The surface production of negative ions from nitrogen doped diamond using hydrogen and deuterium plasmas

Gregory Smith[1*], J Ellis[1], R Moussaoui[2], A Gicquel[3], J Achard[3], T Gans[1], J Dedrick[1] and G Cartry [2]

1 York Plasma Institute, Department of Physics, University of York, Heslington, YO10 5DD - UK
2 Physique des Interactions Ioniques et Moléculaires, service 241, Centre de St Jérôme, 13397 Marseille Cedex 20, Aix Marseille University / CNRS
3 LSPM, CNRS-UPR 3407 Université Paris 13, Avenue J. B. Clément, F-93430 Villetaneuse Labex

* gjs507@york.ac.uk

Introduction

- Sources of negative ions are of significant interest for numerous applications including particle acceleration [1], neutron generation [2], mass spectrometry [3], spacecraft propulsion [4], microprocessor manufacturing, and in partiular the production of neutral beams necessary for the heating of magnetic confinement fusion plasmas. [5, 6]

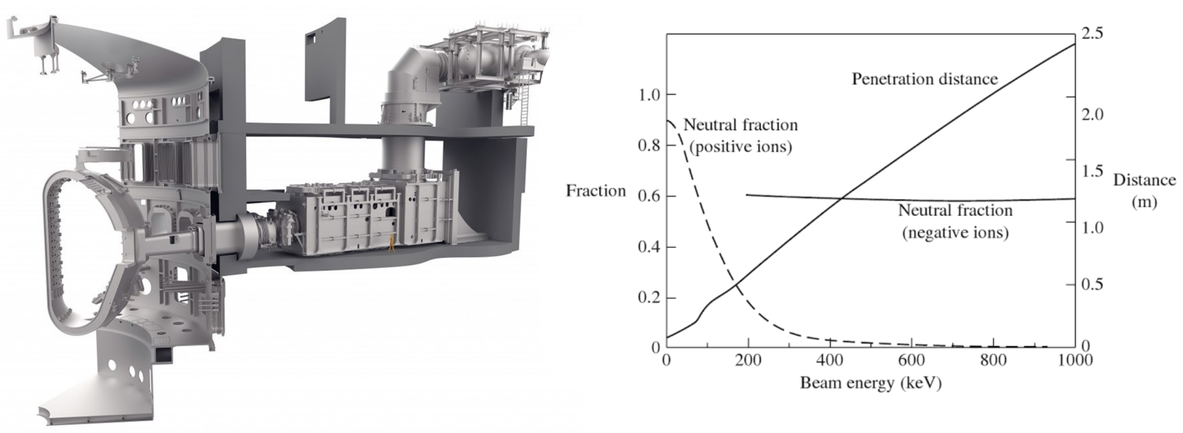

Figure 1. (a) CAD of neutral beam injection device for ITER attached to the fusion reaction chamber (b) Graph of neutralisation efficiency and penertration of ions at increasing energies into the fusion reaction chamber. ITER's neutral beam injection energy is 1MeV as a compromise between shine through, current drive and heating requriements

- Current methods to create negative ions in these applications utilise caesium deposited onto the inside of the ion source, but this introduces complex engineering challenges.

- Diamond, or dielectric materials similar to diamond, are a prospective alternative to caesium and so understanding the production of negative ions from dielectric surfaces is an important research objective [7].

- In this study, micro crystalline diamond coated surfaces are exposed to a 2 Pa, 26 W deuterium plasma and negatively biased in order to bombard them with deuterium ions. This process creates negative ions at the diamond surface that are measured using a mass spectrometer.

Experimental Setup

- The experimental reactor is a 13.56 MHz helicon plasma operating at 26 W and with 2 Pa deuterium [8].

- The reactor consists of a upper plasma source chamber and lower diffusion chamber, with a sample holding arm and transfer rod for manipulating samples in the diffusion chamber.

- An EQP mass spectrometer is positioned above a sample holder, 37 mm from the surfaces of samples held in the sample holder.

- Samples are negatively biased using the sample holder. Positive ions from the plasma are accelerated onto the sample. The interaction of the bombarding ions creates negative ions through a number of different processes. The negative ions are accelerated away from the surface, across the plasma, and detected by the mass spectrometer

