Investigation the solid phase crystallization kinetics at the high-temperature region by annealing amorphous silicon using micro-thermal-plasma jet

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Introduction: Solid phase crystallization (SPC) kinetics of silicon has been researched since the 70th of last century [1-2]. However, they mainly focused on low temperature region. In our knowledge, SPC mechanism at high temperature regime is still matter of research. In this study, we give a method to estimate the nucleation temperature and characteristic crystallization time as function of temperature when annealing amorphous silicon (a-Si) films by micro-thermal-plasma-jet (μ-TPJ) at high temperature.

Experiment: Time resolved reflectivity was used to study the nucleation temperature and crystalline volume fraction. The experimental set-up was shown in Fig.1. Basically, it consists of μ-TPJ to irradiate the samples and HSC was set on the motion stage which moved linearly with sample in front of μ-TPJ with scanning speed ranging from 390 to 2020 mm/s. He-Ne laser was introduced as a temperature probe. The transient reflectivity of a-Si during μ-TPJ irradiation was detected by oscilloscope through a band pass filter.

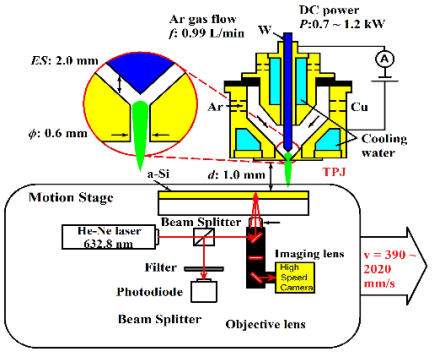

Fig.1. Time resolved reflectivity experimental set-up

Results and discussion: By obtaining the a-Si refractive index as function of temperature (thermo-optic-coefficient TOC), we can estimate the nucleation temperature at different experimental conditions as shown in Fig.2. It is easy to observe, the nucleation temperature increases from 985 to 1071°C when the heating rates increases from 4.45 x 10^5 to 2.28 x 10^6 K/s. The measured reflectivity as a function of time were converted into the volume fraction of crystallized material by modelling the film as a homogeneous optical medium with optical constants equal to a linear combination of the amorphous and polycrystalline Si values. The characteristic crystallization time t_c as function of temperature in our experiments is plotted in Fig.3. The value of t_c decreases from 75 to 20 μs when the annealing temperature increase from 985 to 1071 °C. The activation energy E (solid line) is 2.9 eV. This energy relates to both nucleation and growth process. Blum and Feldman calculated this activation energy of 3.3 eV when performed annealing a-Si films at low temperature region, around 600°C [3].

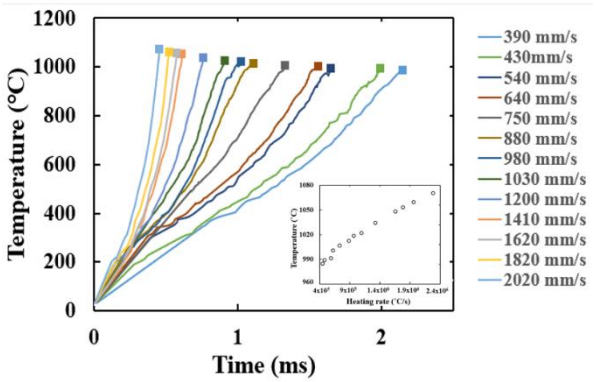

Fig.2. Transient variation of a-Si temperature measured under different scanning speed. ■ marks indicate the onset of nucleation starts. The insert figure shows the dependence of phase transformation temperature on heating rate

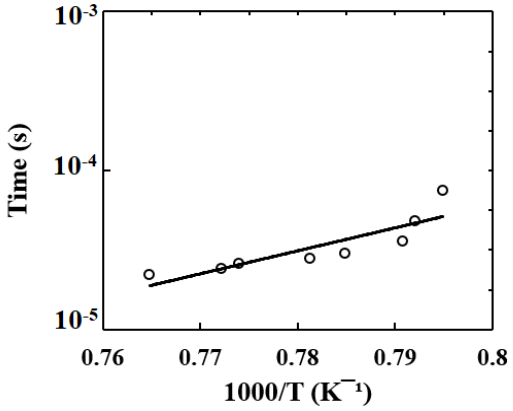

Fig. 3. Characteristic crystallization time as function of temperature. The solid line was fit to the data of this work and corresponds to an activation energy 2.9 eV

References

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