

# NEXAFS study of a *gentle* HNO<sub>3</sub> and HCl acid treatment for functionalization of single-walled carbon nanotubes.

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Carbon nanotubes [CNTs] have been researched for a variety of applications ranging from mechanical structures to chemical storage for hydrogen to electrical transistor devices. Their many unique properties make them ideal materials for new devices and replacements for others. However, processing them for device fabrication is costly due to their near atomic size. One of the largest barriers to producing CNT devices involves manipulating the CNT into the final product structure. One solution to fabrication woes is to functionalize the CNTs to make specific building blocks that fit together to form the final device structure like “lego blocks”. To this end we are studying the functionalization of single-walled CNTs. The typical process of functionalizing CNTs involves acid reflux at temperatures close to 100°C and can be damaging to other micromanufactured components. This study involves the *gentle* acid treatment of CNTs via ultrasonication in HCl and HNO<sub>3</sub>. Here, we examine the effect of varying concentrations to see if a less damaging solution can be found to adequately functionalize CNTs.

To determine the degree of functionalization of the CNTs, we employed near-edge x-ray absorption fine structure spectroscopy (NEXAFS). NEXAFS can provide physical and chemical information, including structural properties and local chemical functionalities (at ppm level content of the bonding examined). The peak intensities in the NEXAFS spectra allows the identification and measurement of specific bonds in molecules, ie the content of C=C, C-C, and C-O bonds, to be detected with high accuracy.

From the NEXAFS data, it appears that lower concentrations of HCl can functionalize CNTs in a shorter period of time compared to HNO<sub>3</sub>. Further studies comparing the effects of HCl and HNO<sub>3</sub> on micromanufactured electrodes needs to be investigated.

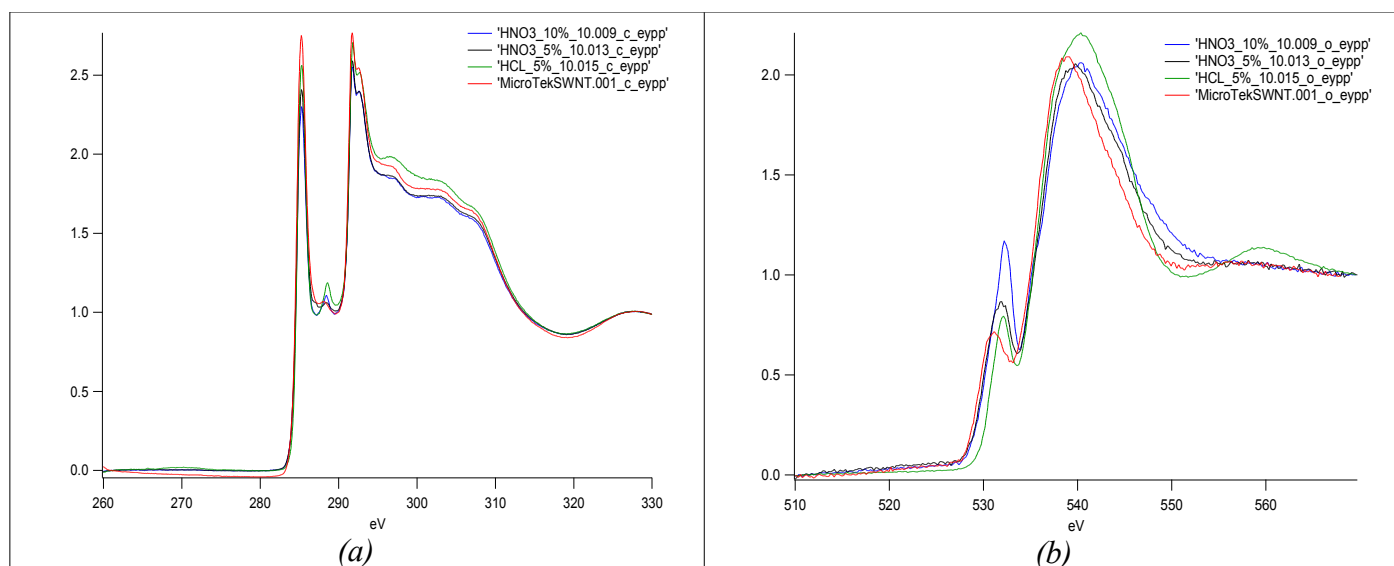


Figure 1. NEXAFS spectra at after 10 hours of acid treatment at the (a) C k-edge and (b) O k-edge. Figures show that before acid treatment C-C and C=C bonding strongest in the non-treated samples. C-O bonding weakest in the nontreated samples. After treating with acid C=O and C-O are found—indicating a breakage of C bonds along with nanotube.