The Structural Property Changes of Thin Film Silicon by Various Anneal Treatment

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This paperer describes work to characterize the crystallized Si films after various anneal treatments. The material characteristics of the as-grown a-Si:H films are compared with those of the anneal treated films using X-ray diffraction (XRD), scanning electron microscopy (SEM), transmission electron microscopy (TEM), Raman spectroscopy, and Fourier transform infrared (FTIR) spectroscopy.

Investigated studies on the influencing factors for the crystallization were doping, temperature, film thickness, and annealing time. Doped amorphous silicon shows better crystallization than intrinsic. Crystallization is initiated at low temperature for the doped amorphous silicon. Doping induced defect states may have assisted crystallization at lower temperature. Anneal time duration effect on crystallization was examined from 2 minutes RTA to 40 hours vacuum anneal. Anneal time duration has only a small effect on crystallization. However, anneal temperature greatly affects crystallization. As anneal temperature increases, the Si (111) peak increased, and FWHM was decreased from 0.583° at 600 °C to 0.343° at 1000 °C for n-type 5 μm thick silicon. This temperature effect was generally observed for various anneal techniques such as RTA, furnace anneal, and vacuum anneal. Increasing anneal temperature means increased grain size. The thin film Si exhibited (111) preferential crystallization below 1000 °C anneal treatment. Unfortunately, silicon interacted with the Mo substrate above 1100 °C. XRD shows strong molybdenum silicide peaks for anneal temperature above 1000 °C. The a-Si:H film thickness over 10 μm showed surface layer peel off after high temperature anneal treatment by the stress relaxation process. The corrected peak intensity indicates that the film thickness below 5 μm exhibited better crystallization.

An as grown sample surface microstructure feature size of around 0.02 μm. The selected area diffraction (SAD) ring pattern indicated no crystalline component. A preferential etch was employed to reveal grain structures prior to the Si film thinning. The etched surface etch pits on an 850 °C, 4 h anneal treated sample exhibited triangular type etch pits which indicates (111) direction preferential crystallization. The structure size of the TEM photograph is around 0.4 μm which may correspond to the grain size of the sample. But in general, the grain boundaries of the crystallized sample were so blurry after heat treatment that no distinguishable grain size was observed. The cross-sectional study of the laser annealed sample indicated that only the top thin layer was crystallized at a laser energy of 310 mJ. This result indicates that the excimer laser anneal is useful for only thin film Si crystallization.

Argon laser driven Raman spectroscopy was employed to examine crystallinity of the thin film Si. Crystallinity examination study on intrinsic a-Si:H shows that the samples started to microcrystallize even for low temperature 600 °C and 4 h anneal. An as-grown a-Si:H peak appears at 480 cm^{-1} and anneal treated sample peak appears at 520 cm^{-1}. As anneal temperature increased, the peak intensity was increased and the FWHM was reduced. This indicates that the grain size increases with an elevated anneal temperature. The Si-H bond (2020 cm^{-1}) can be monitored using the Raman spectroscopy study. The Raman spectra on the a-Si:H and the RF plasma rehydrogenated crystalline Si. The RF plasma rehydrogenation on crystallized sample exhibited no strongly bonded hydrogen peak (Si-H peak). This result indicates that weakly bonded hydrogen may dominate after the rehydrogenation.

A FTIR study was performed on an intrinsic 5 μm thick a-Si:H film with and without anneal treatment. As-grown a-Si:H exhibited the Si-H, Si-H_2, and [Si-H_2]n peaks. The dihydride peak disappeared after 400 °C anneal due to weakly bonded hydrogen evolution. All the hydrogen peaks disappeared after 600 °C anneal treatment. This explains the Raman spectroscopy study result on crystallization after 600 °C, 4 h anneal treatment. The 600 °C anneal treatment completed the hydrogen bond breaking process and initiated crystallization.