Improvement of solid phase crystallization of an Si film on a YSZ gate insulator with a bottom gate electrode

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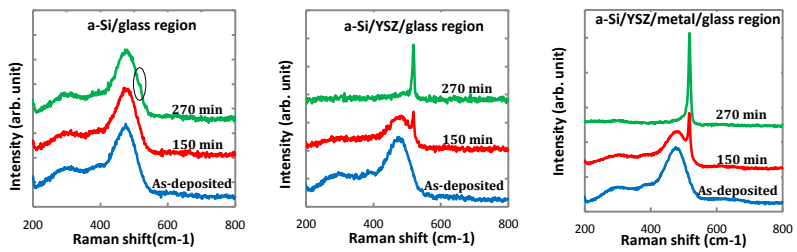
Introduction: Low-temperature polycrystalline Silicon (poly-Si) thin films on insulate substrates such as glass or plastic for thin-film transistors (TFTs) and diodes applications have been attracting material researchers. To obtain a poly-Si film at low temperature and its good property, we proposed to use a stimulation layer of Yttria-Stabilized Zirconia (YSZ) and solid phase crystallization (SPC) method[1,2]. We have reported that the crystalline fractions of a-Si deposited on YSZ/quartz and YSZ/Pt/Ti/quartz layers were much higher than that deposited directly on quartz substrate at lower annealing time. However, the crystalline rates versus annealing time were irregular and the crystalline fraction of Si/YSZ/Pt/Ti/quartz film was lower than that of Si/YSZ/quartz film[2]. This limits the application of YSZ layer to fabricate bottom gate TFTs. To overcome these limitations, we have changed the substrate from quartz to non-alkali glass whose cost is cheaper, the metal thickness, the YSZ deposition conditions, and the cleaning process before a-Si deposition.

Experiments: A 20x10x0.7 mm^3 non-alkali glass substrate was cleaned before deposition of 30 nm Ti and 30 nm Pt layers by magnetron sputtering method. Then, a 100 nm YSZ layer was deposited by magnetron sputtering method. The film was cleaned in de-ionized water (DIW), ethanol, dipped in HF solution, and pre-annealed in vacuum at 500 °C for 30 min prior to the deposition of 60 nm a-Si film at 300 °C. Subsequently, the film was annealed at about 560 °C in nitrogen (N_2) ambient. The degree of crystallization of the Si film was estimated by Raman spectroscopy per 30 min annealing. The crystalline fraction X is determined by $X = (I_c + I_\mu)/(I_c + I_\mu + I_a)$, where I_c, I_μ , and I_a are integrated intensities of c-Si, μc -Si, and a-Si, respectively.

Result: Raman spectra of each region are shown in Fig. 1. It can be seen clearly that the Si films deposited on YSZ layers were crystallized faster than that directly on non-alkali glass. The dependence of X for each region on crystallization annealing time t_A is shown in Fig. 2. From this figure, it can be seen that random crystallization occurred around more than t_A = 150 min for a-Si/YSZ/Pt/Ti/glass and t_A = 210 min for a-Si/YSZ/glass although their X increased almost linearly with t_A. It is considered from this that nucleation occurrs at the YSZ layer and the crystallization proceeds with annealing time linearly from there, but random crystallization occurrs in the remained a-Si film due to long heating. Also, for a-Si/YSZ/Pt/Ti/glass region, X is higher than that of a-Si/YSZ/glass region. This is probably due to the gate electrode layer, which absorbs optical or thermal energy from the furnace to enhance crystallization of a-Si after consecutive annealing process.

Summary: In the presentation, we will discuss the crystallization mechanism in detail.

References: [1] T. Akahori et al., Abstract JSAP 70th Autumn Meeting, 2010, 9a-TG-2. [2] Kenta Morii et al., Abstract JSAP 59th Spring Meeting, 2012, 16p-GP5-7.



(a) (b) (c)

Fig. 1 Raman spectra of (a) a-Si/glass region, (b) a-Si/YSZ/glass region, and (c) a-Si/YSZ/metal/glass region.

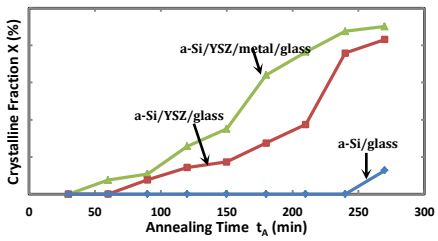


Fig. 2 Dependences of the crystalline fraction X on the annealing time t_A.