# Microwave Plasmas Applied for Synthesis of Free-Standing Carbon Nanostructures at Atmospheric Pressure Conditions

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This lecture addresses selective, single step synthesis of advanced free-standing carbon nanostructures using microwave driven plasmas at atmospheric pressure conditions. Controllable bottom-up self-organization of graphene, N-graphene sheets and nanodiamonds achieved via tailoring of the plasma environment is discussed.

Recently a renewed interest to carbon materials has been generated as new advanced carbon nanostructures are being introduced bringing new prospects for applications. Multiple processes have been reported for free-standing carbon nanostructures synthesis, corresponding to either "top-down" or "bottom-up" approaches. It is to be noted that the main challenge of conventional, i.e., widely used chemical routes, is the very limited control, or lack of, over the synthesis process.

Our work extends the scope of previous efforts to fabricate free-standing carbon nanostructures using large-scale configurations of microwave plasmas driven by surface waves at atmospheric pressure conditions [1-5]. Here, we present a microwave plasma-enabled scalable route for a single step, continuous, synthesis of free-standing graphene sheets and nanodiamond particles. The method's crucial advantage relies on harnessing unique plasma mechanisms to control the material and energy fluxes of the main building units ($C_2$,C) at the atomic scale level. By tailoring the high energy density plasma environment a selective synthesis of high quality graphene sheets at high yield (2 mg/min) with prescribed structural qualities was attained. A high level of control over oxygen functionalities and $sp^2/sp^3$ carbon ratios has been achieved and with approximately 40% of the graphene being synthesized in the form of single atomic layers. The method is highly cost-efficient, fast and environmentally friendly, since it does not require the use of catalysts and noxious chemicals. It is also versatile, allowing the synthesis of different types of 2D nanostructures (e.g. N-graphene) in the same reactor. Furthermore, the high energy density of the generated plasma allows the use of gaseous, liquid or solid carbon precursors.

Here we intent to provide substantial evidence that microwave plasma based technologies are a highly competitive, green, cost-effective and disruptive alternative route to presently used cumbersome, toxics dependant, multistep conventional methods.

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