A thriving field in nanotechnology is to develop synergetic functions of nano-materials by taking full advantages of unique properties of each component. In this context, combining TiO$_2$ nano-crystals and carbon nanotubes (CNTs) offers enhanced photo-sensitivity and improved photo-catalysis efficiency, which is crucial to achieving sustainable energy and preventing environment pollution and hence has aroused a tremendous research interest. Despite progress in synthesis and performance of the material system, further research is required to understand some fundamental aspects of the material system, such as how TiO$_2$ nucleates and grows on CNTs, and what is the bonding at the TiO$_2$-CNT interface. Answers to these questions also help to design nano-composites based on CNTs and metal/metal-oxides with novel functionalities.

In this work an atomic layer deposition (ALD) technique has been adopted to grow TiO$_2$ nano-particles on multiwall-CNTs (MW-CNTs). Control of the crystallinity, particle size and morphology of TiO$_2$ can be obtained through deposition parameters adopted in ALD and a surface pre-treatment of MW-CNTs using O$_2$ plasma. Transmission electron microscopy (TEM) has been very useful to characterize the ensemble structurally, chemically and electronically. In particular, electron energy loss spectroscopy (EELS) in the scanning TEM (STEM) mode has been employed to study C-K and Ti-L$_2,3$ edge fine structures in TiO$_2$, CNTs and their interface, in order to shed light on the mechanism of nucleation and growth of TiO$_2$ on CNTs, as well as the interfacial bonding of the ensemble.

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Fig. 1: TEM micrographs of TiO$_2$ deposited on CNT at 200°C for various ALD numbers of cycles: (a), (c) and (e) are after 20, 200 and 750 cycles respectively, without plasma pre-treatment; (b), (d) and (f) are 20, 200 and 750 cycles respectively, with the CNT subjected to O$_2$ plasma pre-treatment. The insets show the corresponding diffraction patterns.

Fig. 2: Core-loss EELS spectra show the Ti L$_{2,3}$ and O K edges of TiO$_2$ on CNT after 20 ALD cycles with and without O$_2$ plasma pre-treatment. Difference in the near edge fine structure indicates different crystallinity of TiO$_2$. 