Direct observation of phase transformation and transient reflectivity of amorphous silicon film during micro-thermal plasma jet irradiation

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Introduction: Silicon has widely applied in thin film electronic devices (1). However, our knowledge about the silicon crystallization mechanism is still incomplete. In our previous work, we directly observed the grain growth (1) and measured the substrate surface temperature (2), however, direct measurement of the temperature of amorphous silicon (a-Si) during micro thermal plasma jet irradiation (μ-TPJ) is still matter of research. In this research, we introduce high-speed camera (HSC) and He-Ne laser (632.8nm in wavelength) as a temperature probe for direct observation of phase transformation during μ-TPJ annealing.

Experiment: 150-nm-thick a-Si was prepared in the same way as previously reported by plasma enhanced chemical vapor deposition on quartz substrate (1). The experimental set-up for direct observation of phase transformation and transient reflectivity of amorphous silicon is shown in Fig.1. During the μ-TPJ irradiation, the a-Si was irradiated by He-Ne laser, and the reflected light intensity was detected by a photodiode through a bandpass filter.

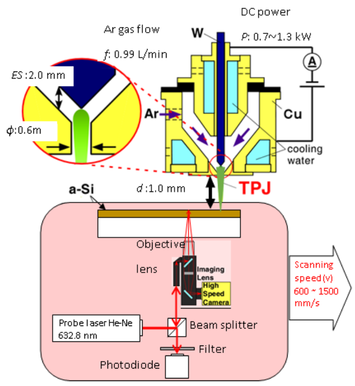

Fig.1. Experimental set up for direct observation of phase transformation and transient reflectivity.

Results:

Fig. 2(a) to (e) show HSC snapshots captured during μ-TPJ irradiation. The probe He – Ne laser is focused on the bottom surface of a-Si film as seen in a bright spot. Fig. 3 shows transient reflectivity observed with the probe laser and (a) to (e) correspond to the HSC capture of Fig. 2(a) to (e). As can be seen in Fig. 3 and Fig. 2, the transient reflectivity of amorphous silicon decreases and slightly increases when μ-TPJ starts to irradiate the sample ((a) to (b)). With the appearance of solid phase crystalline (SPC), there is a slight increase in reflectivity ((b) to (c)). Then, the reflectivity went up sharply when the film was melted and this value kept remaining during the molten region ((d) to (e)). When the laser spot touched high speed lateral crystallization region, the reflectivity moved downward. Since the refractive index of a-Si changes with temperature (thermo-optic coefficient: TOC), the decreasing and slightly increasing reflectivity from (a) to (b) is closely related to the a-Si temperature. By obtaining the TOC, we can determine the temperature for a-Si.

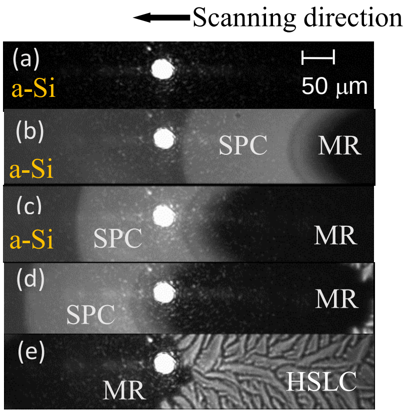

Fig.2. Snapshots of high-speed camera during μ-TPJ irradiation under conditions of P = 756 W, d = 1.0 mm, f_{Ar} = 0.99 L/min, v = 600 mm/s, and R_f = 16500 fps.

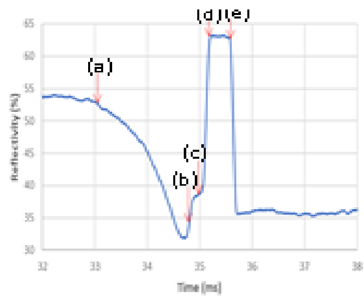

Fig.3. Transient reflectivity of amorphous silicon during μ-TPJ irradiation.

References

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