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Comparison of crystalline quality of SPC Si films grown on YSZ layers with that on glass substrates in pulse laser annealing

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Introduction: Thin-film transistors (TFTs) using a material of polycrystalline silicon (poly-Si) have been studied and applied extensively. In the previous Spring JSAP Meeting, we have proposed a stimulation layer method using yttria-stabilized zirconia [$(ZrO_2)_{1-x}(Y_2O_3)_x$: YSZ] as a stimulation material combined with PLA method. We have, also, reported that an a-Si film on a YSZ layer is solid-phase crystallized successfully by pulse green laser irradiation and microcrystalline fraction of SPC films on YSZ layers is a little lower than that on glass substrates[1]. This indicates that SPC film quality on YSZ layers might be better than that on glass substrates. In this Meeting, we present detailed investigation results of film quality by Raman spectroscopy such as energy density and pulse number dependences of FWHM and crystalline fraction of crystalline silicon (c-Si) peak.

Experimental: A YSZ stimulation layer is deposited on a cleaned quartz substrate (1x2 cm^2) by reactive magnetron sputtering at substrate temperature of 50 °C. Then, an amorphous silicon (a-Si) film is deposited on a YSZ/quartz substrate by e-beam evaporation method at 300 °C, following by crystallization of a-Si film by PLA in N_2 ambient. A Q-Switched Nd:YAG laser (λ = 532 nm) is used for annealing with repetition frequency of 10 Hz, pulse duration of 6~7 nsec, and beam diameter of ~4 mm. Crystallization degree of Si films is estimated by Raman spectroscopy. Crystalline fraction, X_c, is determined by $X_c = (I_\mu + I_c)/(I_\mu + I_c + I_a)$, where I_c, I_μ, and I_a are integrated intensities of c-Si, micro-crystalline silicon (μ-Si), and a-Si peaks, respectively.

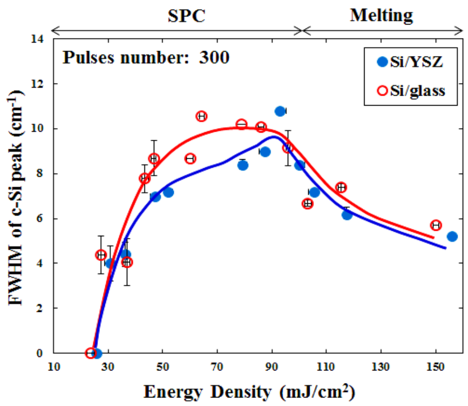

Fig. 1 Dependences of c-Si peak FWHM on laser energy density.

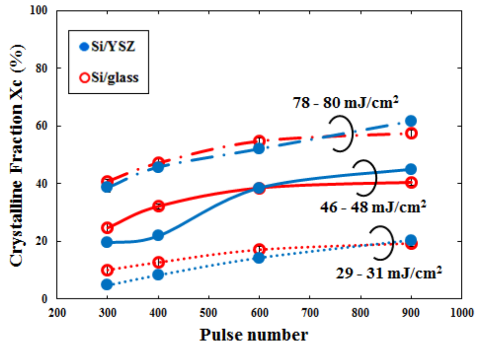

Fig. 2 Dependences of crystalline fraction on pulse number for 3 energy densities as parameter.

Results and discussion: From SEM images of Secco-etched crystallized Si films on YSZ layer and glass substrate[1], it was found that grain size in Si/YSZ/glass sample was more uniform, compared with that in Si/glass. This might be due to stimulation effect of the YSZ layer. For more investigation of YSZ layer stimulation effect, we estimated dependence of c-Si peak FWHM on laser energy density. The result is shown in Fig. 1. Overall, FWHM of c-Si peaks for Si/YSZ samples are seen to be smaller than those for Si/glass ones for both regimes of SPC (i.e. energy density < 105 mJ/cm^2) and melting (i.e. energy density > 105 mJ/cm^2). This means that crystalline quality of Si films on YSZ layers is better than that on glass substrates. Moreover, FWHM increases with energy density for both Si/glass and Si/YSZ samples in the SPC regime, which can be explained partially due to intensification of stress between grains. The grain size increases with energy density and their impingement enhances stress. However, FWHM abruptly decreases at a transition state between SPC and melting regimes (at energy density around 100 mJ/cm^2) and further decreases in the melting regime. This can be explained due to the release and relaxation of stress between grains by melting process. The dependences of X_c on pulse number for both sample structures are shown in Fig. 2. X_c for them increase with pulse number because integrated annealing times are increased with the pulse number so that crystallization of a-Si region is enhanced. At high pulse number (> 600), X_c for YSZ are equal and even higher than those for glass, which may indicate alignment effect of YSZ layer on Si growth direction. We will discuss more results in detail at the conference.

References: [1] K. Mochizuki et al., Abstract JSAP 60th Spring Meeting, 2013, 28p-G6-10.