B-4-1 (Invited) Optical, Electrical and Structural Properties of Plasma-Deposited Amorphous Silicon

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Hydrogenated amorphous silicon (a-Si:H), the first "structure-sensitive" amorphous semiconductor, has attracted an increasing attention as a promising material not only for low-cost solar cell[1)] but also for TFT[2)] and imaging devices[3)]. In general, however, amorphous solid is thermodynamically in a non-equilibrium state, therefore, its structure takes a wide variety depending on preparation condition as well as post thermal treatment. This causes much difficulty for characterizing amorphous semiconductors in comparison with crystalline counterparts. For a-Si:H, in particular, optical gap E_o, photoconductivity $\Delta\sigma_p$ and dark conductivity σ_d vary in a wide range depending on how much quantity and in what manner hydrogen is incorporated in its disordered network, which is the origin of so-called "laboratory dependence" of a-Si:H properties.

We prepared a-Si:H and a-Si:F:H (doped and non-doped) by two essentially different methods; one is glow-discharge decomposition(GD) of SiH_4 or SiF_4, and the other reactive sputtering (SP) of crystalline Si in Ar-H_2 mixtures[4)-6)]. In order to avoid the above confusion, deposition parameters such as substrate temperature, RF power, gas pressure and starting gas materials were scanned in a systematic way. All the prepared samples were subjected to X-ray diffraction, EPMA, ir transmission and ESR measurements, from which we determined the contents of bonded H, Ar, doped element(P) and spin density. σ_d, $\Delta\sigma_p$ and E_o were also measured in parallel and discussed in relation with structural properties.

The main results we have obtained so far are summarized as follows.

(1) As a general tendency, high RF power deposition results in crystallization of deposited films independently of whether they are Si:H or Si:F:H. This tendency is enhanced in doped specimens. All the highly P-doped Si:F:H are microcrystalline while doped Si:H remains amorphous. It is partly because higher RF power is required for Si:F:H deposition compared with that for Si:H deposition.

(2) E_o varies from 1.1 to 2.0 eV as functions of the concentration of Si-H bonds and that of dangling bonds, which are competing factors with each other.

(3) $\Delta\sigma_p$ is mainly correlated with bonded H content and dangling bond concentration (ESR spin density). Another important factor is the concentration ratio of SiH_2 type to SiH type bondings.

(4) SP-a-Si:H films involve several at.% of Ar. Annealing studies have shown that Ar atom inhabits a structural defect associated with SiH_2 configuration, which possibly makes $\Delta\sigma_p$ of SP-a-Si:H lower compared with GD-a-Si:H.

These results will be discussed in a unified manner in connection with plasma emission spectroscopy[7].

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