Structural and morphological features of concentric iron oxide/carbon nanotubes obtained from phospholipids

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Biologically active 1,2-bis(10,12-tricosadiynoyl)-*sn*-glycero-3-phosphocholine ($DC_{8,9}PC$) nanotube-forming phospholipids (PLs) have been utilized as templates to prepare ferromagnetic nanotubes (FMNTs). Combining X-ray diffraction (XRD), selected area electron diffraction (SAD), high-resolution transmission electron microscopy (HRTEM), Raman, and Mössbauer spectroscopy measurements, FMNTs morphological features and chemical composition were determined. These studies showed that FMNTs consist of iron oxide/carbon/iron oxide concentric nanotubes with the amorphous carbon phase sandwiched between two iron oxide layers. The iron oxide phase consists of nanocrystalline magnetite (Fe_3O_4) which coexist as tetrahedral Fe^{3+} and octahedral $Fe^{2.5+}$ sites containing minute quantities of hematite (α-Fe_2O_3) phase. The carbon phase consists of amorphous carbon forming an amorphous carbon nanotube (ACNT). Magnetic measurements showed that saturation magnetization (M_s) of FMNTs is 79 emu/g, but upon removal of the iron oxide outer and inner layers, ACNTs become paramagnetic. The electrical resistivity (ρ) of single FMNT is 3.3×10^{-2} $\Omega \cdot m$, which decreases to 5.06×10^{-4} $\Omega \cdot m$ for ACNT. These magneto-electric properties can be easily tailored, depending upon desired applications and needs.