Au-Ti THIN FILMS DEPOSITED ON GaAs*


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The aim of this work is to study the thermal reactions of thin films of gold and titanium vacuum deposited on GaAs including semi-insulating type GaAs(SI). We have examined Au/Ti/GaAs by the use of different techniques: X-Ray diffraction (XRD), scanning electron microscopy (SEM) and Rutherford backscattering (RBS) analysis in Tandem type accelerator. The deposition of Ti and Au films on (100) surfaces was carried out by thermal evaporation under a relative pressure of 8⋅10^{-5} torr, and then the samples were annealed in a furnace at low vacuum. The SEM image of Ti/GaAs interface presents a clear delimitation without a thermal reaction. For Au/Ti/GaAs (SI) samples Ti signal is interfered with GaAs signal, so it appears an interlayer diffusion process as in literature. The characteristic XRD pattern presented the main peaks for Au, Ti and GaAs. From this stage of experiments, further studies are in progress on the interlayer diffusion phenomenon in the two layers of Au-Ti on GaAs(SI) substrates in order to obtain the technological conditions for good Schottky contacts to be used as nuclear detectors.

INTRODUCTION

The titanium-gold composite layers are used as contacts in integrated circuit technology, including III–V semiconductor compounds. The development on the electronic device market of power devices on GaAs has imposed the requirement of metal contacts with good adhesion and high thermal stability on GaAs surfaces.

The aim of this work is to study the thermal reactions of thin films of gold and titanium vacuum deposited on GaAs, including semi-insulating type GaAs(SI). The main motivation of this study is related to the fact that Au/Ti/GaAs forms an Schottky barrier to GaAs(SI), which can be used as a radiation resistance nuclear detector for charged particles (alpha, beta, and


protons, including protons collider [1]. The development of radiation detectors on GaAs (SI) as a substrate for Schottky diodes is related to the understanding of growth process for GaAs and the deposition of thin metal films. As an example, in literature [1] for the moment (1990) the most accessible material to satisfy the requirements for collider detectors (high-energy physics) is semi-insulating liquid encapsulated Czochralsky GaAs (LEC).

The technological advantage for GaAs devices is that in standard photolithographic method adopted the wafer surface can be passivated and then etched chemically before evaporating the contacts. We expect the presence of a thin (10 Å) layer of oxide normally formed on the surface.

Our standard choice of metals for contacts was Au/Ti for Schottky contact and Au/Ge/Ni/Au for ohmic one. We have examined Au/Ti/GaAs by the use of different techniques: X-Ray diffraction (XRD), scanning electron microscopy (SEM) and Rutherford backscattering (RBS) analysis in Tandem type accelerator.

**EXPERIMENTAL**

The samples used in this experiment were fabricated by liquid encapsulated Czochralsky technique (LEC) and the GaAs wafers were (100) oriented with a resistivity $\rho \sim 10^3 \, \Omega \text{cm}$ for n-GaAs and $\rho > 10^6 \, \Omega \text{cm}$ for GaAs(SI). There were prepared three type of samples as follows: Au (200 nm)/Ti (30 nm)/n-GaAs, Au (200 nm)/Ti (30 nm)/GaAs:O (SI-type), Ti (75 nm)/GaAs (SI) and a reference sample of GaAs (SI). The deposition of Ti and Au films on (100) surfaces was carried out by thermal evaporation under a relative pressure of $8 \times 10^{-5}$ torr. For the first two samples the film deposition respected a source-target geometry with distances $R_{Ti} = 10 \, \text{cm}$ and $R_{Au} = 4 \, \text{cm}$; these samples were annealed in a furnace at low vacuum ($10^{-1}$ torr) in the temperature range $(310–330)\, ^\circ \text{C}$ for $t \sim 10 \, \text{sec}$ which means a rapid treatment annealing procedure (RTA). The third sample Ti/GaAs (SI) was processed by thermal evaporation at a pressure of $p = 10^{-4}$ torr and a distance source-target of $R_{Ti} = 10 \, \text{cm}$. The conditions for annealing were $p = 8 \times 10^{-2}$ torr and $T = (400–408)\, ^\circ \text{C}$, $t \sim 10 \, \text{min}$. For this last sample the deposited film color before annealing was blue-indigo and after annealing was light blue. During experimental procedure the wafers were clean in organic solvents and then chemically etched in HCl:H$_2$O (1:1) for 30 sec.

