Properties of Boron Doped Amorphous Silicon Films Obtained with a Low Frequency Plasma

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The structural and electrical properties of boron-doped amorphous silicon films, obtained with a low frequency plasma (110 KHz), are presented in this contribution. These thin film were deposited on a substrate heated at 270°C by decomposing a mixture of silane and diborane gases. Infrared spectroscopy and current-voltage characterization, for a varying boron doping level, showed that the structural and electrical properties of these films are similar to those of a film obtained for a higher frequency plasma. Specifically, the occurrence of a well-defined peak for the silicon-hydrogen bond, as well as reasonable values for both the temperature dependent electrical conductivity and its activation energy, were observed.

Experimental

An AMP 3300 PECVD system from Applied Materials was used to deposit the amorphous films on substrates held at 270 °C. The planar reactor of this system is formed by two 65 cm-diameter and 5 cm-separation parallel electrodes. The RF power is supplied to the cathode (top electrode) through a coupling network, and its operating frequency can be varied from 8 to 111 KHz. The RF power can be varied up to 3500 W.

Our 250 nm-thick films were deposited at 0.6 Torr by decomposing a SiH_4-B_2H_6 mixture at a 750 scc/min flux. The deposition rate was from 1.3 to 5 Å/s for an RF power of 300 W operating at 110 KHz.

Films deposited on corning glass were used for transmittance measurements in the visible-IR range, 400-4000 nm. Transmittance measurements in the 400-4000 cm^{-1} wave-number range were made on the films deposited on high resistivity crystalline silicon. Electrical characterization was made for the films deposited on silicon dioxide.

Transmittance results, as a function of the boron content, $Xg=B_2H_6/(B_2H_6+SiH_4)$, are shown in Fig. 1. A peak corresponding to a B-O bond can be seen at around $1300cm^{-1}$; this peak is not present for those films with a lower boron content, Xg=0, 0.06. The stretching modes for the Si-H bond increase when Xg increases from 0 to 0.091; nevertheless, these modes decrease for a further increase of Xg.

Aluminum was deposited and patterned to build resistors and the measured current-voltage characteristics are shown in Fig. 2. A fairly ohmic behavior is clearly seen for each value of Xg.

The dark conductivity at 300 K and the activation energy were extracted from the current-voltage characteristics measured at several temperatures; the results are shown in Fig. 3 as a function of the boron content.

With these results we have demonstrated that the properties of the films deposited at low radio frequencies are comparable to those obtained for the most common higher frequency, at 13.6 MHz [1].

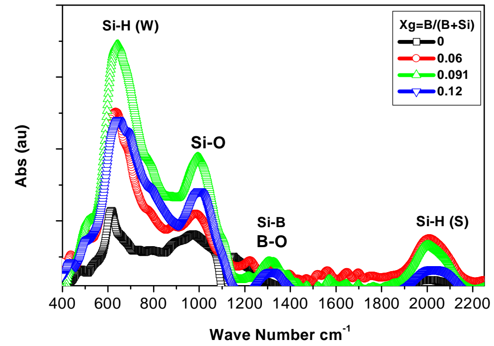

Fig.1: Infrared spectra for the amorphous silicon films with different boron content: Xg=0, 0.06, 0.091 and 0.12.

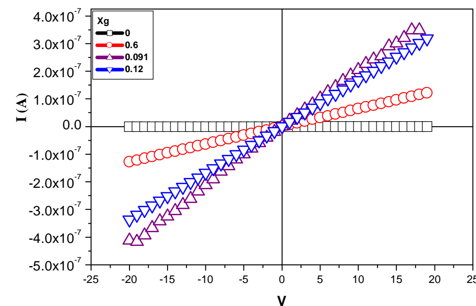

Fig. 2: Current-voltage characteristics for the a-Si-B:H films with varying boron content.

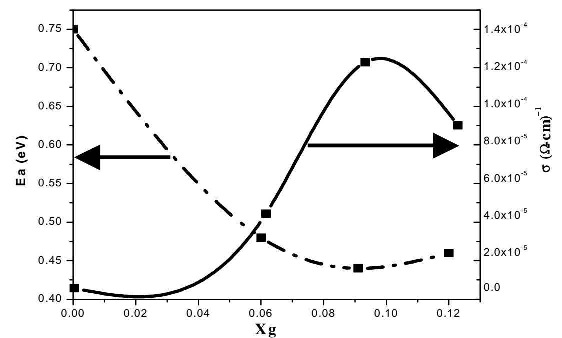

Fig.3: Activation energy (Ea) and dark conductivity (σ) of the a-Si-B:H films with a varying boron content.

References

[1] C. C. Tsai, "Characterization of Amorphous Semiconducting Silicon-Boron Alloys prepared by Plasma Decomposition", Physical Review B, Vol. 19 No. 4, pp. 2041-2055, (1979).