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μc-$Si_{1-x}Ge_x$ Deposition on SiO_2 by RF Magnetron Sputtering

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1. Introduction

Micro-crystalline (μc) $Si_{1-x}Ge_x$ is regarded as one of the promising candidates for high mobility TFT's for AMLCD applications. Several attempts have been made to obtain μc-$Si_{1-x}Ge_x$ films on SiO_2 substrates at low temperatures. These attempts include laser annealing[1], PECVD[2], aluminum induced crystallization[3], SPC[4], and ion irradiation assisted SPC[5]. Compared with these techniques, sputtering is a relatively inexpensive technique, and is easily applicable to large area substrates.

In the sputtering system, it is known that surface migration takes place at about $0.3T_M$(T_M : melting temperature) and bulk migration takes place at about $0.5T_M$. Since the melting temperature of $Si_{1-x}Ge_x$ reduces greatly for higher x and at x~1 T_M is about 1210K, bulk migration is expected to take place at around 600K or about 300°C. Even though report on the sputtering at this temperature regime can be found in a literature[6], detailed behavior has not been reported yet.

In this paper, we report the μc-$Si_{1-x}Ge_x$ (x~0.8) deposition results by magnetron sputtering at this temperature regime together with the substrate bias effects.

2. Experiment

Magnetron sputtering system with the RF frequency of 100MHz and the cathode electrode of Si/Ge co-sputter was used (fig.1). For substrate bias experiments, 13.56MHz RF bias was applied to the substrate. As for the substrates, 33mmφ silicon substrate with SiO_2 layer of 100nm was used.

XRD, TEM, Raman were used to evaluate crystallinity of the deposited films. Silicon content was evaluated by SIMS analysis, which showed about 20% of Si and 80% of Ge for all the samples deposited in this experiment.

3. Results and Discussions

Figure 2 shows the XRD spectra for the samples deposited at 250, 300, and 350°C. It is clearly seen from this figure that the samples deposited at the substrate temperature of 300 and 350°C are the μc-$Si_{1-x}Ge_x$ with the preferential orientation of (220), while the sample deposited at 250°C does not show any peak, and presumably it is amorphous. This point is verified by the Raman spectra (fig. 3). In this figure, samples deposited at 300 and 350°C show three peaks, which can be assigned to Si-Si (~460cm^{-1}), Si-Ge (~400cm^{-1}), and Ge-Ge (~294 cm^{-1}), while 250°C sample shows no such peaks. The peak positions of these Raman spectra agree well with the peaks reported for single crystalline $Si_{1-x}Ge_x$ (x~0.77) prepared by liquid phase epitaxy[7]. This indicates that our films have no considerable stress.

These XRD and Raman results show that when the substrate temperature is higher than the bulk migration temperature ($0.5T_M$), micro-crystalline film can be obtained.

Figure 4 shows low magnification, bright field cross sectional TEM images of the samples deposited at 300 and 350°C. 300°C sample shows amorphous region at the bottom of SiGe layer, while 350°C sample does not show any such region and the nucleation starts from the beginning.

This amorphous layer does not affect the Raman spectrum of the sample as shown in fig.3. This is probably due to the fact that the wavelength of the laser used in the Raman scattering measurement is short, and does not penetrate into the film so that the resultant spectrum has the information only from the surface region.

Figure 5 shows the substrate bias dependence of the samples deposited at 350°C. When the substrate bias power is less than or equal to 2W, both the XRD and Raman spectra show very little change, but as the bias power increases to 3W, (220) peak of XRD becomes markedly small while (111) and (311) peaks show little change. Correspondingly, Raman spectra for 3 and 5W samples show slightly larger FWHM, which means the crystallinity of these two samples are degraded compared with the sample deposited by the bias power of 2W or less.

4. Conclusions

μc-$Si_{1-x}Ge_x$ (x~0.8) films have been successfully deposited by magnetron sputtering when the substrate temperature is higher than 300°C, which is roughly half of the melting point of the material, thereby proving that the bulk migration is necessary to deposit crystalline film by sputtering. However, further increase in the substrate temperature is necessary to deposit the microcrystalline film without any visible amorphous region at the bottom.

When substrate bias of more than or equal to 3W is applied, crystalline phase with (220) orientation vanishes and crystallinity degrades.

References

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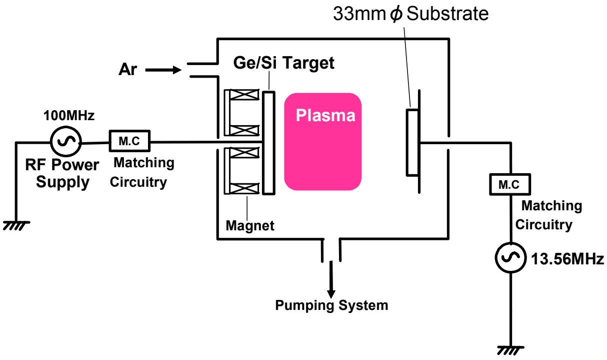