The XRD analysis was performed in a DRON 2.0 system in air with a beam current $I = 20 \, \text{mA}$ at an accelerating voltage $U = 30 \, \text{kV}$ using a Mo anticathode, which means $K_{al} = 1.5405 \, \text{Å}$. The metallurgical quality for the interface metal-semiconductor (M-S) after annealing was investigated by XRD in order to identify the intermetallic character for the interface phases. On the
other hand the RBS analysis put into evidence the depth distribution for reaction products [2]. The backscattering measurements were carried out using a 10 MeV beam of $^{11}\text{B}^{(2+)}$ from NIPNE Van der Graaf accelerator with an Ion Implanted Silicon detector placed at 115° with respect to the beam and the sample was placed at 75° with respect to the beam. The SEM image was performed in a Philips system and the registered photos put into evidence the characteristics of Ti/GaAs interface.

RESULTS

In the SEM image of Fig. 1 the quality of Ti/GaAs interface can be observed. The contact area is well defined and the Ti layer has a thickness of nanometric order. The information that can be extracted from the image regarding a diffusion process between Ti and GaAs (SI) is that in the deposition conditions corroborated with annealing characteristics there is no interlayer diffusion process. The As and Ga atoms do not penetrate the Ti layer during thermal treatment as presented in literature [3]. In this experiment the TiAs compounds reaction compound do not appear.

![Fig. 1. – A SEM image of Ti/GaAs interface.](image)
Fig. 2. – XRD pattern for Au/Ti/GaAs sample.

Fig. 3. – RBS spectrum for Au/Ti/GaAs(SI) sample.
The RX diffraction pattern is presented in Fig. 2. The spectrum offers an image of GaAs and GaAs(SI) wafers for (100) plane together with distinct intense peaks for Au and Ti. In the XRD spectrum as registered from Au/Ti/n-GaAs and Au/Ti/GaAs(SI) an unidentified peak at 24.5° is present. Its intensity is larger for Au/Ti/GaAs(SI) sample. It is possible to have a connection between this peak and the interlayer diffusion of Au-Ti to form an intermetallic compound.

The RBS spectra for Au/Ti/GaAs are presented in Fig. 3. The Au/Ti/n-GaAs interface is responsible for a weak signal from Au and Au-Ti interface is well defined i.e. the two metals do not react with GaAs wafer. As can be observed from RBS analysis and spectrum simulation with RUMP code [4] the thickness of Au was 650·10^{15} \text{at/cm}^2 and for Ti was 500·10^{15} \text{at/cm}^2. In the more interesting case of the second sample Au/Ti/GaAs(SI) the RUMP simulation included a thickness of Au: 1400·10^{15} \text{at/cm}^2 and Ti: (200–300)·10^{15} \text{at/cm}^2. For this sample as can be observed in Fig. 3 the titanium signal interfered with GaAs signal, so it appears a weak diffusion process as in literature [5].

CONCLUSIONS

There were established the experimental conditions for vacuum deposited layers of Ti and Au with thickness in the nanometric range.

The alternative techniques investigations brought a complete image for the quality of Au/Ti/n-GaAs and Au/Ti/GaAs(SI) interfaces together with the interlayer diffusion process.

From this stage of experiments, further studies are in progress on the interlayer diffusion process for Au-Ti on GaAs(SI) substrate in order to establish the technological conditions for good Schottky contacts to be used as nuclear sensors.

REFERENCES