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GaAs Thin Films Grown on Conducting Glass by Hot Wall Epitaxy for Solar Cell

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Abstract

GaAs polycrystalline thin films with good performance were prepared on conducting glass by hot wall epitaxy (HWE), which were used for solar cell. Electron probe micro-analyzer (EPMA) was applied for the composition, morphology of surface and cross-section of grown films, and X-ray diffraction (XRD) for their phase structure; Raman scattering spectrum (RSS) and photoluminescence (PL) were used for evaluating their optical characteristics. The results show that, there is textured structure on the surface of grown GaAs polycrystalline films, which is greatly promised to be suitable for the candidate of solar cell with low cost and high efficiency. It is concluded that the source and substrate at temperature of 900～930℃ and 500℃ respectively would be beneficial for such films.

I. Introduction

It is well know that GaAs solar cells have a higher efficiency and a greater radiation resistance than Si cells. Usually, the application of GaAs crystalline solar cells is limited severely due to the high cost. But due to high absorption coefficient, GaAs material with 5μm thickness could absorb more than 95% of sunshine [1]. This means for commercial wafer of 400μm GaAs, just only 1% is thickness contributes to photovoltaic. In actual uses, solar cell should be protected by quartz doped with cerium or glass for both use in space and terrestrial. It seems that solar cell thin film directly prepared on quartz or glass could make good use of GaAs material with lower cost. Imaizumi *et al.* [2] have reported a study on GaAs/glass films by Chemical Beam Epitaxy(CBE).

In this paper, GaAs thin films were obtained by Hot Wall Epitaxy (HWE) at low temperature. For application in solar cells, a transparent SnO_2 conducting film was needed deposited on glass is needed as an electrode before the GaAs thin films deposition. And the analyses of electron probe micro-analyzer (EPMA) show that the grown films with texture surface and great crystal grain are uniform and compact, and their composition is stoichiometric. Study in X-ray diffraction (XRD), Raman scattering spectrum (RSS) and photoluminescence (PL) have proved that the crystalline quality of grown films is good enough to be a candidate of solar cell with low cost and high efficiency.

II. Experiment

1. Preparation of substrate

Glass with 1 mm thickness was chosen as the substrate. Before deposition, the substrates were rinsed with organic solvent and etched with HF solution (HF: H_2O=1 : 10). After each step, the substrate was cleaned with deionized water, and finally dryed. The transparent conducting film was prepared by chemical spraying on treated glass to form conducting glass (SnO_2/glass) structure. In this procedure, $SnCl_4$ solution was used as the fogging source and the substrate was heated at temperatures of 400℃~450℃. Generally, spraying time was less than 30min for SnO_2, dependent on the requirement of thickness and square resistance. The *n*-type conducting film with 1~2μm of thickness, 10~20Ω/□ of square resistance and preferential (110) crystal face could be obtained with this method.

2. Preparation of GaAs film

GaAs thin films were prepared by improved HWE. Pure Ga (7N) and poly-GaAs (7N) were adopted to be sources. The ratio of content of both sources affects grown films. In order to ensure the saturation of steam in chamber, ratio selection was dependent on preparing temperature. In our laboratory, 100g Ga solvent with 3.8~18g poly-GaAs was chosen when the temperature was 780℃~930℃. The growth time was dependent on thickness requirement. The GaAs thin films were 3~5μm thick. Usually the process lasts for 4 hours. And the substrate temperature was about 450~510℃ in order to avoid the distortion of glass.

3. Measurements

EPMA-1600 type instrument mad in Japan was used for the composition, morphologies of surface and cross-section of grown films, X-ray diffraction (XRD) of Y4Q type for their phase structure; and MKI-1000 Raman spectrometer of Renishaw company with Ar^+ laser for Raman scattering spectrum (RSS) and photoluminescence (PL) were used to evaluate their optical characteristics at room temperature, and four-probe for square resistance.

III. Results and Discussion

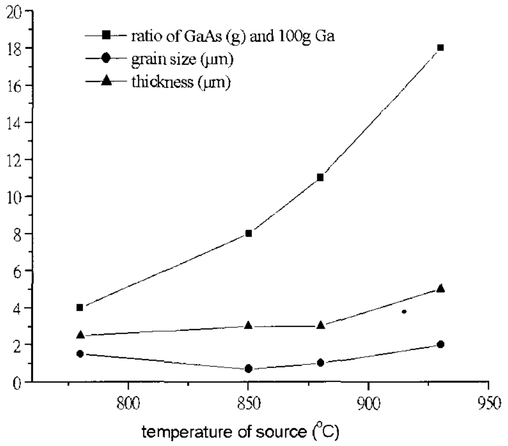
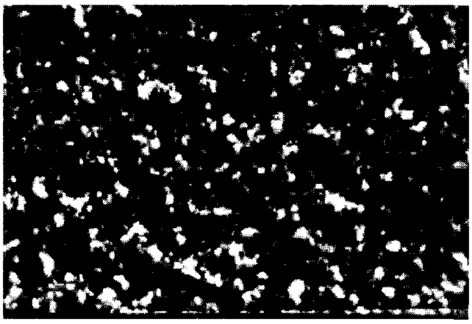


