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Analysis of GaAs-Ti thin films deposited by sputtering onto c-Si and GaAs

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***Abstract*— Some sputtering processes of GaAs and Ti onto glass, c-Si and c-GaAs substrates have been carried out in order to obtain thin films as candidates to be intermediate band photovoltaic materials. This work presents first results concerning the optical and structural properties of the different deposited thin films.**

I. Introduction

Nowadays, some compounds are under study as candidates to intermediate band photovoltaic materials. It has been shown that the introduction of states in a semiconductor band gap presents an alternative to multijunction solar cell designs for improving the power conversion efficiency [1],[2].

Most intermediate band material candidates are based on III-V semiconductors, GaP and GaAs, having transition metal atoms forming part of the structure composition [3]-[5]. Some of most interesting compound candidates could be $Ti_xGa_nAs_m$ compounds [6],[7].

One way to obtain these kinds of compounds is to use rf-sputtering deposition process. Sputtering processes allow depositing thin-films of GaAs and Ti having well controlled properties.

In this work, we study the optical and structural properties of different thin films of GaAs-Ti and GaAs deposited by sputtering on glass, c-Si and c-GaAs substrates.

II. Sputtering process description

Two different structures, obtained from two sputtering deposition processes carried out. The description of these processes is given below.

A. Deposition of thin-film GaAs on glass, c-Si and c-GaAs substrates

A first sputtering process was carried out, using a 4" GaAs target, in a RF Sputtering System : ESM100 Edwards & RFS5 Generator-300W. The GaAs target was undoped, had with (100) crystalline orientation, resistivity >= 10^7 ohm-cm, and a mobility>= 5000 cm^2/V.sec. The process conditions were: 100W power and argon pressure of $5\cdot10^{-3}$ mbar. Thin thin-films 60nm thick were grown by sputtering on substrates of glass, c-Si and c-GaAs.

B. Sputtering of GaAS and Ti on c-GaAs and c-Si substrates

In order to study the incorporation of Ti atoms in the GaAs matrix, a second sputtering process was carried out using the above described 4" GaAs target, and a second Ti target in the same RF Sputtering System, using the same process conditions. In this run we used c-Si and c-GaAs substrates. The first steep was the deposition by sputtering of Ti films, with thicknesses in the range of 50nm, onto the substrates, and later a second GaAs, 50nm thick, over the Ti films.

III. Main results obtained

The GaAs sputtering rates were in the range of 180-200 nm h^{-1}. Optical transmittance measurements on the GaAs thin films over glass, see Fig.1, allow the estimation of the optical gap. The obtained value of 1.5 eV, suggest that the deposited films present amorphous structure [8].

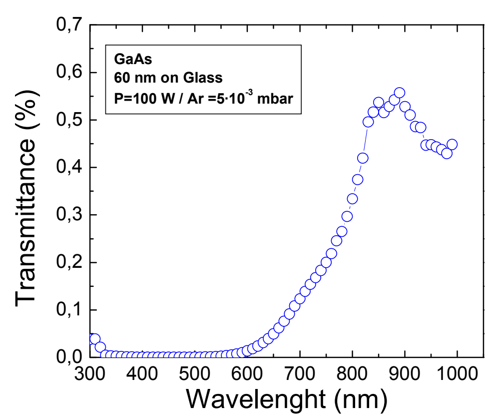

Fig. 1. Optical Transmittance of GaAs sputtered samples on glass.

This amorphous state was also confirmed by Photoreflectance measurements (PR). It has been reported that microcrystalline GaAs thin films with lower energy gap can be obtained increasing the deposition rate and the thickness of the layers.

Some authors have reported that GaAs layers deposited by sputtering presents poor Ga content, because preferential sputtering of As occurs for GaAs [9]. A thermal annealing can help to reduce the As concentration, favouring its crystallization [10],[11]. Following this idea, a thermal annealing in N_2 ambient, was applied to samples obtained in the second sputtering process described above on GaAs substrates. Table I summarizes the annealing conditions. X-ray diffraction (XRD) was used to analyse the structure of the annealed thin films, Fig.2 and Fig.3 show results obtained.

