Lecture 15. Applications of Carbon Nanospheres. Classification, Structure, and Physicochemical Properties of Carbon Nano-Onions

The purpose of the lecture: to give information about applications of carbon nanospheres, classification, structure, and physicochemical properties of carbon nano-onions.

Expected results: to master applications of carbon nanospheres, classification, structure, and physicochemical properties of carbon nano-onions.

Carbon nanospheres can be potentially excellent catalyst support materials. Because of its spherical arrangement, the graphene sheets that form carbon nanospheres are normally unclosed shells with rather waving flakes that follow the curvature of the sphere, creating many open edges at the surface. These create dangling bonds that provide the spheres with high chemical reactivity establishing them as good candidates for catalysis. Kang and Wang dispersed Pt, CdS, and WO3 nanoparticles, and demonstrated that electron transfer was possible in those systems, indicating their use as catalyst supports. Nitrogen doping of the CNSs strongly influenced the catalytic activity. CNSs have been successfully used as Pt carriers for the electrooxidation of methanol in direct methanol fuel cells (DMFC). The behavior of this catalyst was compared with that of Pt supported on commercial MCMB and Pt/Vulcan XC-72, showing a better catalytic activity, given the enhanced mass transport of methanol in the electrode due to the monodispersion of the spheres.

Li et al. supported Pt on nitrogen-doped nanospheres and reported how proper control of nitrogen doping had a great impact on both Pt dispersion and CO tolerance, outperforming the catalytic behavior of the commercial Pt/Vulcan XC-72 in fuel cells.

Carbon nanospheres have also been tested as electrodes for electrical double layer capacitor (EDLC), as an alternative energy storage device to secondary batteries. In addition, CNSs have been used as anode for lithium-ion batteries, exhibiting great electrochemical properties for high rate use as well as good stability toward graphite exfoliation. SnO2–CNS have also shown improved cyclability and high charge/discharge capacity.

CNSs have also been used for applications as fillers in nanocomposites as EMI shielding material. Addition to the polymer matrix even in very small concentrations, strongly modifies the low frequency response of the parent polymer as well as improving its thermal stability.

Other applications include Ni-loaded, highly porous CNSs for hydrogen storage, drug delivery systems, lubricating properties, and rubber reinforcement. Photoluminescence and multiphoton bioimaging could be some of the other potential applications; however, none have yet been developed on a commercial scale.

Classification, Structure, and Physicochemical Properties of Carbon Nano-Onions

The morphology and structure of the obtained products were investigated by fieldemission scanning electron microscope (FESEM), high-resolution transmission electron microscopy (HRTEM), x-ray diffraction, Raman spectrometry, and nitrogen adsorption.

Large quantities of CNOs consisting of quasi-spherically concentric graphitic shells with high purity and uniform size distribution (about 30 nm) were obtained and are shown in Figure 1. The examination by HRTEM (Figure 1c) demonstrates that the spheres have an onion-like structure. The interplanar spacing of 0.34 nm corresponds to that of the (002) plane of graphite.

The short-range order or turbostratic graphite structure gives rise to concentric graphite layers around a hollow and irregular core about 5 nm in diameter. The corresponding selected area electron diffraction (SAED) pattern (inset of Figure 1b) reveals the poor degree of graphitization of the CNOs.

Figure 2a shows XRD measurements conducted on CNOs. The main peak at $2\theta = 25.8°$ can be attributed to the (002) diffraction of hexagonal graphite. The broadening nature of the peak is indicative of the long-range disorder structure of the as-obtained CNOs due to their small sizes. Moreover, the disorder structure can be also reflected by the broad band centered at $2\theta = 43.7°$ showing indistinguishability of the (100) and (101) peaks. Raman spectra is used to identify the

