Synopsis

When materials approach the size of few nanometers, they show properties which are significantly different from their bulk counterpart. Such unique/improved properties make them potential candidate for several emerging applications. At the reduced dimension, controlling the shape of nanocrystals provides an effective way to tune several material properties. In this regard, wet chemical synthesis has been established as the ultimate route to synthesize nanocrystals at ultra-small dimensions with excellent control over the morphology. However, the use of surfactant poses a barrier into efficient realization of its application as it requires a clean interface for better performance. Exercise of available cleaning protocols to clean the surface often leads to coarsening of the nanoparticles due to their inherent high surface curvature. For anisotropic nanomaterials, rounding of the shape is an additional problem. Anchoring nanomaterials onto substrates provides an easy way to impart stability. In this thesis, ultrathin Au nanowires, that are inherently unstable, have been shown to grow over a wide variety of substrates by in-situ functionalization.

Use of nanomaterials as device component holds promise into miniaturization of electronics. But device fabrication in such cases require manipulation of nanomaterials with enhanced control. Dielectrophoresis offers an easy way to assemble nanomaterials in between contact pads and hence evolved as a promising tool to fabricate device with a good level of precision. Herein, directed assembly of ultrathin Au nanowires by dielectrophoresis, has been shown as an efficient strategy to fabricate devices based on the wires.

Combining more than one nanocrystal, to form a heterostructure, often has the advantage of synergism and/or multifunctionality. Therefore, synthesis of heterostructure is highly useful in enhancing and/or adding functionalities to nanomaterials. There are several routes available in literature for synthesis of heterostructures. Newer strategies are being evolved to further improve performance in an application specific way. In that regard, a good understanding of mechanism of formation is crucial to form the desired product with the required functionality. For example, Au due to high electron affinity has been known to undergo reduction rather than cation exchange with chalcogenides. In this thesis, it has been shown that the final product depends on the delicate balance of reaction conditions and the system under study using CdS-Au as the model system. In yet another case, PdO nanotubes have been shown to form, on reaction of $PdCl_2$ with ZnO at higher starting ratio of the precursors. In-situ generation of HCl provides an effective handle for tuning of the product from the commonly expected hybrid to hollow.

Graphene has evolved as a wonder material due to its wide range of practical applications. Its superior conductivity with high flexibility has made it an important material in the field of nanoelectronics. In this thesis, an interesting case of packed crumpled graphene has been shown to sense a wide variety of strain/pressure which has applications in day to day life.

The study reported in the thesis is organized as follows:

Chapter 1 presents a general introduction to nanomaterials followed by the review of the available strategies to synthesize various 1D nanomaterials. Subsequently, a section on the classification of hybrid followed by the different synthetic protocols adopted in literature to synthesize them, have been provided. A review on the available methodologies for directed assembly of nanomaterials has been presented.

Chapter 2 provides a summary of the materials synthesized and the techniques used for characterization of the materials. A brief description of all the synthetic strategy adopted has been provided. The basic principle of all the characterization techniques used, has been explained. A section explaining the principle of dielectrophoresis has also been presented.

Chapter 3 presents a general method to grow ultrathin Au nanowires over a variety of substrates with different nature, topography and rigidity/flexibility. Ultrathin nanowires of Au (~2 nm in diameter) are potentially useful for various catalytic, plasmonic and device applications. Extreme fragility on polar solvent cleaning was a limitation in realizing the applications. Direct growth onto substrate was an alternative but poor interfacial energy of Au with most commercial substrates lead to poor coverage. In this chapter, in-situ functionalization of the substrates have been shown to improve Au nucleation dramatically which lead to growth of dense, networked nanowires over large area. Catalysis and lithography-free device fabrication has been demonstrated. Using the same concept of functionalization, SiO_2 coating of the nanowires have been shown. A comparative study of thermal stability of these ultrafine Au nanowires in the uncoated and coated form, has been presented.

Chapter 4 demonstrates an ultrafast device fabrication strategy with Au nanowires using dielectrophoresis. While dense growth of Au nanowires is beneficial for some applications, it is not so for some others. For example, miniaturization of electronics require large number of devices in a small area. Therefore, there is a need for methods to manipulate nanowires so as to place them in the desired location for successful fabrication of device with them. In this chapter, dielectrophoresis has been used for assembling nanowires in between and at the sides of the

contact pads. Alignment under different conditions lead to an understanding of the forces. Fabrication of a large number of devices in a single experiment has been demonstrated.

Chapter 5 presents a simple route to synthesize CdS-Au_2S_x hybrid as a result of cation-exchange predominantly. Au due to high electron affinity has been shown in literature to undergo reduction rather than cation exchange with CdS. In this chapter, it has been shown that cation exchange may be a dominant product. The competition between cation exchange and reduction in the case of CdS-Au system has been studied using EDS, XRD, XPS and TEM. Thermodynamic calculation along with kinetic analysis show that the process may depend on a delicate balance of reaction conditions and the system under study. The methodology adopted, is general and may be applied to other systems.

Chapter 6 presents an one pot, ultrafast microwave route to synthesize PdO hollow/hybrid nanomaterials. The common strategy to synthesize hollow nanomaterials had been by nucleation of the shell material on the core and subsequent dissolution of the core. In this chapter, a one step method to synthesize hollow PdO nanotubes, using ZnO nanorods as sacrificial template, has been shown. By tuning the ratio of the $PdCl_2$ (PdO precursor) to ZnO, ZnO-PdO hybrid could be obtained using the same method. The PdO nanotubes synthesized could be converted to Pd nanotubes by $NaBH_4$ treatment. Study of thermal stability of the PdO nanotubes has been carried out.

Chapter 7 demonstrates a simple strategy to sense a variety of strain/pressure with taped crumpled graphene. Detection of ultralow strain (10^{-3}) with high gauge factor is challenging and poorly addressed in literature. Taped crumpled graphene has been shown to detect such low strain with high gauge factor (> 4000). An ultra-fast switching time of 20.4 ms has been documented in detection of dynamic strain of frequency 49 Hz. An excellent cyclic stability for >7000 cycles has been demonstrated. The same device could be used to detect gentle pressure pulses with consistency. Slight modification of the device configuration enabled detection of high pressure. Simplicity of the device fabrication allowed fabrication of the device onto stick labels which could be pasted on any surface, for instance, floor. Hard pressing, stamping with feet and hammering shocks do not alter the base resistance of the device, indicating that it is extremely robust. Sealed arrangement of the graphene allowed operation of the device under water in detection of water pressure. Presence of trapped air underneath the tape enabled detection of air pressure both below and above atmospheric pressure.