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Low Temperature Magnetized Plasma for Synthesis and Functionalization of Carbon-based nanomaterials

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Nanomaterials have the potential to revolutionize many fields of science and technology, including electronics, chemical synthesis, energy storage, and environmental applications. [1-2] Plasma synthesis offers the possibility of high throughput, short nanostructure growth time, low cost, and optimized material properties. These remarkable features of plasma synthesis are in great part due to the ability of plasma synthesis methods to sustain a higher yield production of nanomaterials both in volume and on surfaces, and often at lower process temperature and higher chemical purity, than conventional chemical synthesis [3] Due to high-density plasmas (> 10^{19} m^{-3}) can be achieved by helicon wave plasma (HWP) [4] discharge in the presence of magnetic fields, HWP discharge plasma is expected to become one of the most effective cleaning ways for impurity removal. A new PSI research facility, High Magnetic field Helicon eXperiment (HMHX), has been designed and constructed at the Soochow University, which is served as a platform for research of synthesis and functionalization of carbon-based nanomaterials (figure 1). This facility was developed for the following expected objectives: (a) helicon plasma steady state operation with high magnetic field (> 6000 G), (b) create a high-density (>10^{19} m^{-3}) plasma in the plasma processing region to synthesize and function nanomaterials, (c) serve as a in-situ diagnostics of nanoparticles and nanostructures. Most notably are their inherently low electron temperature (<1 eV), and second, that in any gas mixture, complex molecules are dissociated to neutral and ion fragments in proportion to the partial pressure of the parent gas. From a materials processing perspective, these attributes provide straightforward control over species production and can lower the ion energies at surfaces. This provides the potential to synthesise and function the surface morphology and/or chemistry with high precision, and avoid the isotropic chemical etch observed in many discharge based systems. [4] The results of the nanomaterials were characterized using Raman spectroscopy, scanning electron microscopy (SEM), atom force microscopy (AFM) and X-ray photoelectron spectroscopy (XPS). Analysis revealed the growth rate of nanomaterials increased from about 3 to 24 μm/h with increasing the flow-rate of CH_4 from 5 to 45 sccm. The spatial profile of C_2, CH, Ar and H_α line intensities in the plasma during growth were determined with optical emission spectroscopy (OES).The results show that CH and H_α radicles, instead of C_2 radicles, play an important role in the growth of nanomaterials. This research explores the fundamental physics of nanomaterial synthesis by low temperature magnetized plasma with the goals to understand, predict, and ultimately control the synthesis processes, including plasma generation, and nucleation and growth of nanoparticles and nanostructures.

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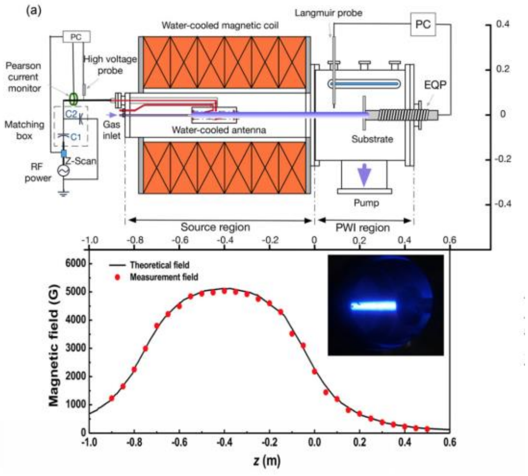

Figure 1. A schematic diagram of the High Magnetic field Helicon eXperiment (HMHX) facility at Soochow University.