Process and Material Properties of PECVD Boron-Doped Amorphous Silicon Film

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The effect of temperature and dopant gas flow on PECVD boron-doped (B-doped) amorphous silicon (a-Si:H) film properties such as deposition rate and resistivity were studied by correlating the chemical and physical characteristics of the films.

PECVD a-Si:H films are used in many applications such as TFT arrays of active matrix liquid crystal display (AMLCDs), p-i-n junction capacitors and solar cells, sensors, and other opto-electronics devices (1). Future applications of low cost, flexible substrates require low deposition temperature of the films. Recent studies showed that it is possible to deposit a high quality a-Si:H film at a temperature as low as 50°C (2,3).

Films reported in this experiment were deposited at 50 kHz using a cold wall reactor with horizontal electrodes. A 2000-Angstrom thick PECVD silicon nitride film was deposited on a glass substrate as an adhesion layer for the a-Si:H film. The coated substrates were placed on the bottom electrode and heated to a temperature range of 100-300°C. The feed gas flew from the center of the reactor to the periphery. It consisted of 1) 40–200 sccm of diborane (5% in hydrogen), 2) 400 sccm of hydrogen, and 3) 35 sccm silane (99.999%). The pressure and plasma power density were kept constant at 0.25 Torr and 205 mW/cm^2, respectively. The thickness, resistivity, chemical composition and bond structure, and morphology of the film were measured with a profilometer, 4-point probe, ESCA, and Raman spectroscopy, respectively.

Figure 1 shows the influence of the substrate temperature and diborane flow on the deposition rate of the film. This is consistent with the reported literature that the deposition rate decreases as temperature increases due to either the higher sticking coefficient of the precursors on the surface or the less aggressive surface reactions at the lower temperature (3). However, deposition rate increases with the increase in dopant gas flow. This could be due to the increase in sticking coefficient by boron segregration on the surface at higher boron concentration (4) or because boron reduces the desorption barrier of the H_2 (5). As shown in Fig. 1, the effect of diborane flow on deposition rate at 300°C was less pronounced compared to that at 250°C. Therefore, in this experiment, the substrate temperature has a more pronounced effect on the deposition rate than the dopant gas flow rate.

Figure 2 shows the influence of the substrate temperature and diborane flow rate on the resistivity of the film. It is observed that 1) resistivity decreases with temperature, and 2) a more uniform resistivity can be achieved at higher temperature. Since all films have broad Raman peaks around 480 cm^{-1}, the resistivity change of the films is not due to the microcrystalline formation as demonstrated in the heavily phosphorus doped silicon film (6). In general, incorporation of diborane increases the conductivity of the film (7). This conductivity change is also related to the location of the boron atoms in the film. ESCA results indicated that there was an optimum concentration of boron atom in the film, i.e., of 13-14%, which had the highest conductivity. This is independent of the substrate temperature. Films with higher boron concentrations probably do not have these atoms located at the electrically active sites. Films with lower boron concentrations probably do not have enough dopant amounts. The 250°C deposited film has a higher conductivity than the 200°C deposited film because of the higher percentage of the dopant activation. ESCA data showed that the 250°C deposited films had a higher Si-O concentration than that of the 200°C deposited films. It is probably due to the higher hydrogen concentration in the latter film.

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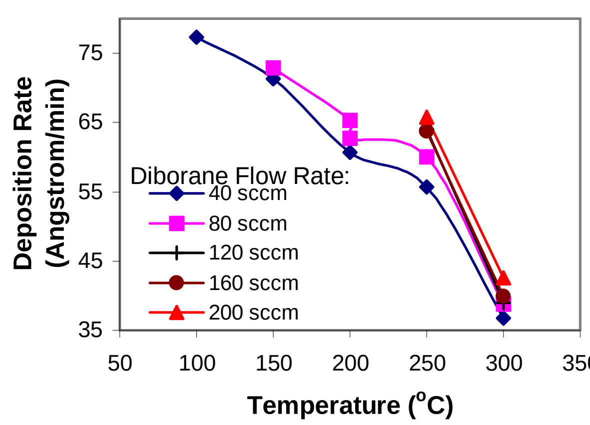

Figure 1. Deposition Rate as a Function of Substrate Temperature

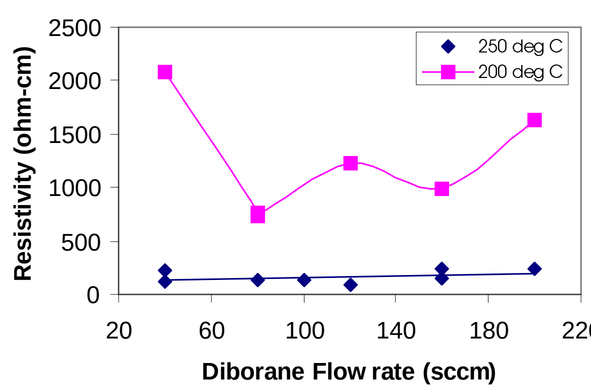

Figure 2. Resistivity as a Function of Diborane Flow Rate