STEM-EDS characterization of Carbon Coated TiO2 Nanowires for the application of dielectric PVDF nanocomposites

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The search for renewable energy has created numerous interest in the energy storage systems, among which conventional electrostatic capacitors posses an intrinsic high power density. The energy storage density (U_e) of a parallel plate electrostatic capacitor is defined as $U_e=\varepsilon E_b^2/2$ where ε is the dielectric constant and E_b is the breakdown strength. Compared with the conventional inorganic ceramics, organic polymer dielectric materials own the advantages of high electrical breakdown strength, easy processing, and mechanical flexibility. Nevertheless, the practical applications in the high-performance electrostatic capacitor are hindered by their intrinsic low dielectric constant values (ca. $\varepsilon< 10$).

In this work, core-shell structured TiO_2@Carbon nanowire (TiO_2@C NWs) hybrids with different carbon shell thicknesses were synthesized by a combination of hydrothermal reaction and chemical vapor deposition methods. The obtained TiO_2@C NW hybrids own a uniform carbon shell layer whose thickness could be precisely designed from 4 nm to 40 nm. With the help of solution and melting blending methods, the TiO_2@C NW hybrids were subsequently incorporated into the PVDF matrix to fabricate the TiO_2@C NW/PVDF nanocomposites. The dielectric properties of the TiO_2@C NW/PVDF nanocomposites could be accurately adjusted by tuning the carbon shell thickness. The highest dielectric constant (2171) of TiO_2@C NW/PVDF nanocomposites is 80 times larger than that of pristine TiO_2-filled ones at the same filler loading. This approach provides an interesting alternative to engineer high-performance dielectric nanocomposites, which is a potential candidate for practical applications in embedded capacitors industry.

SEM, TEM, EDS and STEM measurements were carried out to identify the morphology of the pristine TiO_2 NW and core-shell structured TiO_2@C NW. EDS and STEM images show that the pristine TiO_2 NW is uniformly covered by a continuous and uniform carbon shell from 4 to 40 nm, where no naked TiO_2 NW part could be observed. The enlarged STEM-HAADF of TiO_2@C NW suggest that the crystallinity degree of carbon shell in the TiO_2@C NW is extremely low. As the Ti and O signals exhibit strong intensity in the nanowire center and a sharp disappearance in the shell layer. In contrast, the signal intensity of C atom in the shell is stronger than that in the core. From the enlargement of nanowire's diameter, the thickness of carbon shell could be calculated, which is in agreement with the results in STEM images.

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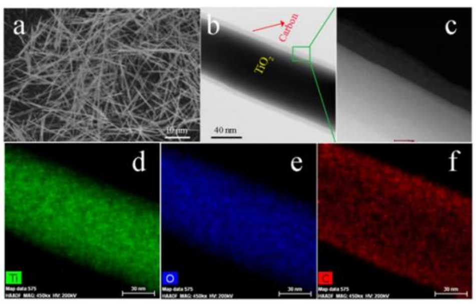

Figure . (a) SEM image of TiO_2 NWs; (b) BF-STEM image of the single core-shell structured TiO_2@C-15 NW hybrid; (c) HAADF-STEM image of the corresponding enlarged region indicated by the green rectangle in part b; (d-f) EDS elemental maps of Ti, O, and C, respectively.