Development of an ion micro-beam facility at Institute of Physics, Bhubaneswar

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Received 7 November 2000

An ion micro-beam facility has been set up at one of the beam lines of the 3MV tandem Pelletron accelerator facility at IOP, Bhubaneswar. This is the first facility of its kind in the country having potential applications in the growing fields involving semiconductors, materials science, biology, archeology and environmental science, from both scientific and industrial point of view. So far we have achieved a spatial resolution of 4 μm. A brief description of the experimental set-up is given. Elemental maps, obtained by RBS measurements on a transmission electron microscope grid and on epitaxial gold-silicide islands grown on Si(110) surfaces, are presented.

Introduction

A high energy ion scattering facility for carrying out research in atomic physics, molecular physics and condensed matter physics, particularly materials analysis using a 3MV tandem Pelletron accelerator, (9SDH-2, NEC, USA) was set up at the Institute of Physics (IOP), Bhubaneswar, in 1992. This set up has been routinely used for carrying out materials analysis using the techniques of Rutherford back-scattering spectrometry (RBS), ion channeling, particle induced X-ray emission (PIXE), nuclear reaction analysis (NRA) etc. by a large group of scientists from various institutions within the country. In all these experiments one typically uses a beam of about 1-2 mm in diameter and hence studies are confined to samples or structures a few mm in size. However, as has been demonstrated at various places all over the world, reducing the probing ion beam size to a few micrometers to sub-micrometers, opens up the possibility of applications in a host of new systems in semiconductors (microelectronics), environmental, archeology and biological studies. Together with the ability of ion beam analysis to provide depth profiling, the ion micro-beam is used as a powerful tool to carry out materials analysis with 3D elemental imaging capability. Keeping these applications in mind, one beam line with this facility has been set up at the IOP pelletron in collaboration with State University of New York at Albany, USA.

Fig. 1 — A photograph of ion micro-beam facility at IOP, Bhubaneswar

2 Description of the system

To achieve a beam of a few microns in diameter (Fig. 1), first the accelerated ion beam is reduced to about a hundred microns in size with a micro-polished slit assembly, and then focussed to the desired spot size using a powerful magnetic quadrupole doublet (Microquad lens, QL300, Dyer Energy System, USA) with $MEq^{-2} -16$. The positions of the focussing elements were optimised using the
The target chamber is mounted on a X-Y stepper table for the precision movement of the target locations.

The necessary hardware and software have been developed for control of the beam, data acquisition and auto-pumping/venting of the target chamber, using a 486 Personal Computer (Fig. 2). Both RBS and PIXE data are collected, stored and displayed simultaneously through the PC. The same computer is also used to store the digitized image of the sample in SEM mode and to control the X-Y stage for the sample holder. In the SEM mode a picture of the target surface (typically less than about 500 μm across) is reconstructed by collecting the secondary electrons through the SEM detector, while the incident ion beam is scanned across the sample by biasing the pole pieces of the microquad lens in a programmed manner. The picture is displayed in a frame of 256 x 256 pixels, which helps in locating the regions of interest in the target. The system (Figs 3 and 4) also allows four elemental mapping of the regions of interest in the sample, after selecting particular windows from the RBS and PIXE spectra. These maps are intended to represent the amount of a given chemical element which is present at each pixel location in a 3D color code.

necessary beam optics calculations. The microquad lens, along with sample chamber have been mounted on a vibration isolated table placed at the end of the beam line. The sample chamber houses three detectors, a Si(Li) detector to analyze X-rays, a surface barrier detector to analyze backscattered ions and an aluminiized plastic scintillator for detecting secondary electrons from the target. A high resolution CCTV camera-microscope (located in the front side of the chamber) along with a light guiding system have been installed to view the target optically. The system is also equipped with a rear microscope for directly looking at the beam spot, which is highly essential in initial alignment and focusing.
3 Analytical Capabilities and Some Results

The IOP ion micro-beam facility currently has the following capabilities:

As an application of this ion microprobe we have analyzed self-assembled epitaxial gold-silicide islands, which show a shape transition and gold fractal structures\(^1\) formed on Si(111) and Si(110) surfaces, using both RBS and PIXE maps. An elemental map of such epitaxial gold silicide wire-like islands on a Si(110) surface is shown in Fig. 5.

4 Conclusions

A brief description of the development of an ion micro-beam facility at IOP, Bhubaneswar, along with some results has been presented. The facility has evolved as a characterization tool with a capability of providing multidimensional concentration profiling of elements in solids.

Acknowledgement

This work has been supported under the INDO-US collaboration project No USIF 9403-01.

References