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Deposition of nanostructures by chemical vapour deposition enhanced with an atmospheric pressure remote Ar-O_2 plasma.

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Plasma assisted nanofabrication is one of rapidly emerging approaches for the production of numerous nanostructured materials, nanostructures and elements of nanodevices. Recently, atmospheric microplasma assisted nanofabrication has shown outstanding capability of promoting self-organization [1]. Self-organization can be driven under certain conditions by applying external energy drivers, like electric fields. For instance, in oxidation processes where charged species play an important role, the presence of electromagnetic fields orientate the growth. Microwave excited microplasmas can create strong electromagnetic fields at the processing surface and the field strength patterns contribute to the self-assembly of the surface features.

A recent work showed that microwave resonant cavities are suitable to reach elevated gas temperature [2]. We developed a micromave remote microplasma. An atmospheric microwave plasma is created in a fused silica tube (27 mm inner diameter) placed in a 2.45 GHz resonant cavity. The power supply is a GMP 03 KE SAIREM device and it delivers 70 W under the present conditions. A rotating fan is used to center the plasma on the axis of the tube. Matching is ensured by two Teflon ® rungs mounted on screws located on two opposite sides of the cavity. Flow rates of gases are controlled by two mass flow controllers and the total flow rate is varied in the study from 0.5 to 5 standard liters per minute. A partial pressure of oxygen in argon is kept constant to 20 vol.%. Extracting a jet from such a source is possible by drilling a tiny hole on a brass plate that is screwed on one side of the resonant cavity specially designed for this. The size of the hole got by mechanical drilling is set to 400 or 600 µm. The flow escapes through this hole and forms the flame outside. This flame is a clearly a post-discharge and contains only neutral species as we could check it by several means (no emission of ionized species, no influence of a biased-plate on the size of the plasma, etc.)

A laminar flow can be obtained by controlling the total flow rate of the gas mixture (Fig. 1). Under these conditions, the post-discharge is roughly a beam of atoms that can be handled like a pen to “write” structures on surfaces.

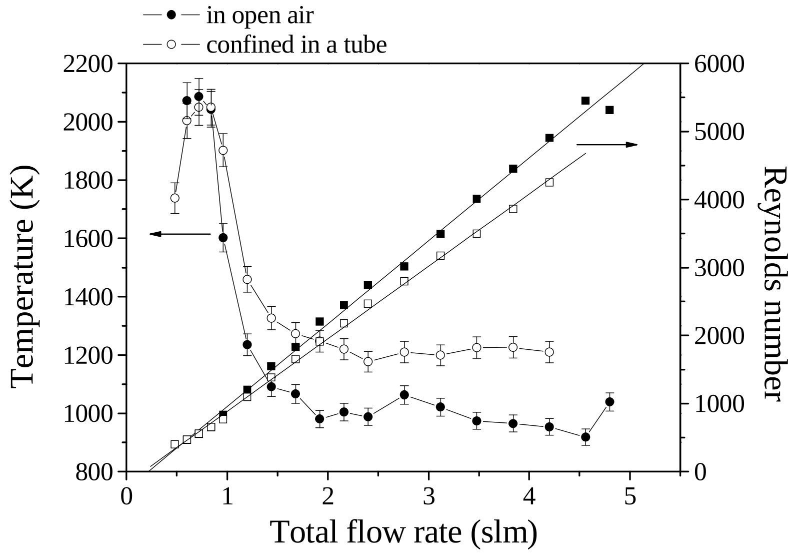

Fig. 1: Mean temperature of the remote plasma and evolution of the Reynolds number as a function of the total flow rate for two conditions: confined in a tube or in open air. Ar–20vol.%O_2 plasma through a 600 μm hole. Power: 70 W.

We report some results showing the synthesis of nanostructures on 316 L stainless steel by chemical vapor deposition out of hexamethyldisiloxane (HMDSO) with an atmospheric pressure remote Ar-O_2 plasma operating at high temperature (~1700 K). SIMS analyses and X-ray diffraction show that no carbon is present in the coating and that it is amorphous.

Surface nanostructuration in our case is mainly due to the thermal gradients that appear as a function of time when the deposition of a thermal barrier, the silica layer, occurs on a thermal conductor, the metallic substrate. These gradients have various consequences.

For thick coatings (> 1 µm), droplet-shaped coatings with a gaussian distribution in thickness over their width are deposited. The coatings are submitted to high compressive stress. When it is relaxed, “nest-like structures” made of nano-ribbons are synthesised. When the coating becomes thinner (~ 1µm), and for relatively high contents in HMDSO, SiOx walls forming hexagonal cells are obtained on a SiOx sub-layer. When it is thin enough (<500 nm), the dewetting of the film being deposited is found to be partly responsible for the synthesis of nanodots that are self-organised.

Reference

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[2] T. Belmonte, R.P. Cardoso, G. Henrion and F. Kosior, *J. Phys. D: Appl. Phys.* **40** (2007) 1394