ECRIS ON HIGH VOLTAGE PLATFORM FOR ENGINEERING AND MODIFICATION OF MATERIALS

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Abstract

An all permanent magnet electron cyclotron resonance ion source (ECRIS) along with the associated components like 10GHz UHF transmitter, vacuum pumps, vacuum gauges, vacuum pump controllers, gas handling systems with gas bottles, local command and controls systems, etc are set up on a 200kV platform for providing various ion beams having energy in the range of a few tens of keVs to a few MeVs. Understanding of charge transfer processes during collision with molecules and dissociation of molecules are discussed. The capability of ECRIS in producing multiply charged ions is being used for engineering and modification of materials. The beam currents available from the first few charge states are mainly used for these studies. The 10 GHz all-permanent-magnet ECR ion source on high voltage platform at Inter University Accelerator Centre (IUAC) has been in regular operation since 2000 for delivering various ion beams for research in materials science, atomic and molecular physics. The salient features of ECRIS based Low Energy Ion Beam Facility (LEIBF) at IUAC, operational experience of the ion source for producing some of the special beams and some of the experimental results are presented.

INTRODUCTION

To get the operational experience of ECR ion source [1] on high voltage platform and to provide the low energy ion beams from gaseous and solid species, the LEIBF [2] has been been set up at IUAC. The most important feature of the facility (LEIBF) is that the ECR ion source and all its peripheral components including electronics (power supplies, RF power amplifier, etc.) and vacuum systems are placed on a high voltage (200 kV) platform. The various parameters of the source are controlled through fiber optics communications at 200 kV isolation. The regular operation of this facility provided us experience and expertise to design and build the world's first High Temperature Super-conducting ECR Ion Source (PKDELIS) [3] for use on a high voltage (400 kV) platform. The ion source has been tuned to get optimum intensities of gaseous, semi metallic and metallic ion beams which are being used for research in emerging fields like nano science and spintronics. To engineer the optical, electrical and structural properties of materials via ion implantation and ion irradiation, first few charge states of beam and moderate beam intenisty (~ 1μA) are mainly required. Nanostructured materials play an important role in technology as they exhibit different, and quite often, unique physical properties relative to their macroscopic counter parts. These composites have drawn a lot of attentions due to their applicability for fast switching devices, single electron transistors, gas sensors and nano-electronics in one dimensional molecular wire. In comparison of other methods, ion implantation allows us to obtain well controlled nanostructures by choosing suitable ion implantation conditions and subsequent thermal annealing. In this paper, development of Ni and Si beams using ECR ion source and fabrication of their nanocomposites in different matrices are presented.

DEVELOPMENT OF NICKEL AND SILICON BEAMS

For the development of Ni beam, Metal Ions using VOlatile Compound (MIVOC) method was used. In order go get enough throughput required for high intensities of lower charge states, the pellet (6mm in diameter and 3 mm thick) of nickelocene was prepared and placed into the source inside the bias tube (a negatively polarized copper tube placed axially into the source from the injection side to reflect the electrons back into the ECR plasma to increasing electron density for ionization) for the development of the ion beams. A mesh of metal wires was used at the open end (towards the plasma) of the bias tube to avoid falling of the volatile compounds from the tube during initially pumping of the source for vacuum. With this technique, we got enough intensities (of the order of 1 μA) of the beams. The analysed charge state distribution (CSD) of Ni is shown in figure 1.

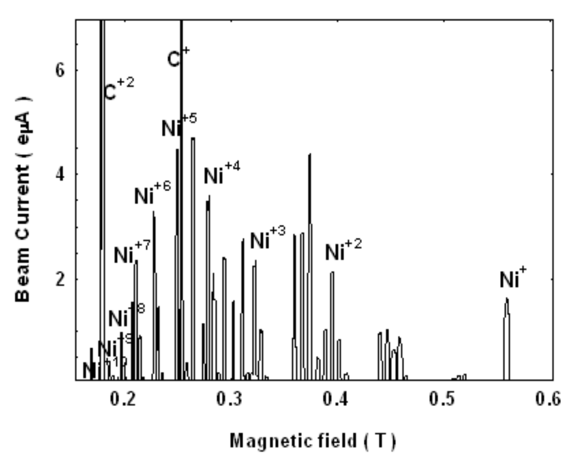


Figure 1: Charge state distribution of Ni optimized for +1 charge state

The optimized source parameters for the extraction of nickel beam are listed in table 1.