Fig.1 Schematic Illustration of the sputtering chamber used in this experiment

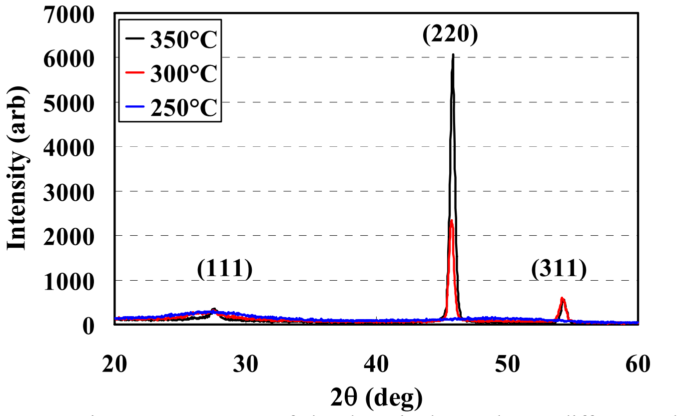

Fig.2 XRD spectra of the deposited samples at different substrate temperature. No peak is observed for the sample deposited at 250°C, while 300 and 350°C samples show (220) preferential orientation.

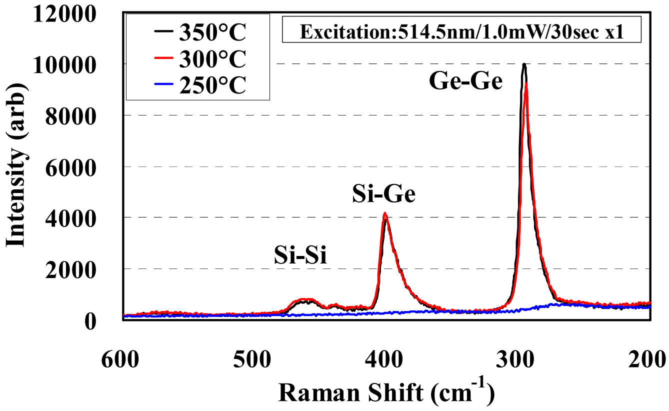

Fig.3 Raman spectra of the deposited samples at different substrate temperatures. Three peaks are observed for the sample deposited at 300 and 350°C. These peaks can be assigned as Si-Si(~460cm^{-1}), Si-Ge(~400cm^{-1}), and Ge-Ge(~294cm^{-1}).

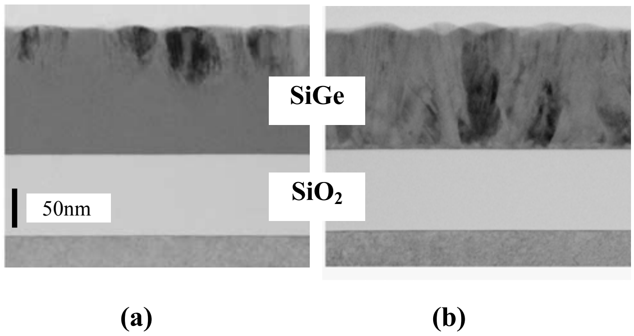

Fig.4 Low magnification, bright field cross sectional TEM images of the samples deposited at 300°C (a) and 350°C (b). 300°C sample has amorphous layer at the bottom of SiGe layer, while the nucleation of 350°C sample starts at the bottom of the deposited layer.

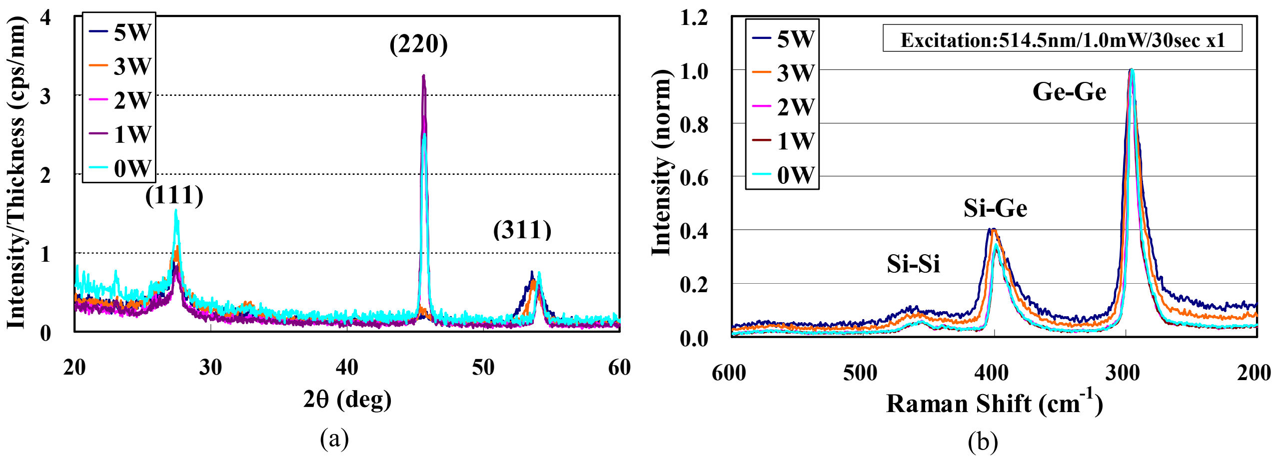

Fig.5. Substrate bias dependence of the samples deposited at 350°C. XRD spectra(a) and Raman spectra(b). At the bias power of 3 and 5W, XRD spectra show that (220) peak becomes small while other two peaks, which are (111) and (311), stays almost the same, and Raman spectra show that these samples have less crystallinity compared with other three samples.