High Energy Efficiency Field Emission and Energy Storage Devices: Application of Interface Engineered Carbon Nanotubes

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In the current age of fast-depleting conventional energy sources, top priority is given to exploring non-conventional energy sources, designing highly efficient energy storage systems and converting existing machines /instruments /devices into energy-efficient ones. 'Energy efficiency' is one of the important challenges for today's scientific and research community, worldwide.

This presentation will focus on research activities centered on the theme of 'energy efficiency'. The main goal of this research was to develop two highly energy-efficient devices – field emitters and Li-ion batteries, using beneficial properties of carbon nanotubes (CNT). Interface-engineered, directly grown CNTs were used as cathode in field emitters, while similar structure was applied as anode in Li-ion batteries. Interface engineering was found to offer minimum resistance to electron flow and strong bonding with the substrate. Both field emitters and Li-ion battery anodes were benefitted from these advantages, demonstrating high energy efficiency. Field emitter, developed during this research, could be characterized by low turn-on field, high emission current, very high field enhancement factor and extremely good stability during long-run. Further, application of 3-dimensional design to these field emitters resulted in achieving one of the highest emission current densities reported so far. The 3-D field emitter registered 27 times increase in current density, as compared to their 2-D counterparts. These achievements were further followed by adding two new functionalities, *(i)* transparency and *(ii)* flexibility, to field emitters, keeping in view of current demand for flexible displays. A CNT-graphene hybrid structure showed appreciable emission, along with very good transparency and flexibility.

Li-ion battery anodes, prepared using the interface-engineered CNTs, have offered 140% increment in capacity, as compared to conventional graphite anodes. Further, it has shown very good rate capability and an exceptional 'zero capacity degradation' during long cycle operation. Enhanced safety and charge transfer mechanism of this novel anode structure could be explained from structural characterization. In an attempt to progress further, CNTs were coated with ultrathin alumina by atomic layer deposition technique. These alumina-coated CNT anodes offered much higher capacity and an exceptional rate capability, with very low capacity degradation in higher current densities. These highly energy efficient CNT based anodes are expected to enhance capacities of future Li-ion batteries.

Overall, the outcomes of this research has shown appreciable progress towards attaining high energy efficiency in two important devices – field emitters and Li-ion batteries, through application of interface-engineered carbon nanotubes and demonstrated good promise for further development.