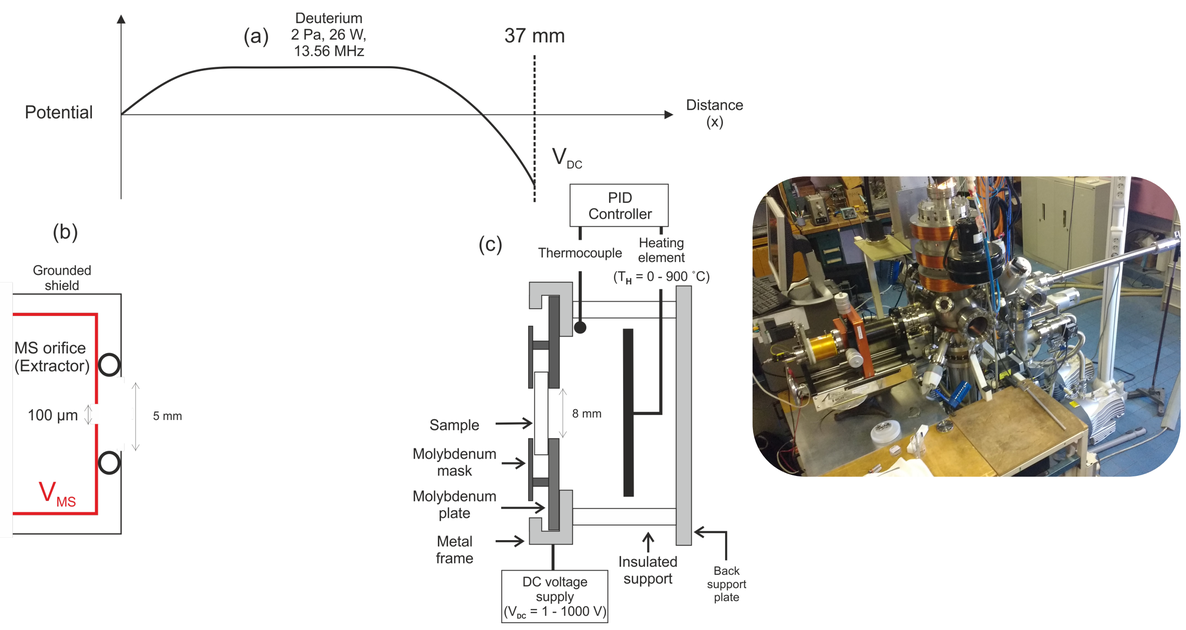

Figure 2. (Left) Schematic of the experimental setup used to measure the negative ions. (a) The plasma potential across the system from the mass spectrometer orifice to the sample surface. The plasma parameters are also shown. (b) The mass spectrometer orifice arrangement. The internal orifice can be biased to a voltage (V_{MS}) to control ion energies entering the mass spectrometer (c) Schematic of the sample holder including the heating system and voltage supply. (Right) Photograph of the experiemental setup. The samples are held within the lower sphereical diffusion chamber seen in the centre of the photograph.

Results

- Micro crystalline diamond samples with between 0 ppm and 200 ppm of nitrogen doping are exposed to deuterium plasma at temeratures between 30 °C and 750 °C.

- The point at which the nitrogen doped diamond becomes conductive is visible as a transition from the background measurement of negative ion counts, to multiple 1000's of counts.

- For nitrogen doped diamond, the measured counts are at a maximum at temperatures near to the transition temperature, and decreases as temperature increases above this.

- For all levels of doping, the addition of nitrogen increases the number of counts over that of un doped diamond. But the level of doping does not seem to correlate to the number of counts.

- The maximum number of counts is seen coming from 50 ppm nitrogen doped diamond.

- The experimental setup is slightly different compared to previous work which influences the number of negative ions counted. Comparing between old samples and new ones shows the relative change and therefore how the nitrogen doping influences the negative ion counts.

- The comparison of boron doped diamond (MCDBDD) to un doped micro crystaline diamond (MCD) in both studies are similar. The increase from nitrogen doping is notable.

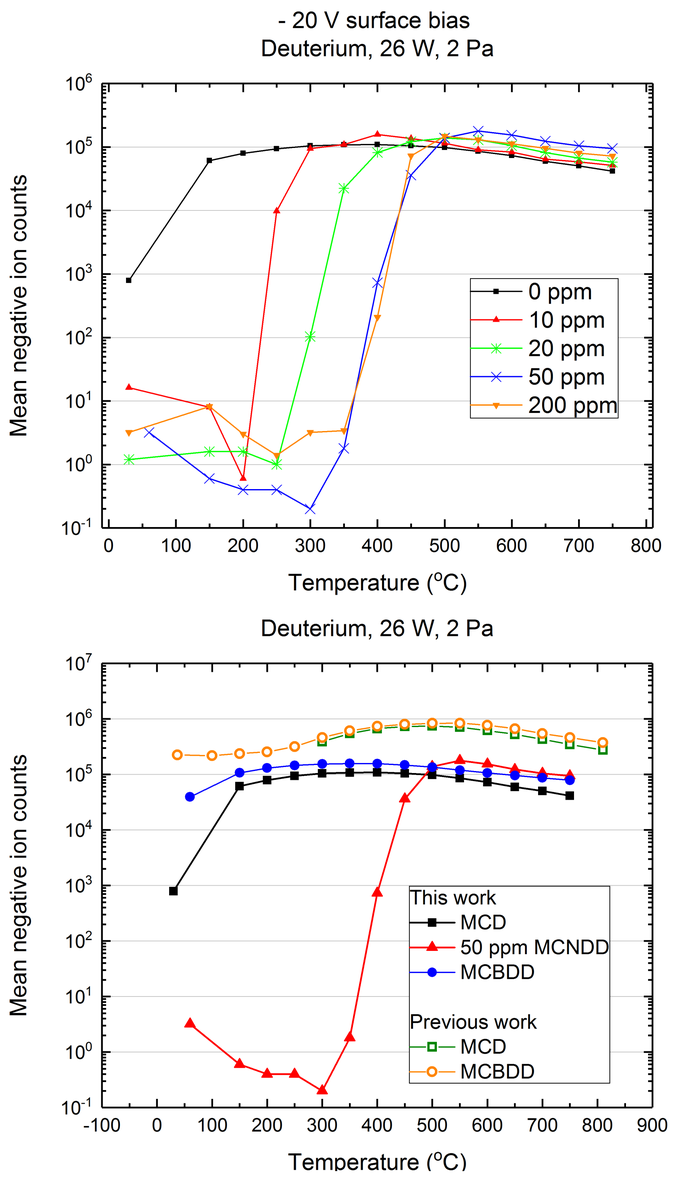

Figure 3. (Top) Mean negative ion counts from un-doped diamond and samples of nitrogen doped diamond between 10 and 200 ppm at increasing temperature from 30 °C to 750 °C. (Bottom) Previous results plotted with a comparison to previous study into boron doped diamond [9]

Conclusion

Micro crystalline diamond is a material of interest to increase surface production of negative ions using plasmas. A study of the influence of doping diamond with nitrogen has been carried out and compared to previous studies. The results show that nitrogen influences the behviour of the diamond, whilst increasing the negative ion counts over that of un doped diamond [10].

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