A thermal plasma route for the generation and functionalization of highly crystalline graphene structures and stable nanofluids

Jean-Luc Meunier,
Ulrich Legrand, Norma Mendoza-Gonzalez, Dimitrios Berk

Chemical Engineering, McGill University,
3610 University St, Montreal (Qc), Canada
jean-luc.meunier@mcgill.ca

Abstract

Thermal plasma (TP) reactors are used extensively for the generation of particles having specific compositions or phase structures. Nanoparticles (NPs) are also being generated using precursors that are either in the gas phase, in liquid solutions or even sometimes in the solid phase. More difficult is the controlled homogeneous nucleation of pure nanomaterials (chemically and structurally), and controlled nucleation of non-isotropic structures such as graphene. This talk will concentrate on achieving the 2-D structure of graphene in a TP system enabling extremely high purity and crystallinity of the material produced. The very high temperature homogeneous nucleation window (~4000-5000 K) involved in the TP processing route enables a bottom-up approach, provided one can control the 2-D structural evolution of the NP nucleated. Modeling of the energy/fluid fields as well as the graphene particle nucleation/growth fields indicate the critical clusters of carbon set the thickness (number of atomic layers) of the graphene, while the residence time in the growth field correlates with the sheet side lengths (on the order of 100nm x100nm, with on average 10 atomic layers in thickness; namely forming graphene nanoflakes (GNF)). An understanding of the physical processes enabling the 2D growth provides separate control parameters for playing on the number of layers and sheet scale lengths. The crystallinity parameters for these GNF from TEM and Raman spectroscopy are exceptional in comparison to regular top-down synthesis approaches. The graphene NPs most often require some chemical functionalization for specific applications, and again a TP can provide the active species for functionalization scenarios forming primary bonds between the functional group and graphene. The high temperature plasma forms a unique environment allowing purity from the simple precursors, unrivaled crystallinity from the extreme temperatures of nucleation and growth, and in situ flexibility for tuning of the functionalities directly inside the synthesis reactor through the use of the colder downstream recombining plasma.

This talk will describe the road for a controlled and pure graphene nucleation, followed in the same reactor by nitrogen, oxygen and iron functionalization of the graphene structure. The aimed applications here are for catalytic activity, in particular for a non-noble metal catalyst in fuel cells, and in the generation of graphene-based nanofluids that show full stability over time and high temperatures without the use of surfactants.

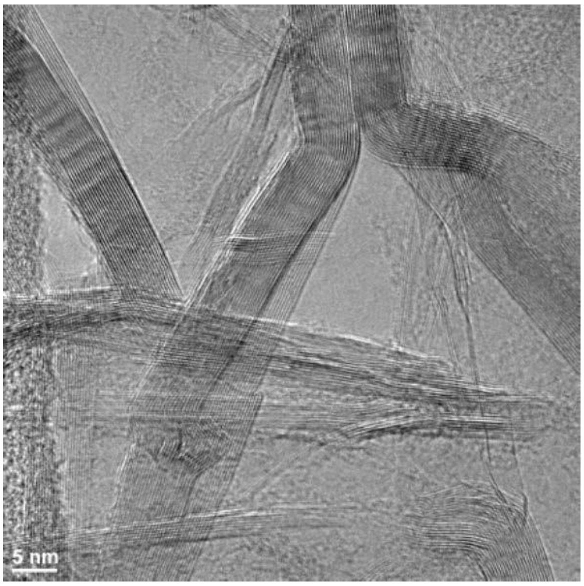

Figure: Highly crystalline graphene nanoflakes (GNF) generated in a thermal plasma environment.

References

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