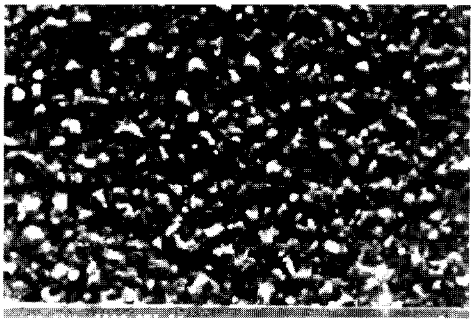
Fig. 1. Effect of source temperature on the ratio of source grain size and thickness.

Figure 1 shows the ratio of GaAs (g) and 100g Ga used, grain size and thickness of grown films at different source temperature. As reported before [3], source and substrate temperature were 900℃~930℃ and 500℃respectively, and the ratio was GaAs(g)/Ga(100g)=12.25~18, the composition of grown film was Ga : As=1.059 under this condition. It is found that at the same substrate temperature and growth time, thickness would increase by increase in source temperature, and large grain could be obtained at either higher or lower source temperature. And the films at lower source temperature seemed loose, crystal grains looked like spherical; with increase of temperature, films became compact, grain with cubic shape is formed, namely texture structure.

Substrate temperature plays an important role in influence on morphology of grown GaAs films. At lower substrate temperature, films would be loose with small grain size, which were obtained by simple cumulating. Figure 2 shows the surface morphology of grown GaAs films deposited at source temperature of 900℃ for 4h, the substrate temperature were 450℃ and 500℃respectively. The compact and texture structure could be obtained at higher temperature of source (900℃~930℃)and substrate(500℃), which was suitable for solar cells. Figure 3 shows the scanned cross-section distribution of elements of GaAs/SnO_2 film grown at



(a) 450℃



(b) 500℃

Fig. 2. Surface morphology of grown GaAs films at different substrate temperatures.

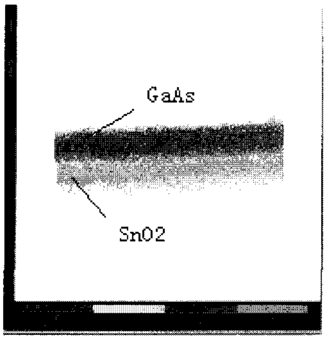
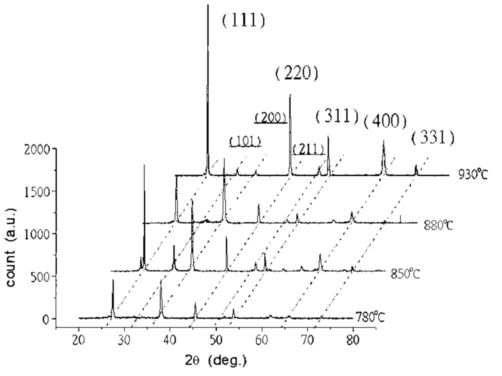
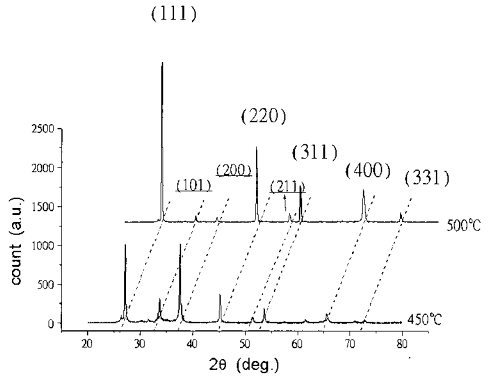


Fig. 3. Cross-section of GaAs films at T_{source}=930℃ and T_{sub} = 500℃.



a. at different source temperatures (T_{sub}=500℃)



b. at different substrate temperatures (T_{sour}=900℃)

Fig. 4. XRD pattern of GaAs films.

T_{source}=930℃ and T_{sub}= 500℃. The top layer is GaAs, and the bottom is SnO_2 about 2 μm. And in the middle of them, there are two thin layers, one is the admixture of Ga, As and Sn and the other is admixture Ga and Sn.

