Joule heat induced synthesis of Y junction carbon nanotube in *Insitu* TEM

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Since its discovery in 1991, carbon nanotubes (CNTs), a tube of sp^2 hybridized carbon atom, has been in the scientific spotlight due to its unique electrical, chemical, and mechanical properties. Due to very high current density in CNT (theoretically 1000 times the Cu wire), its potential application as electric wires and interconnects in nano-scale circuits is attractive. Precise and seamless soldering of CNTs is prerequisite for fabrication of complex structures to avoid high contact resistance in nano-circuits. In this work, we perform series of Insitu TEM experiments to demonstrate synthesis of CNT from Pt embedded amorphous carbon nano fiber (Pt-CNF) using joules heating followed by electric field controlled flow of molten Pt to connect broken CNT ends. We also demonstrate fabrication of Y junction CNT by seamlessly connecting two separate CNF with the Pt electro-migration.

For fabrication of Pt-CNF, the edges of the graphite foils and Pt wall were irradiated with argon ions (Ar+) simultaneously. Long conical amorphous Pt-CNF fibers were fabricated with embedded Pt nanoparticles on edge of graphite foil. The graphite plate containing Pt-CNF was cut into small sizes of 2 mm width and directly mounted on the TEM sample holder without any additional post-treatment before *Insitu* TEM experiments. We used a TEM sample holder (JEOL; EM-Z02154T) with a tungsten nano-probe controlled by nano-manipulator and electrical biasing equipment for applying voltage. In first part of experiment low bias voltage up to 0.8 V was applied to the Pt-CNF via W probe. At 0.7 V abrupt increase in current was observed implying formation of graphitic carbon. This was also confirmed by simultaneous observation of electro-migration of Pt leaving behind tubular CNT structure. Further direction of metal flow could be controlled by varying direction of applied voltage. This controlled metal flow technique was employed to demonstrate connection of broken CNTs by following metal through the broken ends. Finally, we brought together two separate CNFs to form Y shaped structure. This Y shaped CNF was transformed to seamlessly connected Y junction CNT by electro-migration of Pt. Method presented in this work can be employed for on the spot synthesis of CNT and create complex structures by nano-soldering the desired CNT ends.

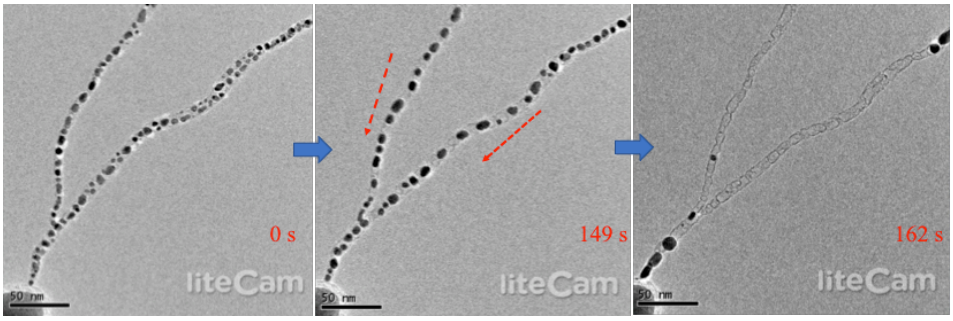

Figure 1. Transformation process of Y CNF to Y junction CNT at different time interval, showing (a) Pristine CNF (b) electro-migration of Pt and (c) formation of Y junction CNT