Table 1: The optimized source parameters for the extraction of Ni ion beam from the ECR plasma

Source parameters	**Values**
E/q (Total potential difference)	100 kV
Beam	$^{58}Ni^{+}$
Einzel lens voltage	7.0 kV
Source pressure	5.0 x 10^{-6} mbar
Microwave power	20 W
Bias voltage	130 V
Beam current	1.63 μA

200 keV silicon ion beam was developed successfully using tri-methylchlorosilane liquid volatile compound. For introducing vapors of liquid compound into plasma chamber, the gas feed network (mainly used for introducing gas into plasma chamber from lecture bottles) was modified. The CSD of Si optimized on +3 is shown in figure 2.

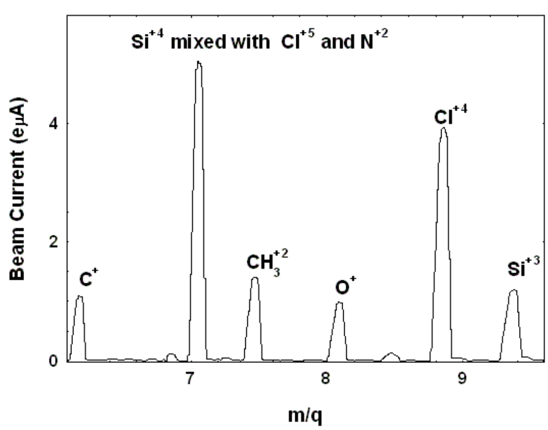


Figure 2: Charge state distribution of Ni optimized for +2 charge state

The total potential difference of 66.6 kV was set for the extraction of 200 keV Si^{+3} ion beam. The source was operated at a pressure of 4.2 x 10^{-7} mbar and input microwave power was 5 W.

EXPERIMENTAL

The implantation of 100 keV Ni ions was performed in quartz matrix at room temperature at fluences ranging from 5x10^{15} ion/cm^2 to 2x10^{17} ion/cm^2. The typical beam size on the target was ~ 5 mm. The analyzed beam current on the target was 1.63 μA. The beam was scanned on the target (scanning area = 10 mm x 10 mm). Implantation was performed in a vacuum chamber having a pressure of the order of 5 × 10^{-7} mbar. The implanted samples were post annealed at 600^{0}C and then characterized by UV-Visible Absorption Spectroscopy, Magnetic Force Microscopy (MFM), Atomic Force Microscopy (AFM), X-Ray Absorption Spectroscopy (XAS), Zero Field Cooled (ZFC) and Field Cooled (FC) magnetization measurements.

200 keV Si beam was implanted (at room temperature) in optical grade fused silica (SiO_2) at an ion fluence of 2.5 x10^{16} ion/cm^2. The samples were annealed at high temperature as well as using swift heavy ions (athermal annealing). The samples were characterized using UV-visible spectroscopy, photoluminescence and transmission electron microscopy.

RESULTS AND DISCUSSION

Charge state analyzed beams of Nickel and silicon at desired energies were produced successfully using ECRIS on high voltage platform (figures 1 and 2) for implantation. The UV-visible spectra of the annealed samples (for all ion fluences) are shown in figure 3.

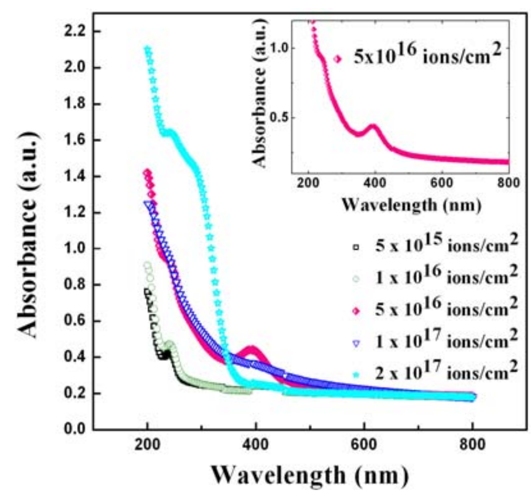


Figure 3: Optical absorption spectra of Ni implanted and annealed (at 600^{0}C) quartz samples at different fluences

The AFM and corresponding MFM images of the sample implanted at ion fluence of 5x10^{16} ion/cm^2 are shown in figure 4.

