Different Analytical Techniques to Investigate Ion Implantation Effects in Semiconductor Thin Film

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ABSTRACT

The present paper has explained the details of the experimental stages like the details of ion implantation and the different analytical techniques like, X-ray diffraction, Raman scattering spectroscopy, optical absorption spectrometry and electron microscopy.

Keywords--- Nitrogen, Pressure, Magnet

I. DETAILS OF ION IMPLANTATION

By using a J-15 Sames, 150 kV accelerators, the implantations were carried out. The positive ions are accelerated from the high voltage terminal, in this accelerator. The potential of which is varied from 40 kV to 145 kV, to the target, which is kept at ground potential. Thus, ions of any energy between 40 keV to 145 KeV can be implanted. Figure 1 shows a schematic of the accelerator.

Into the ion source, a controlled gas feed of about 10-20 cc/hour is maintained. To ionize the gas, a 100 MHz, 100 W RF power supply is capacitatively coupled to the ion source bottle. Applying an extraction potential of 0 to 6 kV, the ions are extracted from the source. The beam is focused by applying a voltage of 0 to 14 kV to the focus electrode at the exit of the ion source. The ion source can give intense beams of gaseous ions, typical yield being as high as 1 mA.

By using of an oil diffusion pump, a vacuum of $10^{-6}$ mbar is maintained inside the accelerator. The accelerated ion beam is mass analyzed using H shaped magnet producing a saturation field of 1.5 Tesla in the pole gap of 30 mm. As the magnetizing coil, square section hollow copper conductor is used. A 200 ampere 100 ppm stabilized power supply is used to energize the magnet coil. The mass energy product of the magnet is 15 amu MeV. A 2 port magnet chamber is used for the ion beam transport. The 45° port is used for the analyzed beam. The straight port is used for the beam alignment and for providing additional evacuation to the magnet chamber.

For maintain the sample surface clean, as the range of the implanted ions with low incident energy. Therefore the beam line starting from the mass analyzing magnet chamber and the implantation chamber are made compatible with ultra high vacuum. A turbo molecular pump evacuates the magnet chamber to a pressure of the order of $10^{-6}$ mbar. A liquid nitrogen trap is provided in the beam path to reduce contamination of hydrocarbon vapors emanating from the oil diffusion pump used for pumping the accelerator.

Fig.1: A schematic view of the 150 kV accelerator used for the irradiation experiments
The chamber is of small volume, pumped differentially by a turbo molecular pump to maintain a pressure of \(10^{-8}\) mbar. It is provided with multiport having facilities for beam entry, beam viewing and vacuum measurements. The beam entry port has provision for fixing a demountable collimator of varying size to define the beam, falling on the target.

The sample holder is attached to the top flange of the implantation chamber by means of a mini Leybold DNPS 35 UHV manipulator, capable of linear (±10 mm) and rotary (360°) motions. The sample holder is a 25 x 25 x 40 mm copper block, fixed to the manipulator shaft. The samples are fixed on the faces of the copper block by silver paste. The copper block is electrically insulated from the manipulator shaft by a machinable ceramic disc, so that the beam current falling on the sample holder can be measured. By using a digital beam current integrator, the measurement of beam current and the integrated charge is carried out.

By knowing the integrated charge and diameter of the incident beam, the accumulated irradiation dose in terms of ions/cm² can be calculated. Emission of secondary electrons takes place, when energetic charged particle impinges on a target, which introduces errors in the dose measurement, essentially giving rise to an overestimate of the dose. This occurs because the current integrator senses the emission of the each secondary electron from the target as the arrival of a positive ion. For remove this error, a secondary electron trap is used. This essentially consists of a thin walled stainless steel cylinder suspended from the top flange around the target. It is insulated from the top flange as well as the target. This cylinder is maintained at -60 to -70 V with respect to the target, in order to repel the secondary electrons back to the target. For the beam entry and beam viewing, openings are provided in the secondary electron trap.

II. EXPERIMENTAL TECHNIQUES

2.1: X-ray diffraction

By X-ray diffraction, the structure of the films is analyzed before and after implantation of ions. By using Siemens D-500 diffractometer, room temperature X-ray powder diffractiongrams were recorded with PW 1140 X-ray generator coupled to a Cu-target X-ray tube. The diffractometer was equipped with a diffracted beam monochromator set up for accepting CuK\(\alpha_1\), CuK\(\alpha_2\) wavelengths. The contribution from K\(\alpha_2\) was eliminated by a numerical processing of the data.

2.2: Raman scattering

Raman scattering is ideally suitable for probing the implantation induced lattice damage in semiconductors, mainly because the thickness of the damaged layer and the optical skin depth are essentially of the same order. The block diagram of the Raman scattering set-up used in the present investigations is shown in figure.
2.3: Optical absorption spectrometry

To study the optical band gap of the films, the optical absorption spectrometry is a very important. Optical absorption measurements of the thin films were carried out at room temperature using the UV-VIS Chemito spectrophotometer. The absorption data were collected in the wavelength range of 500 to 1100 nm.

2.4: Transmission electron microscopy

For identification of structure, A Philips EM 400T transmission electron microscope was used in the present investigations. The accelerating voltage was 120 kV. The microscope has maximum magnification of $4 \times 10^6$ and the 'line to line' and point resolutions are 3 and 5 Å respectively. The microscope is fitted with a Link AN 10000 energy dispersive spectrometer, using which it is possible to obtain quantitative micro chemical information of the samples. The heating holder (hot stage) of the microscope is capable of going up to a maximum temperature stability of $\pm 5^\circ$C. A liquid nitrogen trap surrounding the sample for reduces the contamination on the sample during hot stage experiments. The samples were vacuum evaporated on NaCl crystals, for the TEM observations. By dissolving the NaCl crystals in water, the films were after transferred to electron microscope grid.

2.5: Scanning electron microscopy

Using scanning electron microscopy, the surface morphology and micro chemical uniformity of the films are characterized. These studies were carried out using a Philips PSEM 501 scanning electron microscope attached with an EDAX (Energy dispersive analysis for X-rays) 711B analyzer. The minimum spot size is about 70 Å and the maximum possible magnification is $2 \times 10^5$. The accelerating voltage is at 20 kV. The three modes of operation available are (i) backscattered electron imaging mode, (ii) secondary electron imaging mode and (iii) X-ray imaging mode. The secondary electron imaging mode provides information regarding the surface topography, whereas Energy dispersive analysis of X-rays (EDAX) attached to the microscope provides chemical information.

III. SUMMARY & CONCLUSION

Thus, the irradiation effects in semiconductor thin films can be investigated by different techniques such as Raman scattering spectroscopy, positron annihilation spectroscopy, optical absorption spectrometry, and X-ray diffraction. Photoconductivity studies can be also carried out on the as-deposited and irradiated films.

REFERENCES