doi:10.1017/S1431927610059635
Microsc. Microanal. 16 (Suppl 2), 2010

XPS and FESEM/STEM Surface Characterization of Activated Carbon, Carbon Black, and Carbon Nanotubes

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Carbon-containing nanoparticles, such as activated carbon, carbon black, and carbon nanotubes, are finding an increasing number of industrial and scientific applications. Activated carbons are used as adsorbents for impurities in liquids and gases, as catalyst supports for the active phases, and as catalysts on their own. Carbon blacks are primarily used as reinforcing agents in the rubber industry. Carbon nanotubes have unique physicochemical, mechanical, and electronic properties and accordingly have many new potential applications in catalysis, electronics, optics, and other fields. The surface chemistry and other surface properties of carbon-based materials influence how they react with other substances and therefore play an important role in their behavior and ultimate performance. Greater knowledge of the surface chemistry and morphology of carbon-containing nanoparticles will allow the development of more specific and effective materials for a given product or process.

X-ray photoelectron spectroscopy (XPS) is a potent qualitative and quantitative surface characterization technique. Nanometer scale sampling depth ($\leq$ ~10 nm) and its ability to determine unique chemical and oxidation state information make XPS an ideal technique for investigating the surface composition of nanomaterials. In particular, XPS provides information on the types and relative amounts of organic functional groups (e.g., C-O, C=O, O-C=O, C-N, etc.) present on carbon surfaces (see FIG. 1) and the presence of surface impurities that can affect material performance. Field emission scanning electron microscopy (FESEM) and scanning transmission electron microscopy (STEM), along with energy dispersive X-ray spectroscopy (EDS), are valuable microscopic techniques for characterizing the structure, morphology, and subsurface composition of nanomaterials (see FIG. 2). This poster presentation will demonstrate the advantages of using a state-of-the-art XPS instrument (Thermo Scientific K-Alpha) together with a combined FESEM/STEM ultra-high resolution electron microscope (Hitachi S-5500) to provide complementary information on the surface chemistry and surface morphology of activated carbon, carbon black, and carbon nanotube materials (see FIG. 3).

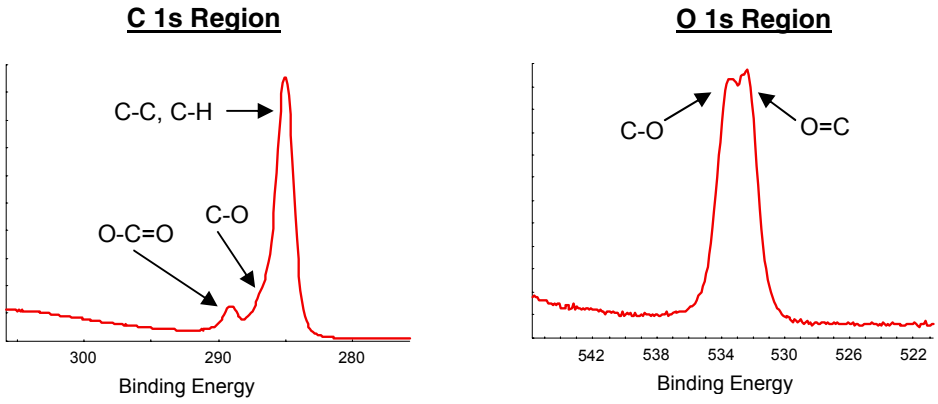

FIG. 1. High resolution C 1s (left) and O 1s (right) XPS spectra for an activated carbon powder (1,500 m^2/g surface area) indicating the presence of carbon-oxygen functional groups on the surface.

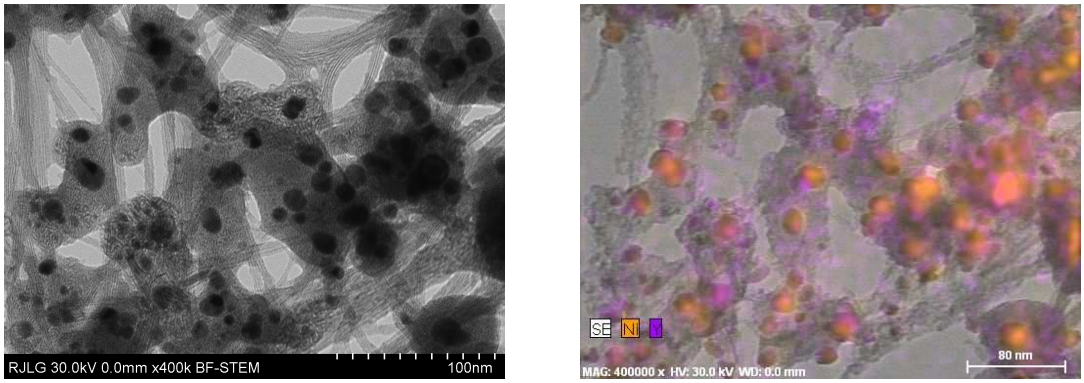

FIG. 2. Bright field (BF) STEM image (left) and EDS nickel and yttrium maps (right) for single-walled carbon nanotubes (SWCNT) containing impurity nickel/yttrium catalyst nanoparticles.

FIG. 3. Thermo Scientific K-Alpha XPS (left) and Hitachi S-5500 30 kV FESEM/STEM (right).

https://doi.org/10.1017/S1431927610059635 Published online by Cambridge University Press