Abstract:
We report the morphology of gold clusters in contact with carbon nanotubes using electron tomography which provides three-dimensional information at the spatial resolution of 2 nm. Investigating the three-dimensional morphology of and the interfacial structure between gold clusters and carbon nanotubes is important as they influence the contact potential significantly. From the tomographically reconstructed three-dimensional data, we observe that the gold clusters facet and the interfacial plane between the gold clusters and the carbon nanotubes is flat. The flat interfacial plane leads to deformation of the carbon nanotubes at regions in contact with the gold clusters. We also report that nucleation energy of the gold clusters is inversely proportional to the diameter of the nanotubes. Furthermore, the gold clusters elongate along the long axis of the carbon nanotubes as the surface across the nanotubes is highly curved to increase the nucleation energy of the gold clusters.

Experimental Details:
Single-walled nanotubes were dispersed in pure hexane solvent and sonicated to isolate the individual nanotubes. A drop of the solution was applied to a TEM grid that is coated with a thin holey carbon film. Then four monolayers of gold were deposited on the nanotubes by E-beam evaporation. A scanning electron transmission microscope (STEM) which provides an atomic resolution of 0.16 nm was used to investigate the structure of the gold-deposited carbon nanotubes. The gold-deposited carbon nanotubes were tilted from -75° to + 75° at a tilt increment of 2° and a projected image at each tilt angle was acquired to generate a tilt series [1]. The acquired tilt series was then used to reconstruct a three-dimensional representation of the gold-deposited nanotubes. The morphology of the gold clusters[2, 3] reconstructed from the tilt series was investigated as a function of the diameter of the carbon nanotubes [4] as well as a function of the number of monolayers of gold deposited on the nanotubes. Nanodiffraction patterns and high resolution TEM images of the gold-deposited nanotubes were taken as well to complement the tomographically reconstructed data.

Different metallic elements such as gold-palladium alloy, nickel, iridium, and etc., will be deposited on the carbon nanotubes [5] to observe different morphologies of these ad-clusters from which the contact potential can be deduced.

Conclusions:
Investigating the three dimensional morphology of an interfacial structure between the gold clusters and the carbon nanotubes using electron tomography has been successfully achieved. The experimental results show faceted gold clusters and flat interfacial plane between the gold clusters and the carbon nanotubes. The flat interfacial plane signifies deformation of the carbon nanotubes at regions in contact with the gold clusters. Moreover, the nucleation energy of the gold clusters increases with decrease in the diameter of the carbon nanotubes. From the structural investigation on different metallic adatoms on carbon nanotubes with electron tomography, we hope to develop a method to minimize the contact potential between metallic leads and carbon nanotubes.

References:
Gold clusters facet on carbon nanotubes.

Interfacial plane between gold clusters and nanotubes is flat.

Carbon nanotubes deforms due to the flat interfacial plane.

Figure 1: Gold clusters on carbon nanotubes of different diameters (STEM-HAADF images) show that the gold clusters elongate along the nanotubes.

Figure 2: Hi-res TEM image shows that the gold cluster on the carbon nanotube is strongly faceted.

Figure 3: Tomographically reconstructed gold clusters on carbon nanotubes reveal that the interfacial plane between the gold clusters & nanotubes is flat.