films of CdSe and various metal films are being investigated. It is too early to report on these results.

(3) Microwave Bolometers. Bolometers (constructed to conform to the standard microwave mounts) are being produced using thin films of Ag and Au and possibly other metal and semiconducting films. At the present the sensitivity of these bolometers results in a signal to noise ratio of about 26 Db. Optimization of the physical designs as well as the testing of other film materials is in progress.

(4) Surface Field Studies. A chopper type of field strength meter has just been modified for use in the studies of the surface potential semiconducting films. This equipment should be in full operation by the first of February. There is no question but that we need to know a great deal more about surface potential and its relation to charge carrier transport in thin polycrystalline semiconducting films.

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