Carbon-Carbon Nanocomposite thin films based on fullerene-like powder in hydrocarbon matrix formed in ECR plasma

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Fabrication of nanocomposite thin film generally takes several steps involving different processes [1]: synthesis of nanostructure, then mixing with the matrix and finally thin film deposition. PE-CVD processes enable to simultaneously combine powder formation in the plasma volume and the deposition of a matrix material on surfaces, thus emerging as a new and interesting route to elaborate nanocomposite thin films in one single process.

Carbon-Carbon nanocomposite thin films find their application in different fields such as hard coating for mechanical applications [2], nonflammable [3] or biocompatible coatings [4], field emitting materials [5], etc…

Dust formation in hydrocarbon RF plasma processes is well known [6]: the pressure and the sheath width favor the confinement of C_2H^-, which is the elementary building block for powder formation.

In contrast, it is generally admitted that recombinations in the volume are negligible in Multipolar Microwave Plasma excited at Distributed Electron Cyclotron Resonance (MMP-DECR). However, we recently reported that powders are produced in C_2H_2 processes [7]. Thus, by combining powder formation in the plasma volume and matrix deposition on the reactor wall, Carbon-Carbon nanocomposite thin films can be formed in MMP-DECR. Indeed, SEM and TEM pictures reported in figure 1 show that powders with an average diameter of about 200 nm are dispersed in amorphous hydrogenated carbon.

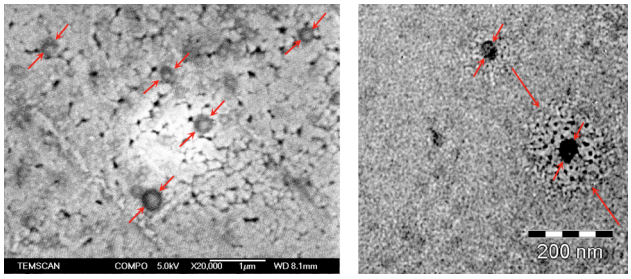

Fig.1 SEM and TEM pictures of Carbon-Carbon nanocomposite thin films formed in C_2H_2, P=800 W, p=0.1 Pa.

This paper deals with the formation of powders and of Carbon-Carbon nanocomposite thin films depending on plasma power in MMP-DECR. Langmuir probe measurements shows that C_2H_2 MMP-DECR presents the characteristics of dusty plasmas [8]: a decrease of electron density due to dissociative attachement and electron loss on powder surfaces, an increase of electron temperature (to compensate the decrease of electron density) and thus an increase of ion density and, finally, an evolution of the floating potential (less and less negative showing that negative particles are confined in the lobes). In contrast to RF plasma where powders are formed above the sheath, in the case of MMP-DECR, a key role of the magnetic field can be highlighted: negative particles are trapped in the lobes increasing the probability of recombination and thus leading to powder growth mechanisms.

Moreover, the role of the magnetic field can be deduced from in-situ FTIR spectroscopy of the diffusion plasma: from Rayleigh scattering and IR absorption, it appears that the average powder diameter is independent of the microwave plasma power and the deposition time, these two parameters only modifying the powder density. It suggests that the static magnetic field traps powders until they reach a critical size (diameter of 200 nm). On the other hand, these powders are composed of aromatic sp^2 C=C and sp^1 C≡CH bonds suggesting that they are formed by classical growth mechanisms of soot particles [9].

Finally, ex-situ FTIR and Raman spectroscopies show that the matrix is an amorphous hydrocarbon thin film and that powder cristallinity increases with the plasma power.

Then, by varying microwave plasma power, a large panel of Carbon-Carbon nanocomposite thin films can be formed in C_2H_2 MMP-DECR processes.

References

[1] P. Calvert, Nature 399 (1999) 210.
[2] J. Patscheider, MRS Bulletin 28 (2003) 180.
[3] S. Bourbigot, S. Duquesne, C. Jama, Macromol. Symp. 233 (2006) 180.
[4] T. Das, D. Ghosh, T.K. Bhattacharyya, T.K. Maiti, J. Mater. Sc.: Mater. Medicine 18 (2007) 493.
[5] I. Alexandrou, M. Baxendale, N.L. Rupesinghe, G.A.J. Amaratunga, C.J. Kiely, J. Vacuum Sc. Technol. B 18 (2000) 2698.
[6] C. Deschenaux, A. Affolter, D. Magni, C. Hollenstein, P. Fayet, J. Phys. D: Appl. Phys. 32 (1999) 1876.
[7] M. Calafat, D. Escaich, R. Clergereaux, P. Raynaud, Y. Segui, Appl. Phys. Lett. 91 (2007) 181502.
[8] A.A. Fridman, L. Boufendi, T. Hbid, B.V. Potapkin, A. Bouchoule, J. Appl. Phys. 79 (1996) 1303.
[9] N. Aggadi, C. Arnas, F. Benedic, C. Dominique, X. Duten, F. Silva, K. Hassouni, D.M. Gruen, Diam. Relat. Mater. 15 (2006) 908.