TABLE I
THERMAL ANNEALING CONDITIONS

Sample	Time (min)	T(ºC)	Structure
GaAs1	20	250	GaAs-Ti-GaAs
GaAs2	20	350	GaAs-Ti-GaAs
GaAs3	20	450	GaAs-Ti-GaAs
GaAs4	20	550	GaAs-Ti-GaAs
GaAs5	20	650	GaAs-Ti-GaAs
Si1	20	250	GaAs-Ti-cSi
Si2	20	350	GaAs-Ti-cSi
Si3	20	450	GaAs-Ti-cSi
Si4	20	550	GaAs-Ti-cSi
Si5	20	650	GaAs-Ti-cSi

As can be seen in Fig.2, some peaks corresponding to (111), (220) and (311) sets of crystalline GaAs planes appear. These crystalline diffraction peaks increase with annealing temperature, indicating an increase of the crystalline phase. The increase of the crystallization is more evident for samples deposited on c-GaAs substrates, where an annealing temperature of 450ºC is needed to clearly observe this effect, see Fig.3.

Finally, secondary ion mass spectroscopy (SIMS) analysis of the samples was performed.

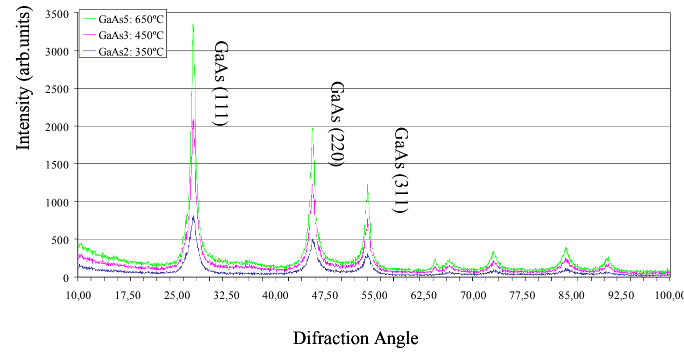

Fig. 2. XRD measurements of GaAs-Ti-GaAs annealed samples.

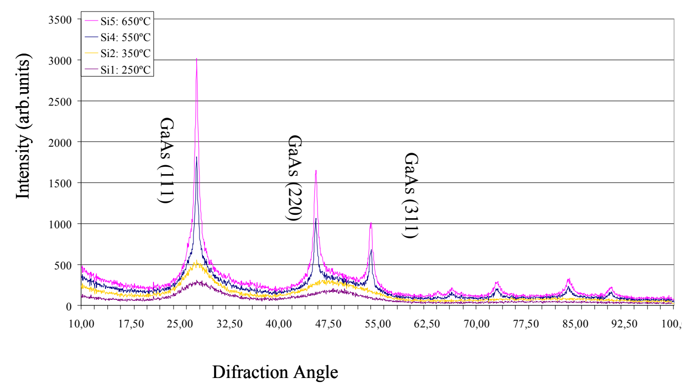

Fig. 3. XRD measurements of GaAs-Ti-(c-Si) annealed samples.

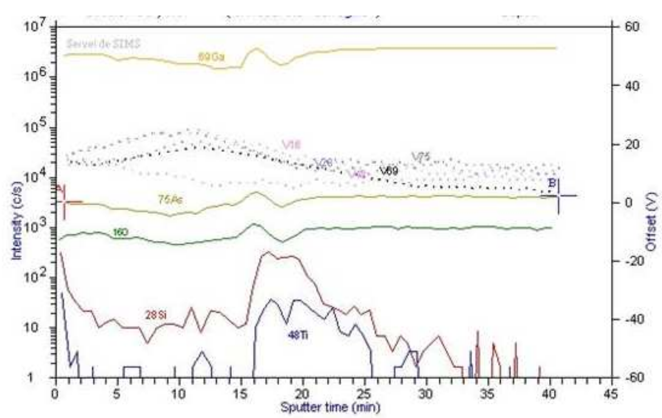

Fig. 4. SIMS results for a GaAs-Ti-GaAs sample.

Results corresponding to the structure GaAs-Ti-GaAs are shown in Fig. 4. SIMS measurements allow estimating depth profiles of different elements. In our case we were interested in the estimation of Ti atoms distribution in the bulk of GaAs thin film. In the figure is clearly observed the presence of Ti thin-film layer intercalated between GaAs films.

IV. CONCLUSSION

The thermal annealing of sputtered GaAs samples allows the As excess to migrate to the sample surface and sublimate. The diffractograms of the annealed films show the partial crystallization, mainly to the (111) planes of c-GaAs. The crystallization process of sputtered GaAs films deposited on Ti-(c-GaAs) and Ti-(c-Si) substrates has preferential growth along (111) GaAs, and is more efficient on Ti-GaAs substrates, especially for annealing temperatures below 450ºC.

ACKNOWLEDGMENT

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