bonding and structure of the as-obtained CNOs and is shown in Figure 2b. The two broad peaks centered at about 1303 and 1571 cm–1 are ascribed to the D peak for disordered carbon and the G peak for graphite carbon, respectively. The intensity ratio (ID/IG) in Raman spectra is a typical parameter to quantify the disorder degree of carbon materials, that is, a greater value of the ratio means a higher disorder degree for graphite.
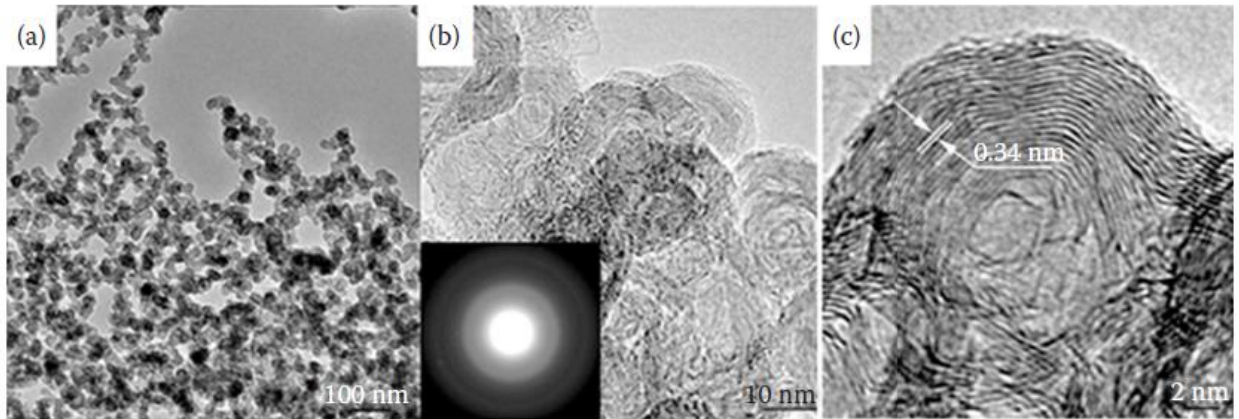

FIGURE 1. (a) FESEM image, (b) energy-dispersive x-ray spectroscopy (EDX) spectrum, and (c) HRTEM images of the asobtained CNOs. The inset in (b) is the corresponding SAED pattern
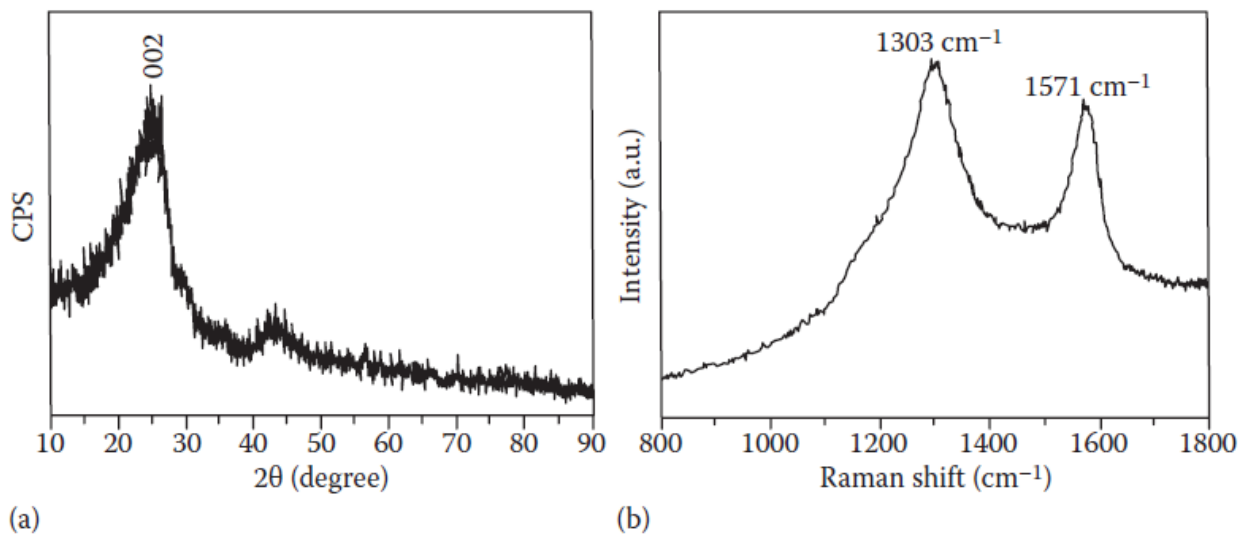

FIGURE 2. (a) XRD pattern and (b) Raman spectrum of the as-obtained CNOs