Amorphous carbon nanoparticles obtained from anodic alumina/carbon composites

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Carbon nanoparticles (CNPs) are a new class of carbon nanomaterials suitable for biological applications due to their chemical stability, non-toxicity, biocompatibility, low cost, and well-defined luminescence signal with tunable wavelength options. In this study, we synthesized and characterized fluorescent amorphous carbon nanoparticles obtained by dissolving anodic alumina/carbon composites. Anodic alumina/carbon composites were obtained by electrochemical oxidation of pure Al foil (100 μm, AlfaAesar) in a complex electrolyte containing formic acid, ammonium heptamolybdate, and oxalic acid at 60 V and 80 V (constant voltage mode), 18 °C for 120 min. The Pt grid was used as a counter electrode. Then, Al was etched, and the resulting films were dissolved in a hot aqueous solution of 0.1 M HCl. The resulting solutions were dialyzed (to wash away Al^{3+} ions), centrifugated, and filtrated. The pH of the final solutions was ca. 5–6.

The morphology, composition, and fluorescence (FL) properties of CNPs were characterized. According to the TEM studies, CNPs were 20–25 nm in diameter. The zeta potential of the CNP solutions showed a single negative peak at −29.2 mV with a width of 8.20 mV. The value and sign of potential indicate that CNPs are stable in water solutions, and the surface of CNPs has negatively charged moieties, such as C=O, C–O, and O–H. Surface-enhanced Raman spectroscopy confirmed the amorphous nature of CNPs: two predominant peaks observed at 1365 cm^{-1} and 1600 cm^{-1} can be attributed to the *D*-band and *G*-band, respectively. The intensity ratio of the G- to D-band peak was 2.20, indicating that the synthesized CNPs mainly comprise sp^2 graphitic carbons with sp^3 carbon defects originating from oxygen-containing groups. CNPs exhibited an excitation-dependent emission behavior at 280–450 nm excitation wavelengths with average lifetimes of 7.25–8.04 ns. In our case, average lifetimes are longer than in the case of CNPs synthesized electrochemically and solvothermally and comparable with those of hydroxyl-coated CNPs (9.5 ns). The origin of the FL of CNPs can be explained by the presence of two different FL centers, namely the core of CNPs and various emission centers on the CNP surface: carbonyl, carboxyl, and hydroxyl groups. As CNPs could be exceptional candidates for detection technologies, the biocompatibility assays were performed with living COS-7 mammalian cells, showing a minimal negative impact on the living cells.

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