AN EXPERIMENTAL STUDY OF ADHESION AND ATTRACTIVE FORCES OF DIFFERENT FLAME-FORMED CARBON NANOPARTICLES USING ATOMIC FORCE MICROSCOPY

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Atomic force microscopy (AFM) is a well-known scanning probe technique, mainly used for its capability to achieve topographic images with subnanometer resolution. In addition to surface topographies characterization, AFM is also a powerful tool for sensitive force spectroscopy measurements; in this operation mode, the forces acting between the AFM tip and the surface under investigation are recorded during approach and retract of cantilever to and from the sample, and plotted as force-distance curves. From these measurements, short-range attractive and adhesive forces can be quantitatively evaluated.

The purpose of this work is to investigate attractive and adhesive forces of incipient and mature soot particles formed in flames across the soot threshold limit. To this aim, carbon nanoparticles were produced from fuel-rich ethylene/air laminar premixed flames, at a fixed height above the burner (HAB) of 15 mm, with different equivalent ratios Φ. Particles were then collected on mica substrates by means of a thermophoretic sampling system and analyzed by AFM operating in contact and force spectroscopy modes. Attractive and adhesive forces between silicon probe and collected particles were both found to increase with flame equivalent ratio, moving from non-sooting flame conditions (Φ=1.85), in which 2-5 nm diameter organic carbon nanoparticles are mainly produced, up to fully-sooting conditions (Φ=2.58), in which 50-100 nm soot aggregates are mainly produced. As expected, adhesive forces are 5-7 times greater than attractive forces in the same conditions. This is evidenced by the fact that particle deformation and bonding with AFM tip occurring during contact results in a curve-distance hysteresis contribution. The measurement of the attractive force by the AFM force-distance curve allows the evaluation of the Hamaker constant for the different carbon particles. The Hamaker constant of investigated nanoparticles was also theoretically derived from Lifshitz theory; Van der Walls interactions were indeed calculated and compared to experimental data. The study of surface properties of flame-formed nanoparticles, by means of AFM force-distance spectroscopy, appears to be promising for a better understanding of the coagulation and coalescence phenomena between carbon particles in the soot formation process.

10.4405/profic2014.C8