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Magnetically constricted anode fireball for making super-hydrophobic nanodot surfaces and role of plasma flux

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Electron sheath and fireball has been the topic of recent investigations. Electron sheath occurs when the current drawn by the electrode or wall is larger than that which can be provided by the random electron motion. When the sheath potential reaches the necessary potential for excitation of neutral atoms (few eV below ionization potential for Argon), the sheath glows. If this sheath potential reaches above the ionization potential, the sheath breaks down in its own plasma with plasma potential higher than the ambient potential, hence establishing a double layer. This double layer is visually observed as a glow with a sharp boundary, also known as the fireball [1-3]. As mentioned earlier, the electron sheath can only be formed when the current requirement on any electrode exceeds the local electron saturation current. Since the electrons are highly mobile species in plasma, this becomes difficult to satisfy, except for very small area electrodes. In the current work using permanent magnets cusp arrangement, effective electrode collection area is reduced by restricting the electron movement to obtain the electron sheath and larger fireball (Fig. a & b). The discharge produced in the device is mainly divided into two types. The bright droplet shaped anode glow and the bulk plasma, which fills the rest of the vacuum chamber. The anode fireball and the bulk plasma are separated by a double layer visible as a sharp boundary of the anode fireball (Fig. d). The electrons from the bulk region are accelerated to ionization potential by the double layer. These accelerated electrons produce the glow and plasma inside the droplet shaped fireball. In the bulk plasma, the electron temperature is found to be 3 to 4 eV and the typical plasma density is in the range of 1×10^{9} cm^{-3}. The plasma density in the fireball is about an order of magnitude higher than that of the bulk plasma. The necessity of the fireball arises from the excessive current requirement on the electrode, ionization in the fireball provides the required current. Hence the volume of the fireball and the surface area depends upon the bulk plasma density and the ionization inside the fireball. Since the electrons produced inside the fireball cannot cross the double layer potential, they can be lost only to the anode. Changing the background gas pressure changes both the bulk plasma density and the ionization inside the fireball. Thus the length and volume of the fireball reduces with an increasing pressure (Fig. e), however, the width at the anode increases due to collisional diffusion [1-3].

Rapid developments in metal/semiconductor nanofabrication technologies have seen an exciting and emerging trend towards the development of the periodic nanodot structures (Fig. c) for Photonics and Magnetism applications [4-5]. Normally commercial expensive ion sources or lithographic devices are used for making such nanopatterns. Both the methods cannot produce nanodots over large area due to limitations of beam dimension. In the current work, we have demonstrated a highly economical technique using plasma fireball as explained earlier for making nanodot patterning over large area. This device is not only capable for making nanodot pattern over large area, but also capable to make nanoparticles in another mode. The discharge properties of the device and parameters for making nanodot patterns will be presented [4]. Since fireball has an order higher plasma density, the ion flux plays a very crucial role in pattern formation. Higher plasma flux produces smaller nanodots patterns due to redeposition of the eroded material from the surfaces; a theoretical understanding for the same will also be presented using Damped-Kuramoto–Sivashinsky (DKS) equation [4,6]. Nanodots pattern produced on GaSb surface found to have super-hydrophobic behavior with a water contact angle of 150^{o} and highly light absorbing in nature [3]. In this way the produced fireball in our device can be used to produce super-hydrophobic nanodots surfaces for various applications like sensing application and photovoltaic [5-6].

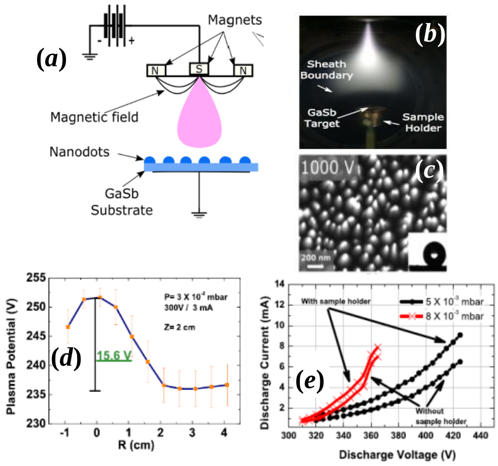

Fig. : (a) Schematic of fireball, (b) Actual fireball in front of sample holder. (c) Super hydrophobicity on GaSb dot pattern. (d) Jump in plasma potential near fireball. (e) Discharge I-V at various pressures.

References

[1] S. Chauhan, M. Ranjan, M. Bandyopadhyay, S.Mukherjee, *Phys.Plasmas* **23**, 013502 (**2016**).

[2] S.Chauhan, M.Ranjan, M. Bandyopadhyay, S. Mukherjee, *Phys of Plasmas* **23**, 123524 (**2016**).

[3] S. Chauhan, T. Barman, M. Ranjan, S. Mukherjee, *Review of Scientific Instrument*, **88** (**2017**) 063507

[4] M. Ranjan, P. Joshi, M. Bhatnagar, S.Mukherjee, *Nanotechnology* 28 (**2017**) 394002

[5] Sooraj.K.P, M. Ranjan, R. Rao, S. Mukherjee, *Applied Surface Science* 31 (**2018**) 576.

[6] M. Arya, M. Bhatnagar, M. Ranjan, S. Mukherjee *Journal of Physics-D: Applied Physics* 50 (**2017**) 455603.