Plasma reshaping carbon: The role of plasma species in surface interactions with carbon

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The selection of different discharge parameters e.g. gas composition, flow rates, etc., lead to different plasma parameters. These are outlined by various densities of plasma species, which have terminative effects on reshaping of surfaces including carbon-like materials. The game of ions and neutrals can, depending on the plasma used gas, create different structures through bond etching, bond recombination or bond termination. All these examples are presented in this presentation.

The carbon is very popular material due to its wide use in broad range of applications. In order to improve its properties either for sensing applications, microelectronic, lab-on-a-chip, etc., we need to reshape the surfaces. Plasma is becoming more and more important medium for designing such properties either by etching carbon material or deposition of plasma species to the surface. Beside this, we can have intermediate steps, where we can design carbon-like material, normally particles, inside plasmas by tailoring their surface bonds. This can be done by bond termination with functional groups containing hydrogen or by adding atoms like boron. The important role in this process is off course attributed to different plasma species inside the plasma. These processes will be outlined in the presentation.

Generally, we can claim that oxygen containing plasmas oxidise the surfaces, whereas oxygen atoms and ions change properties and etch the carbon surfaces. If we take an example of highly oriented surface of graphite, then we can see that neutral oxygen atoms slowly etch the carbon atoms from surfaces. If the surface temperature changes, the etching rate changes as well as surface reactions. Adding oxygen ions into the mixture causes reactive etching or even ion sputtering, depending on ion energy. However, the most interesting surface effects occur when ions have just proper energies ranging from 10 to 100 eV. Impacting ions change hybridization of carbon bonds from sp2 to sp3. This on the other side influences the etching mechanisms, and localized spots are not etched as effectively as before. In such cases we can create graphite cones at the surface.

In the second case, we have deposition of carbon material to the surface from hydrocarbon gas (metan, etc.), normally with addition of hydrogen gas. In these cases, we deposit thin graphene layers to the surface, where the homogeneous surface recombination at the substrate material plays one of the most important roles. Not only that this enables unified deposition but also defines their structural properties. Similarly, proper plasma species can create the H-bond terminations and reshape the carbon. Recently we observed that this holds not only for hydrogen bond termination, but for other atoms as well. We observed reshaping of carbon particles by boron atoms inside the plasma. The boron gets integrated on the nanoparticles surfaces and terminates the bonds enabling very exotic shapes of nanoparticles.

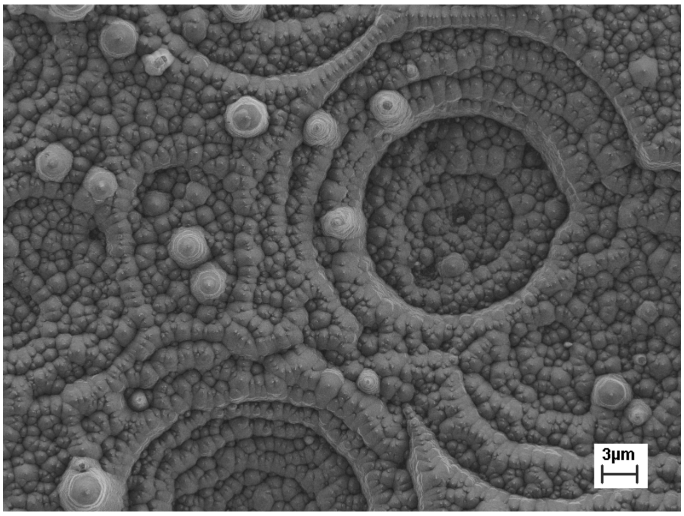

Fig. 1: SEM image of HOPG graphite surface after interaction with oxygen plasma species in weakly ionised highly dissociated plasma.

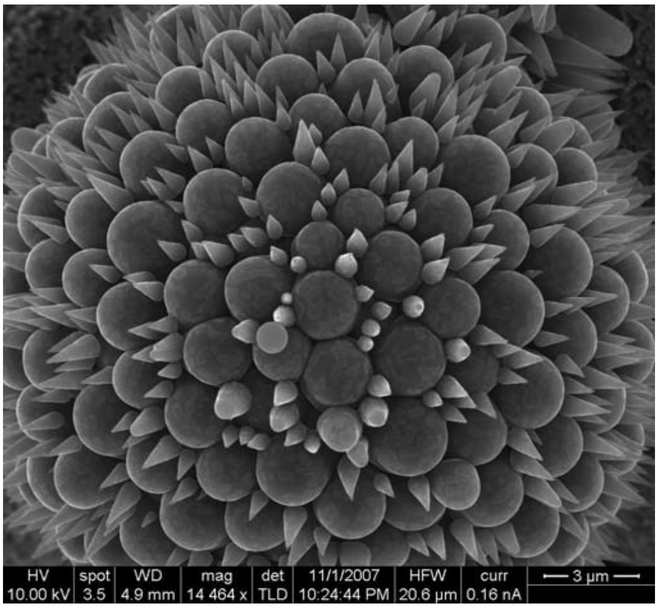

Fig. 2: SEM image of a reshaped carbon structures with the CH4 plasma and Boron atoms.