STUDY OF REACTIVE ION BEAM SPUTTERED HYDROGENATED AMORPHOUS SILICON GERMANIUM AND THEIR ALLOY FILMS

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DEDICATED

TO

MY RESPECTED GRAND FATHER
WHO ENCOURAGED ME TO
PROVE MY WORTH

AND

MY MOTHER AND FATHER
WHO BOOSTED MY
POWER AND PLANS

CERTIFICATE

We are satisfied that the thesis entitled **"Study of Reactive Ion Beam Sputtered Hydrogenated Amorphous Silicon, Germanium And Their Alloy Films"** presented by **Mohan Krishan Bhan** is worthy of consideration for the award of the degree of Doctor of Philosophy and is a record of the original bonafide research work carried out by him under our guidance and supervision, and that the results contained in it have not been submitted in part or full to any other university or institute for the award of any degree/diploma.

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ABSTRACT

The incorporation of hydrogen in the network of amorphous silicon and its alloys is now an accepted means for reducing the density of defect states in the midgap and making them useful optoelectronic materials. A number of deposition techniques such as glow discharge (gd), sputtering, chemical vapour deposition and reactive evaporation have been used for the deposition of these films. Reactive ion beam sputtering (RIBS) is one such technique which has a great potential for deposition of good quality amorphous films and has not been extensively explored so far. The present work is an attempt to thoroughly exploit the utility of this technique in terms of the quality of the deposited films.

The hydrogenated amorphous silicon (a-Si:H), germanium (a-Ge:H) and their alloy (a-$Si_{1-x}Ge_x$:H) films have been prepared on various substrates - Corning 7059, quartz, polished Si wafer, fluorine doped tin oxide (FTO) conducting glass and NaCl crystals, by varying deposition parameters such as beam voltage (V_B), H_2:Ar flow ratio and substrate temperature (Ts). One of the three deposition parameters has been varied in a given set of experiments, leaving the remaining two unchanged. The films have been subjected to various measurement techniques such as methods of thickness measurement, transmission electron microscopy, x-ray diffraction, Auger

electron spectroscopy, infrared spectrophotometry, spectroscopic ellipsometry and method for determination of optical constants.

The films of a-Si:H, a-Ge:H and a-$Si_{1-x}Ge_x$:H have been grown by RIBS technique at a typical deposition rate of 1.0 A°/sec. All the films deposited under varying deposition conditions, except the a-Ge:H prepared at Ts = 350°C, are amorphous in nature. The later is polycrystalline and shows a strong orientation of (111) planes parallel to the film surface. These films possess their electrical and optical properties comparable to those of reactively sputtered and glow discharge deposited films. However, the RIBS prepared films are observed to be more inhomogeneous than the gd deposited ones, due mainly to the presence of dihydride species. The a-Si:H films show mainly the presence of SiH_2, $(SiH_2)_n$ and SiO species. The a-Ge:H films have been found to contain both GeH (monohydride) and GeH_2 (dihydride) species. Both the a-$Si_{1-x}Ge_x$:H films deposited with increasing Ge content (x) and a-$Si_{28}Ge_{72}$:H films prepared at increasing H_2:Ar flow ratio show a preferential attachment of H to Si rather than to Ge. The a-$Si_{28}Ge_{72}$:H films grown at lower substrate temperature and beam voltage show an unusual enhanced hydrogen bonding to Ge rather than to Si. The bonded hydrogen content in all the three types of films increases with increasing H_2:Ar flow ratio and/or decreasing both beam voltage and/or substrate temperature. In a-$Si_{1-x}Ge_x$:H films, the hydrogen content decreases almost linearly, with increasing Ge context (x). The increasing hydrogen content makes the film density - deficit and inhomogeneous, as estimated by ellipsometric studies. The a-$Si_{1-x}Ge_x$:H films when prepared at $0.0 < x < 0.80$ are inhomogeneous and contain both compositional disorder and high volume fraction of voids than the films deposited at $x > 0.80$. Association of device quality with maximum density and monohydride type of bonding do not hold in RIBS prepared films. For a material to be of good quality the films show the necessity of compromise between hydrogen content and void-structure. The a-Si:H films of minimum conductivity ($= 2.9 \times 10^{-9} \Omega^{-1} cm^{-1}$) and maximum activation energy (0.68 eV) have been prepared. These films show an optical bandgap near 1.85 eV and contain the hydrogen content of about 17.4 at.%. The a-Ge:H films of $10^{-4} \Omega^{-1} cm^{-1}$ conductivity, 0.36 eV of activation energy, 1.04 eV of bandgap and about 11.5 at.% of hydrogen content have been prepared. The difference between optical gap of a-$Si_{1-x}Ge_x$:H films, when $x=0$ and $x=1$, is 0.95 eV. These films show a change in the ratio of conductivity by five orders. The photo conductivity / dark conductivity ratio is only of 1 order in a-Si:H films, possibly because of high density of states and large recombination centers in the midgap created by SiH_2, $(SiH_2)_n$ and SiO species. The a-Ge:H and a-$Si_{1-x}Ge_x$:H films are non photoconducting.

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