RESULTS FROM MICROWAVE AND GLOW DISCHARGE PLASMA IMMERSION ION IMPLANTATION EXPERIMENTS

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1. Introduction

Plasma Immersion Ion Implantation (PIII) is a novel technique developed recently for the improvement of the surface of materials. It is a non-line-of-sight ion implantation method, which allows three-dimensional treatment of manufactured workpieces, at high speed and low cost [1]. In PIII, the ions of interest are extracted directly from a plasma in which the samples to be treated are immersed, hence without the need of extraction grids. This is achieved by applying a negative high voltage pulse (10 to 50 kV, 10 to 1000 Hz, typically), with tens of microseconds to the sheath formed between the plasma and the sample piece.

We have tested both microwave plasma (higher density case, $n_e \leq 7x10^{10}$ cm^{-3}) and a glow discharge plasma (medium density case, $n_e \leq 1x10^{10}$ cm^{-3}), for PIII nitrogen ion implantation in Al, Stainless Steel and Si wafer samples.

2. PIII device at INPE

The schematic drawing of the PIII of LAP/INPE is shown in Fig.1. In one of the PIII experiments, the nitrogen plasma is produced by a 500W microwave source, at 2.45GHz [2]. A short negative high voltage pulse (10 to 20 kV, 5 μs duration) is applied repetitively (5 to 20 Hz), to the samples immersed in the plasma. The high voltage pulse is produced by a line type pulser consisting of a pulse-forming network (PFN) and an air core transformer [3]. Due to a severe window heating by the produced plasma, the microwave operation has to be intermittent in our present set-up.

In another PIII experiment, using the same vacuum chamber and pulse power system, we operate a glow discharge of about 200W to obtain a nitrogen dc plasma which can be

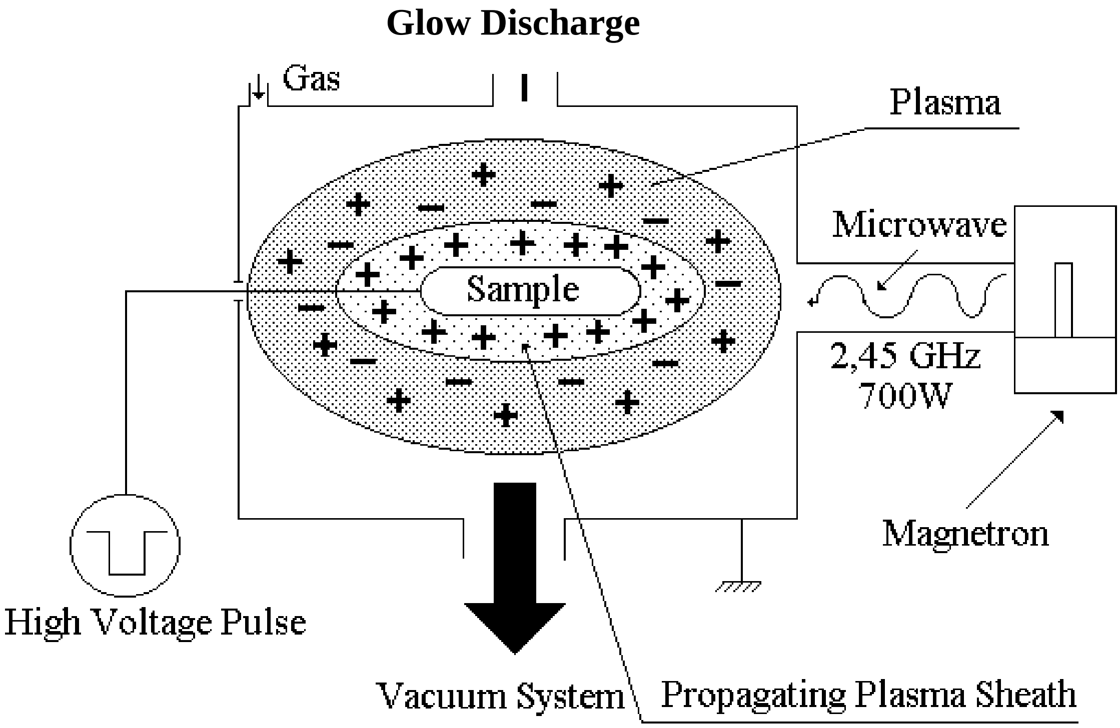

Fig. 1. Schematic drawing of the microwave and glow discharge PIII

sustained for more than 50 h continuously. This second possibility is also shown schematically in Fig.1.

