OPTICAL CHARACTERIZATION OF SOLID PHASE CRYSTALLIZATION OF SILICON THIN FILMS OBTAINED BY LPCVD

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LPCVD polycrystalline silicon (polysilicon) has been intensively studied due to its important applications to microelectronic as gate materials for field-effect transistors, as emitter in bipolar transistors, and as parts of interconnects. Thin film transistors fabricated of polysilicon have attracted considerable interest for large-area electronics and for the application to three-dimensional integrated circuits.

Surface roughness, grain size and trap density of the active polysilicon layers are very important variables for this last type of applications because they determine the speed of the active matrix (AM) LCD. Strong visible photoluminescence (PL) at room temperature from polysilicon thin film has opened the way for new applications of polysilicon in the optoelectronic area [1].

This work investigated the low (500°C and 600°C) and high (900°C) temperature solid phase crystallization (SPC) of silicon thin films prepared by low-pressure chemical vapor deposition. Silicon thin films were deposited by low-pressure chemical vapor deposition (LPCVD) on oxidized silicon substrates, from silane decomposition. The deposition temperatures used in our experiment have been 500, 530, 550, 590 and 615°C and the pressure values were 20, 53 and 100 Pa.

Spectroscopic ellipsometry (SE) was used in order to show the phase transition of as-deposited and annealed LPCVD silicon from amorphous to crystalline state via a mixed phase. The dependence of the structural parameters on the deposition ones has been investigated. We achieve, using the optical model: c-Si/SiO_2+voids/c-Si+a-Si+voids/SiO_2+c-Si+a-Si+voids a better fitting of the ellipsometric data than other models in the literature. This model offers the possibility to extract information about optical and microstructural properties and also on surface roughness.

X-ray diffraction (XRD) and atomic force microscopy (AFM) techniques have been used in order to corroborate the SE results.

The relation between the LPCVD processing parameters and the deposition growth rate (v_{dep}) of polysilicon thin films is summarized in Figure 1.

The variation of the crystalline fraction (resulted from SE measurements) in the polysilicon films with the deposition temperature and with deposition pressure as parameter is presented in Fig.2.

The results presented in Fig. 2 show that the polysilicon films deposited at 500°C, 530° and 590°C have a mixed structure with some grains in an amorphous silicon matrix.

The results are generally in good agreement with the XRD measurements, with the exception of the samples deposited at 530°C.

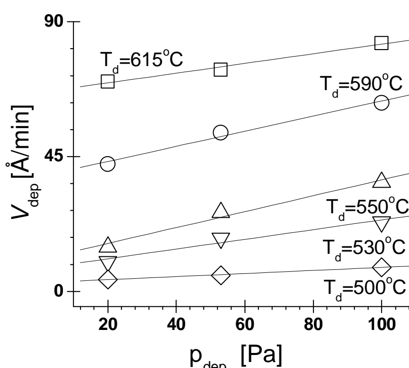
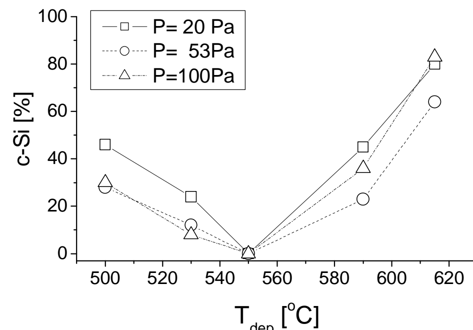


Fig.1 The dependence of v_{dep} on deposition pressure for different deposition temperatures.

Fig.2 Crystalline fraction of as-deposited LPCVD Si films as function of deposition temperature.

SE results regarding the crystalline state of the films deposited at 530°C are in agreement with previous UV reflectance results [2]. The difference between the SE and UV results on one hand and the XRD results on the other hand can be explained by the existence of grains having a size below 5nm which are too small to be observed by our XRD setup.

The annealing at 500°C for 72 hour on forming gas made only slight changes in the structure of the LPCVD polysilicon films as observed from the SE measurements. The SE results show that the temperature of 500°C and ambient gas do not induce the solid phase crystallization of the polysilicon. The slight decrease of the crystalline fraction is probably due to the hydrogen ambient and long annealing time both of which can reduce the grain size.



The temperature of 600°C is high enough to induce the solid phase crystallization in the polysilicon films. High quality polycrystalline films (with high c-Si fraction) can be obtained at temperatures as low as 600°C.

As expected the annealing temperature of 900°C is sufficient to lead to the solid phase crystallization of the LPCVD silicon films that in the as-deposited state were amorphous or in mixed state.

SE has proved to be more sensitive than XRD to the microstructural change in the polysilicon films. SE can also provide information about the films roughness in good agreement with the results obtained from AFM measurements

References:

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