Vacuum 124 (2016) 55–59

Contents lists available at ScienceDirect

Vacuum

journal homepage: www.elsevier.com/locate/vacuum

Development and test of 2.45 GHz microwave ion source based intense ion beam experimental facility

Narender Kumar*, G. Rodrigues, Y. Mathur, S. Ojha, R. Ahuja, D. Kanjilal

Inter University Accelerator Centre (IUAC), New Delhi 110067, India

A R T I C L E I N F O

Article history:
Received 30 July 2015
Received in revised form
20 October 2015
Accepted 15 November 2015
Available online 24 November 2015

Keywords:
Microwave ion source
Ion implantation

A B S T R A C T

An intense low energy ion beam facility has been designed, developed at Inter University Accelerator Centre (IUAC), New Delhi. This facility comprises of a 2.45 GHz microwave ion source, multi-electrode extraction system and an experimental chamber. The facility was designed to perform experiments using intense ion beams having energy in range of a few keV to a few tens of keV. The plasma chamber was designed keeping two additional ports for plasma diagnostics. In order to deliver intense ion beams on the target with low electric field, a four-electrode extraction system has been developed. This facility has been used for 10 keV N^+ & O^+ ion implantation in silicon at varying doses. The implanted samples have been characterized by using Rutherford Back Scattering (RBS), RBS Channeling (RBS-C) and Nuclear Resonance Analysis (NRA).

1. Introduction

High intensity ion beam facilities have been considered for diverse applications in various laboratories such as high current ion implanters [1], high accelerator driven sub-critical system [2,3] etc. Microwave ion sources can produce very high intensity ion beams with the help of high electron density plasma which can be obtained at higher gas pressures and at high magnetic fields (higher than electron cyclotron resonance magnetic field) [4]. In microwave ion source based ion beam facilities, characteristics of ion beam are deeply dependent on plasma density as well as extraction system. Dependence of plasma density on the ion source cavity's design and on the coupling of microwave power to the cavity are current areas of interest [5]. In low energy domain (typically from a few keV to a few tens of keV), ion beams with significantly high current density are difficult to transport from the source to the experimental chamber due to large beam emittance. This paper presents the development and testing of 2.45 GHz microwave ion source based intense ion beam facility at IUAC. The source has been designed and developed by introducing modification in earlier developed system [6,7]. The new microwave coupling and extraction system is used for developing this compact intense beam facility. This facility is planned to be used for various materials science experiments i.e. ion implantation, ion beam etching etc., as well as for plasma diagnostic experiments i.e. Langmuir probe measurements of plasma, x-ray detection etc.

The ion implantation technique is used for many applications i.e. doping in semiconductors, forming buried layers e.g. Silicon on Insulator (SOI) structures. The formation of SiO_2 by high dose ion implantation into silicon by varying dose was reported by several research groups [8,9]. Low energy ion implantation is one of the methods to produce hydrogen and oxygen free silicon nitride films [10,11]. The silicon nitride thin films have important applications for very large scale integration (VLSI) in silicon as well as III-V semiconductor technology, for a surface passivation layer, as a dielectric layer in metal-insulator-semiconductor devices. This paper also presents the experimental details of 10 keV nitrogen and oxygen ions implantation in silicon with varying fluences which were further investigated for determining the distribution of nitrogen and oxygen in silicon by RBS, RBS-C and NRA techniques.

2. 2.45 GHz microwave ion source based intense ion beam experimental facility

A 2.45 GHz microwave ion source based high intense ion beam facility has been designed and developed. The schematic of the facility is shown in Fig. 1. The ion source which is integrated to develop this facility is the upgraded version of the microwave ion source which was designed and developed at IUAC [7]. In the earlier development, microwave ion source comprised of a single walled

* Corresponding author.
E-mail address: nk.iuac@gmail.com (N. Kumar).