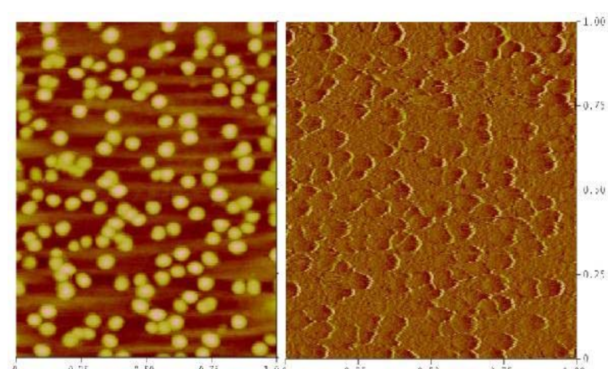


Figure 4: AFM image and corresponding MFM contrast of the quartz implanted at 5x10^{16} ions/cm^2

For the same ion fluence, field cooled and zero field cooled magnetization measurements are shown in figure 5. With these measurements, development of uniformly distributed Ni nanoparticles (4.8 nm in diameter) in quartz is accomplished for optimum ion fluence of $5x10^{16}$ ion/cm^2 [4].

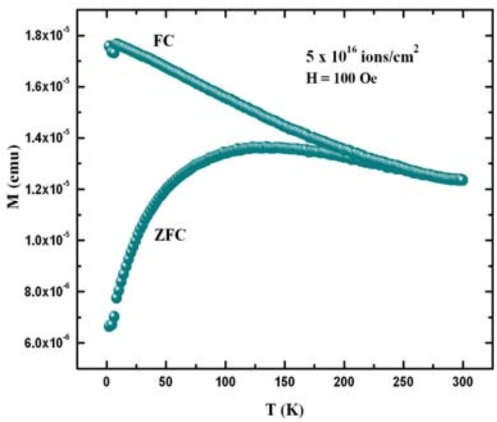
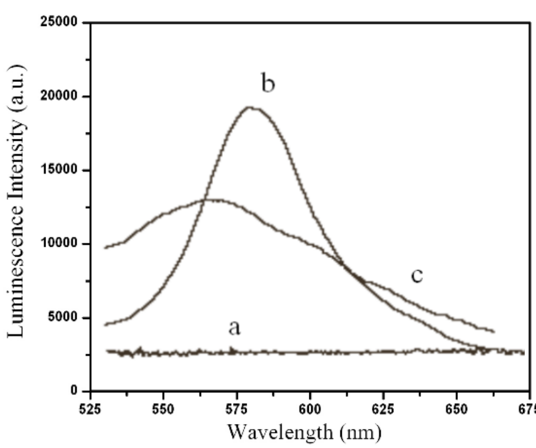


Figure 5: Variation of M vs T for zero field cooled and field cooled measurements of the sample having ion fluence of $5x10^{16}$ ions/cm2

The annealing of Si implanted fused silica leads to the formation of Si nanocrystals in the matrix which is confirmed by absorption and photoluminescence (PL) analysis. The typical PL spectra are shown in figure 6 [5].

Figure 6 : Photoluminescence spectra of (a) Si-implanted



and unannealed SiO_2 (b) Si-nanoparticles grown in SiO_2 due to thermal annealing at 1050^0C and (c) Si nanoprecipitates grown in SiO_2 due to 70 MeV Si-irradiation-induced annealing.

CONCLUSION

ECRIS based LEIBF is in regular operation and is being used by a large number of research groups from various universities for conducing experiments mainly related to materials engineering and modifications. For material engineering, beam energy in the range of a few keV to a few MeV (i.e, beam of first few charge states for ECRIS on HV platform), moderate beam intensities, multi-element beams and long term beam stability are mainly required. ECR ion sources on high voltage platform can meet these requirements and can find applications in this emerging area of science and future technology.

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