3. Experimental Results

Nitrogen plasmas produced with microwave and glow discharge sources were characterized using a Langmuir probe. In Fig 2(a) we show the variation of the microwave nitrogen plasma density and temperature with the gas pressure, near the center of the vacuum chamber where the sample holder is located. The optimum pressure of operation in the implantation mode is around $5x10^{-3}$ mbar under which maximum densities of $6x10^{10}$ cm^{-3} has been attained. Over

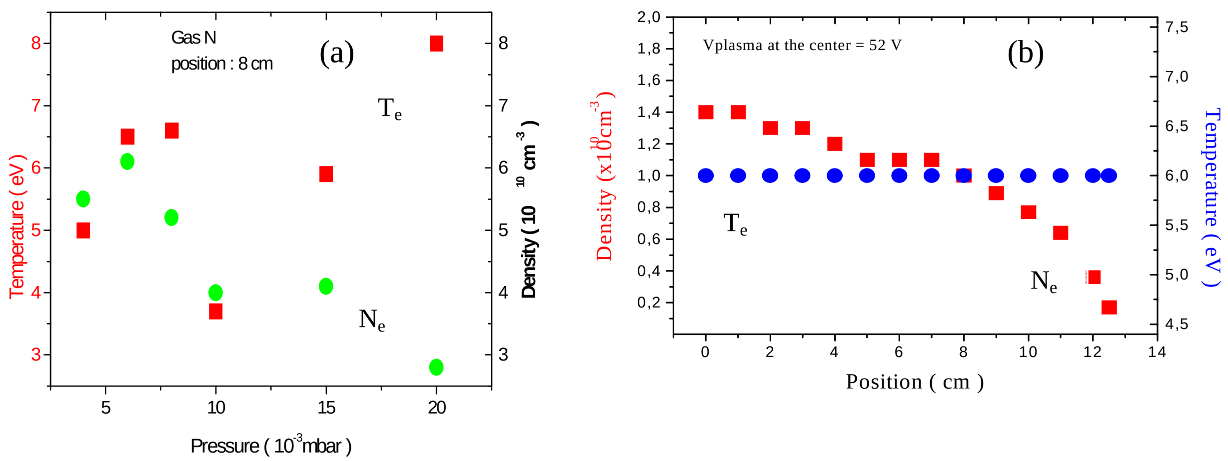

Fig. 2. (a) Plasma parameters in a μwave discharge; (b) Plasma parameters in a dc glow discharge.

that range, when the samples are pulsed, arcs develop which is detrimental to the surface treatment of the samples. Below that range the plasma becomes unstable or turn-off.

The dc glow discharge plasma is operated best around $8x10^{-4}$ mbar, and provides plasmas with densities and temperatures shown in Fig. 2(b). Under the conditions stated in the figure we attained central densities of about $1.4x10^{10}$ cm^{-3}.

It should be noticed that the measurements of these plasma parameters were carried out without the presence of the PIII high voltage pulses.

Typical waveforms for applied voltage to the samples and for collected current obtained in our PIII device with the microwave plasma load are shown in Fig. 3(a). Total currents of about 9A at 13 kV peak voltage have been obtained in the high density microwave plasma case. The corresponding waveforms for the glow discharge plasma PIII are depicted in Fig. 3(b). In spite of smaller current achieved in this case (1.3 A for 10 kV), the great stability of PIII using glow discharge plasma is a very attractive feature for long time irradiation of samples.