http://dx.doi.org/10.1016/j.vacuum.2015.11.014
0042-207X/

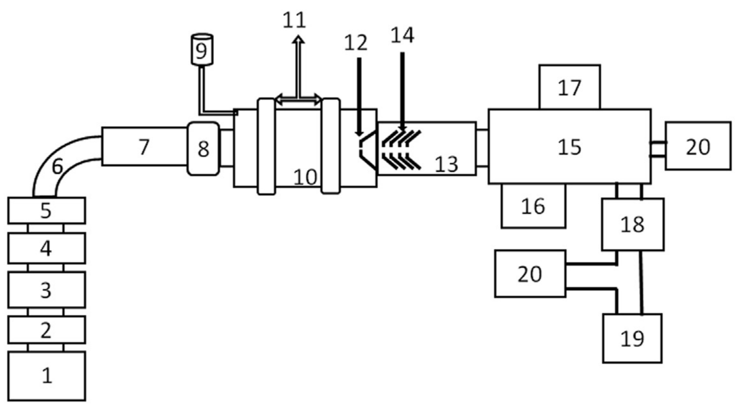

Fig. 1. Schematic of the 2.45 GHz microwave ion source based high intensity ion beam facility.

compressed air cooled plasma chamber, a 2 kW magnetron for microwave generation, standard WR340 waveguides to couple the microwaves to the plasma chamber, two NdFeB permanent magnet rings to confine the plasma whose axial field can be tuned by moving them with respect to each other, a "three-stub" tuner to minimize microwave reflection and a "three-electrode" system operated in "accel-decel" mode for extraction system [7].

In order to improve the performance of the ion source, modifications are incorporated to the ion source in terms of microwave coupling to plasma chamber by introducing 4 step ridge waveguide, a double walled water cooled plasma chamber with two diagnostic ports and a four-electrode extraction system [6]. The view of the facility with improved version of microwave ion source is shown in Fig. 2. Fig. 3 shows the cross-sectional schematic view of multi-electrode system coupled with plasma chamber and magnetic rings. The two diagnostic ports on the plasma chamber body can be utilized for performing plasma diagnostics using Langmuir probe and x-ray measurements. The simulation on the design of the extraction system using IGUN for a total source current of 0.5 mA, including effect of axial magnetic field is shown in Fig. 4 [12]. In this design, a number of electrodes were chosen and optimised with as minimum length as possible to extract the beam without any loss in the intensity. Special care was taken in the design of all the electrodes with proper field shaping and to minimise sparking. The beam is extracted from the microwave ion source and transported to the ladder of experimental chamber where various samples can be mounted for various experiments i.e. ion implantation, etching, surface patterning etc. This facility is capable of performing implantation experiments on surface having area varying from a few mm^2 to a few tens of mm^2 and plasma diagnostic experiments. The

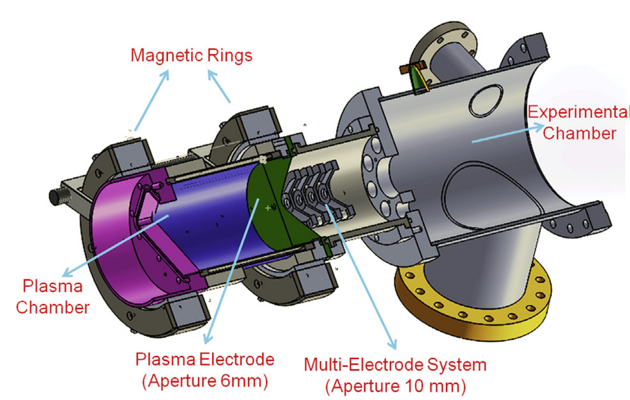

Fig. 3. The cross-sectional schematic view of the multi-electrode system coupled with plasma chamber.

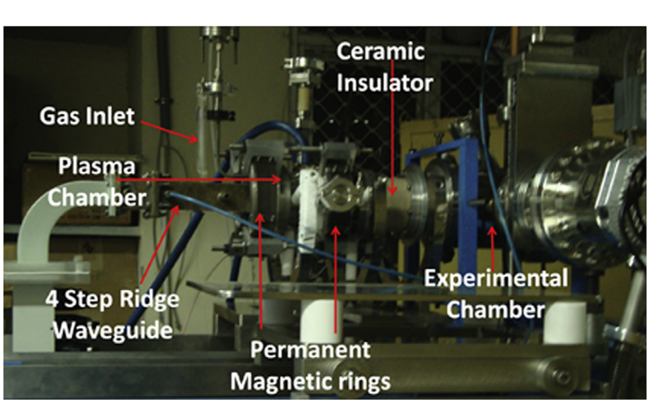

Fig. 2. View of 2.45 GHz microwave ion source based high intensity ion beam facility.