Micro-glass capillary focusing of plasma ion beams and creation of microstructures

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Intense microwave plasmas have been used as an ion source for applications in microstructuring. Microstructures having aspect ratio in the range 100 - 1000 have been created using 26 keV Ar, Kr and Ne ion beams with beam size ~ 1.5 µm. To prevent loss of beam current and further focus the beam, micro-glass capillary will be employed after the plasma electrode, from where the beams are extracted. Ion beam current and beam spot size, will be measured as a function of extraction voltage for different capillary outlet diameters. The capillary which provides the smallest beam spot size, will be implemented in the system. Further, different structures will be created using Ar, Kr, and Ne ion beams.

1. Introduction

Ion beam is a necessary tool in science and technology and can be used in many applications such as milling, patterning, high resolution imaging and implantation. Many emerging applications require rapid processing and non-toxic inert gaseous ion beams. In order to serve above applications, there are efforts to develop gaseous plasmas ion beam tools which can be non-toxic and therefore suitable for biomaterials and semiconductors, and provide an option for rapid processing without metallic contamination due to higher currents. To address these requirements, a microwave plasma based multi-element ion beam system has been developed in our laboratory which can deliver ions of a variety of gaseous elements (Ar, Kr, Ne) of beam size ~ 1.5 µm, beam currents in the range ~ 1.5 nA – 10 µA and beam energy up to 30 keV [1].

2. Experimental Setup

The experimental setup consists of three major parts namely, plasma column, beam column and experimental chamber.

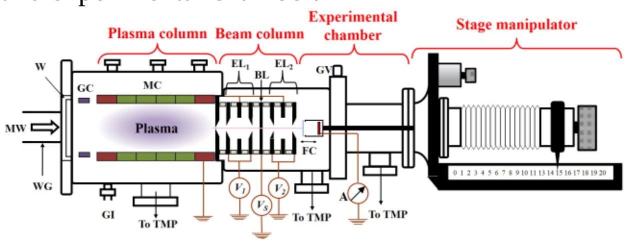

FIG. 1. MW: microwaves, WG: wave guide, W: quartz window, GC: guiding cylinder, GI: gas inlet, MC: multicusp, TMP: turbo molecular pump, EL: Einzel Lens system, BL: beam limiter, FC: Faraday cup, GV: gate valve, V_1, V_S, V_2: high voltages, A: ammeter

In the plasma column, a high density plasma (~10^{11} cm^{-3}) is created with the help of 2.45 GHz microwave and confined in an octupole multicusp. Beam column consists of plasma electrode (PLE), Einzel lens (EL) and beam limiter (BL) which are used to extract and focus the ion beams. EL_1, EL_2 and BL electrodes are biased to negative high voltages V_1 (~ –2 kV), V_2 (= 18–30 kV) and V_S (= 2/3 V_2) respectively to provide the desired acceleration and adequate focusing to the beam. A copper (Cu) thin film (50 nm) biased to V_2 is mounted on the XYZθ stage manipulator for moving the sample in the desired direction with required writing speed. For measuring the ion beam current, a Faraday cup is used after EL_2.

3. Results: Different microstructures (array of spots, lines and a group of letters) have been created on 50 nm Cu thin film using 18 – 30 keV Ar, Kr and Ne ion beams. For Ar ion beams, sputtering yield and milling rate are calculated at normal incident and found to be ~ 8.8 atoms/ion and ~ 0.65 µm^{3}s^{-1}nA^{-1} respectively which are higher than Ga^+ focused ion beams (30 keV/1pA) for which calculated values are ~ 1.27 atoms/ion and ~ 0.09 µm^{3}s^{-1}nA^{-1}.

Next for further reduction of beam size, micro-glass capillary will be employed after PLE through which ion beam will pass, which will provide self-focusing of the beam without reducing the beam current [2,3]. For this first ion beam current will be measured by varying the extraction voltage (V_1) using only capillary after PLE and then spot size of beam coming out from capillary will be measured. Microstructures will be created employing a capillary in the present ion beam system.

4. References

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