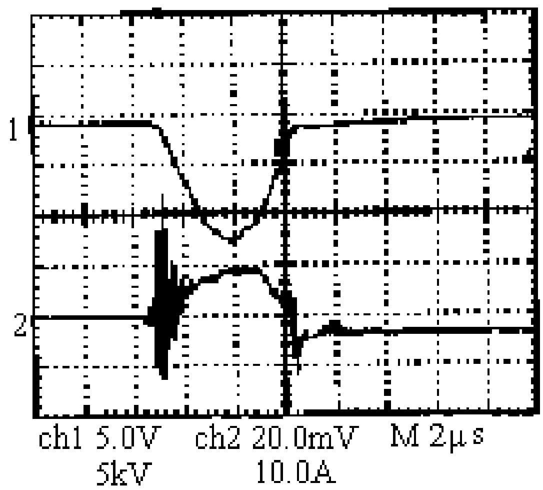

Fig. 3(a) Voltage and current waveforms in µwave PIII

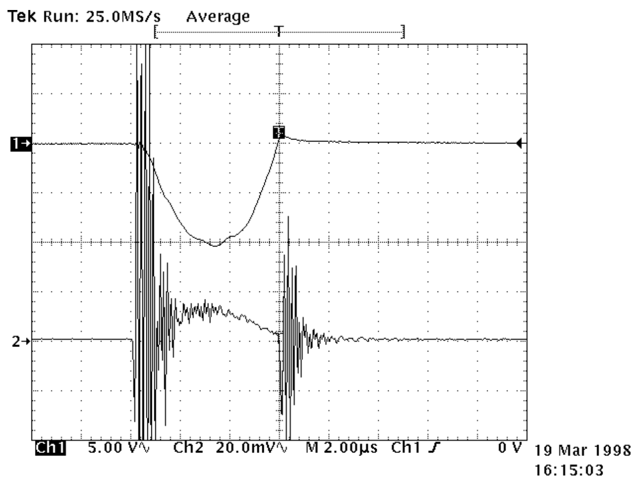

Fig. 3(b) Voltage and current waveforms in a dc a glow discharge PIII

The surfaces of the samples irradiated by both methods of PIII have been analyzed by techniques of X-ray diffraction, high resolution and grazing incidence X-ray diffraction, XPS (X-ray Photoelectron Spectroscopy), microhardness, EDX (Electron Dispersion X-ray), etc.

A strong evidence of good nitrogen implantation into a crystalline structure of a Si wafer can be seen through the high resolution X-ray diffraction data shown in Fig. 4. Strong deformation of the rocking curve corresponding to the (004) orientation can be seen in the

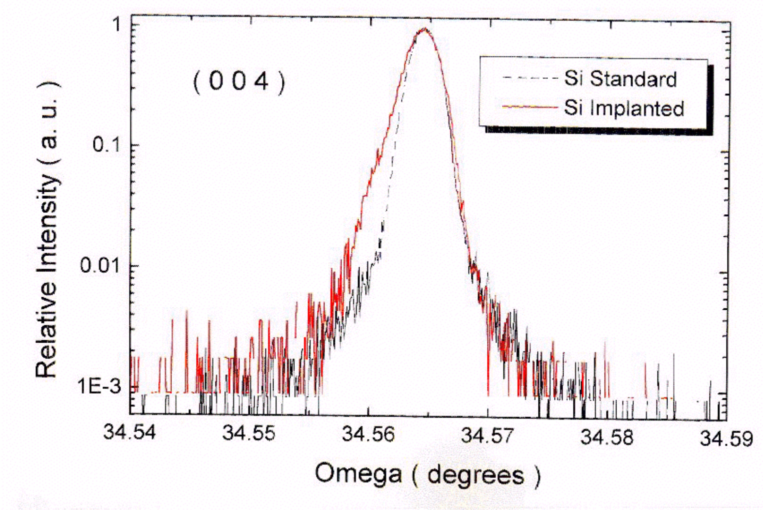

Fig. 4. High resolution X-ray rocking curves for implanted and non-implanted Si samples

implanted wafer compared to a non-implanted one. Various other surface analysis data corroborate the successful implantation of ions in the targets by the PIII process in our device.

4. Conclusions

Plasma Immersion Ion Implantation is being investigated in our laboratory. High dose implantations which are required for tribological improvements in metal surfaces (> 10^{17} cm^{-2} doses) has not yet been achieved in our first PIII device but there are strong indications from various surface characterization analysis that nitrogen implantations are occurring in our glow discharge PIII experiments. Si wafers are working as high sensibility detectors, especially for low dose range and allow non-destructive analysis of the implanted surface through high resolution X-ray technique. Using these sensors and measured plasma parameters as well as high voltage characteristics, we are optimizing the plasma sources/PIII process in our laboratory.

References

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