Figure 4 shows X-ray diffraction patterns of grown films at different temperature of source and substrate. Figure 4(a) shows the patterns at different source temperature(930℃, 880℃, 850℃, 780℃)when the substrate temperature is 500℃; while figure (b) for patterns at different substrate temperature(500℃, 450℃) when the substrate temperature is 900℃. It is found that, the located peaks exactly coincide with those in the standard card of GaAs, while the intensity of (111) is particularly high compared with (220) and (311) showing preferential growth, which means that the grown GaAs films are sphalerite structure. Except for the film grown at T_{source}=930℃ and T_{sub}= 500℃, additional peaks of (200), (101), (211), (110)and (321) showing SnO_2 could be seen in films grown at lower temperatures of either source or substrate. Higher temperatures of source and substrate could strengthen crystaliztion of GaAs and hence is good for the crystal of film.

The optical performances of films were evaluated by

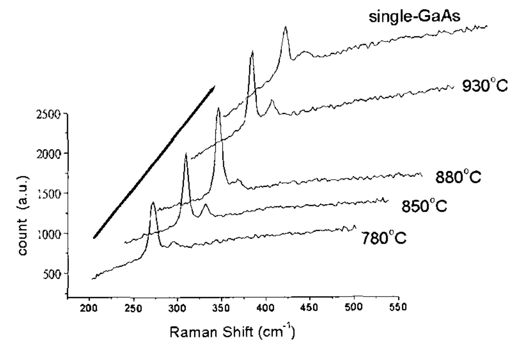


Fig. 5. Raman spectrum of GaAs films grown at different source temperatures (T_{sub}=500℃).

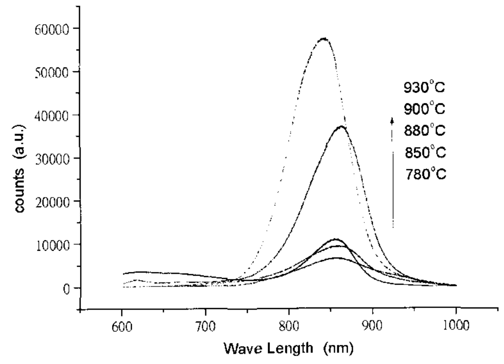


Fig. 6. PL spectrum of GaAs films grown at different source temperatures measured at room temperature (T_{sub}=500℃).

Raman scattering spectrum (RSS) and photoluminescence (PL) at room temperature. Figure 5 shows Raman spectra of GaAs films grown at different source temperatures. For comparison that of single GaAs is also shown. The main peak located at 272cm^{-1} was due to oscillation shift of horizontal optical phonon (TO) and the hypo-peak located at 294cm^{-1} due to vertical optical phonon (LO). It is well known that FWHM and shift of RSS peaks are determined by stress and quality of crystal. The shifts of scattering peaks happened with respect to standard spectrum (TO : 269 cm^{-1}, LO : 292 cm^{-1}), while their FWHM were moderate. This means that there is stress in the grown films. Furthermore, the intensities of LO of films deposited at different source temperatures are different. Figure 6 shows PL spectrum of GaAs films grown at different source temperatures measured at room temperature(T_{sub}=500℃). The intensities increased obviously with the increase of source temperatures, and FWHM of these peaks changed also. While location of peaks moved slightly. For the sample grown at T_{source} = 930℃ and T_{sub} = 500℃, the fluorescence peak was located at 845 nm and the intensity was rather high, FWHM was 80 nm, which hints a good crystal.

Table 1 Resistivity (Ω · cm) of grown films at different source and substrate temperatures.

Tsub (℃)	Tsource (℃) 780	 850	 880	 930
450	-		-	0.355
500	0.3765	0.2325	0.1867	0.1785

Due to the diffusion of Sn to GaAs (as shown in fig.3), the films formed in our experiment were n-type checked by thermal-probe. The square resistance measured by four-probe (and their resistivities) was changed at different temperature of source and substrate shown in table 1. Prepared with optimised procedure (T_{source} = 930℃ and T_{sub} = 500℃), the resistivity was 0.1785Ω · cm. Compared with that of n-GaAs (0.776 Ω · cm, doped concentration of 1~5×1018cm^{-3}), the doped concentration for n-GaAs films should be about 10^{18}~10^{19} cm^{-3}.

IV. Conclusion

Poly-GaAs films with texture were developed by HWE at low temperature on conducting glass. The detailed investigation on composition, phase structure, electric and optical characteristics showed that the crystal quality of grown film satisfied the requirement of solar cell. After analyzing the influence of procedures on performance of films, it is discovered that the substrate temperature is more influential than source temperature, and the optimized temperature of source and substrate are concluded to be 900~930℃ and 500℃, respectively.

Acknowledgements

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