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Pulsed-Laser-Microcrystallization of Si Thin Films on Metal Films with Crystallization-Induction Layers of YSZ by the Two-Step Irradiation Method

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Introduction: In the previous meeting, we have proposed a new two-step irradiation method with pulse laser annealing (PLA) for further improving quality of microcrystallized Si film on crystallization-induction (CI) layer of YSZ [$(ZrO_2)_{1-x}(Y_2O_3)_x$], compared with the conventional one-step method[1]. In the two-step method, an a-Si film is irradiated on a YSZ layer covering a glass substrate, using two kinds of energy densities *E*. At first, in the initial stage, it is irradiated at a low *E* for a short time to promote nucleation at the interface between Si and YSZ with perfect suppression of bulk-nucleation. Next, in the second step of growth stage, the Si film is irradiated at a higher *E* to speed up its crystallization. In order to fabricate poly-Si TFTs with a bottom gate, the optimum annealing condition of a Si/YSZ/**metal**/glass structure should be found for crystallization in the two-step method.

In this meeting, we report the detailed investigation results of crystallized Si films quality on YSZ/**metal**/glass by the two-step method, comparing with the structures without metal films.

Experimental: A triple-layered structure of 30-nm SiN_x/30-nm W/30-nm Ti is deposited on a quartz substrate at 100 °C by RF sputtering. Then, a 120-nm YSZ CI layer is deposited on the SiN_x/W/Ti/quartz at a substrate temperature of 50 °C by sputtering, following by deposition of a 60-nm a-Si film by e-beam evaporation at 300 °C. Next, crystallization of the a-Si film is carried out in N_2 ambient by a pulse Nd:YAG laser (λ = 532 nm) with a repetition frequency of 10 Hz and a pulse duration of 6 ~ 7 nsec. The two-step method is illustrated in Fig. 1, in which the total pulse number *N* is kept constant of 100 while the pulse numbers of initial stage N_i and growth stage N_g are changed so as to keep $N = N_i + N_g$. The crystallization degree of Si film is estimated by Raman spectroscopy.

Results: At first, the results of the one-step annealing are shown as a basic annealing information. Figure 2 shows the dependence of crystalline fraction X_c on the pulse number *N*, where the energy density is a parameter. It can be seen that increasing *N* (or annealing time) makes X_c's of Si films increase for all structures. At the high energy density *E*, X_c increases rapidly and saturates even with the small *N*, which indicates bulk nucleation and growth for all structures. X_c of Si films on glass substrates are found to be higher, indicating faster crystallization, than those on YSZ/glass and YSZ/metal/glass at the same *E* and *N*. This is because optical absorption in Si film for the former is larger than those for the two latters. X_c of Si/YSZ/metal/glass is a little higher than that of Si/YSZ/glass. This is probably due to the metal film, which absorbs optical energy from the laser beam, so that temperature of the Si film is a little higher than that in the Si/YSZ/glass.

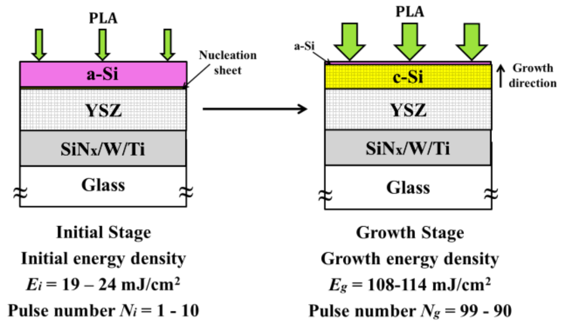

Fig. 1 Schematic illustration for the new two-step method and the annealing conditions.

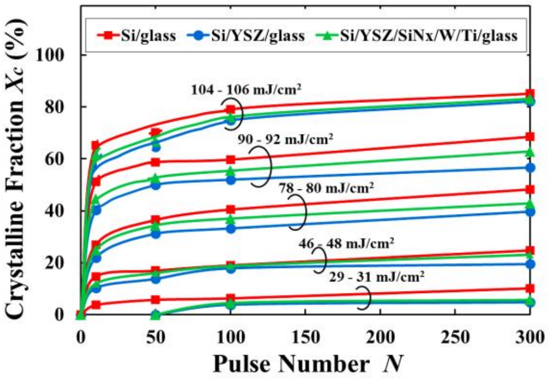

Fig. 2 Dependences of crystalline fraction X_c on the pulse number *N*. The energy density is a parameter.

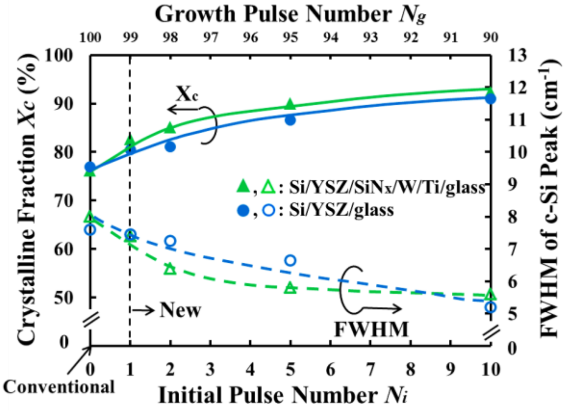

Fig. 3 Dependences of crystalline fraction X_c and c-Si peak FWHM on initial pulse number N_i where the different optimum annealing condition is used for each sample structure.

From the above results, we determine the energy densities for initial and growth stages of the two-step method, which are 19-24 and 108-114 mJ/cm^2, respectively. Figure 3 shows the dependences of crystalline fraction X_c and FWHM of c-Si peak on pulse number *N* of 100 for Si/YSZ/**metal**/glass and Si/YSZ/glass structures in the two-step method ($N_i \neq 0$), compared with the conventional one ($N_i = 0$). It can be seen that FWHM is reduced while X_c increases with N_i, compared with $N_i = 0$ for the both structures. This indicates that the crystalline quality of Si film is improved significantly by using the two-step method. Moreover, at the same $N_i > 0$ (for the two-step method), X_c of Si/YSZ/**metal**/glass is a little larger while its FWHM is slightly smaller than those of Si/YSZ/glass. This shows that the metal film has a role in enhancing crystalline quality of the Si film on the YSZ by the two-step method.

Summary: In the presentation, we will discuss more results in detail.

Reference: [1] M. T. K. Lien et al., Abstract JSAP 61st Spring Meeting, 2014, 20a-E14-8.