CHAPTER 7

SUMMARY AND OUTLOOK

Materials science has been going through an unprecedented growth in the past couple of decades primarily due to the newfound interest in the creation and organization of structures on the nanometer size scale and their important applications in diverse disciplines of science and technology. This importance is due to the size- and shape- dependent tunability of physicochemical properties exhibited by these materials in this size range. Significant quantum of work has been dedicated to this area for the creation and utilization of these nanostructures as well as developing methods for characterizing such materials and properties precisely. Over the years, science of these materials and their technological advances has made inroads in almost any area of Science and Technology. Among the various NPs, metal and semiconductor NPs are of special importance due to their spread of applications in areas such as photonics, biomedical engineering, medicine, imaging, industrial catalysis and sensing. The work presented in this thesis is in line with the developing aspects related to this area.

A general introduction to Nanoscience and Nanotechnology is presented in Chapter 1. Therein we have presented the literature survey on the overall developments in the area and introduction to the present work. In Chapter 2, the various instrumental methods for the analysis of nanostructured materials are presented briefly.

Chapter 3 deals with the green synthesis of Au, Ag, and Au-Ag NPs and their antimicrobial studies. The objective of the work was to investigate the antibacterial activity of these NPs. Since it is already established that the surface plasmon absorption of the alloy NPs can be tuned by varying their composition, we
anticipated that we may be able to control their biological activity in a similar way by alloying it with the more benign Au atoms. Glucose-reduced, starch-stabilized Ag and Au as well as their alloys of various compositions were synthesized and their bactericidal effects against various bacterial strains are studied. The results reveal that Ag NPs exhibit strong bactericidal tendency against gram-positive and gram-negative bacteria whereas the Au and alloy NPs exhibit no noticeable activity against these microorganisms. The results also point out some sort of deactivation of the Ag atoms/clusters by their coupling with Au atoms/clusters. This deactivation may be correlated to the changes in the surface plasmon absorption by alloying. The exact mechanism of the action of the NPs is not clear. However, from the results of the AFM studies and the disc diffusion studies it is revealed that the Ag NPs rupture the bacterial cell walls leading to the overall collapse of the biological system. On the other hand, no significant effect is observed for the Au and Au-Ag alloy NPs. In all the bacterial samples investigated, the mechanism of operation of the Ag NPs appears to be the same, viz., the breakdown of the cell structures. This supports the view that Ag NPs could find application as a broad spectrum bactericide.

In Chapter 4, we have dealt with the theory and applications of networking of MNPs for the formation of mesoporous Au NP networks. A theoretical perspective on how the NPs can be made to self-assemble into mesoporous thin films and sponges is presented. High resolution TEM and SEM images of the samples are taken showing the formation of self-supporting networks of mesoporous architectures through the welding of the NPs following the partial stripping of the Au NPs, facilitated through a pH switch. The thermal stability of these systems and the variation of their surface areas as a function of temperature are presented. It is
seen that at temperatures above 150 °C, these networks slowly melt into the formation of metallic systems.

We also investigated the possibility of transforming such mesoporous Au thin films and sponges synthesized into superhydrophobic systems by treating them with n-decanethiol. The superhydrophobic mesoporous Au thin films were investigated by following contact angle measurements of water droplets using a goniometer system. Surface modification of the Au sponge resulted in a sponge system that stabilized air around it when immersed in water, indicating its extreme superhydrophobicity, much like the superhydrophobic surfaces of some marine species which stabilizes air in water making their friction-free movement in sea depths. These artificial systems hold several promises for in-water applications such as sensing, separations, and as a source of oxygen for microbial growth.

In chapter 5, we have investigated the method of dealloying as a route to make catalytically active nanoarchitectures. The Au-Ag alloy sponges of varying compositions are prepared by reduction using β- D- Glucose as the reducing agent. These alloy sponges are dealloyed with dilute HNO₃ and the results reveal that the resulted Au structure has a three dimensional porous morphology with high surface area and stability. This mesoporous Au is found to be a good heterogeneous catalyst for the reduction of 4-nitrophenol to 4-aminophenol. The Au catalyst can be recycled again for the reduction reaction.

In Chapter 6, we have dealt with the networking of the metal oxide NPs such as Titania leading to the template-free formation of industrially important, high surface area, meso-structured oxide networks. Herein, it is shown that the simple, neutral, room temperature hydrolytic condensation of Ti(IV) n-butoxide dispersed in ethyl acetate yields meso-structured, sub-micron sized anatase spheres with high surface
area and thermal stability (400°C). It is plausible that the charge separations in the TiOB molecule (with partial positive and negative charges on the Ti and the O atoms, respectively, and the non-polar alkyl chains) may guide the self-assembly of these systems. Although there is no long range meso-scale order in the systems (as evidenced from the absence of higher order reflections in the small angle XRD) present in these systems, these results are significant, not only from an industrial stand-point but also from the understanding of nanoscale organizations. The spherical morphology of the aggregates formed is also of importance. This may be explained based on the energetics of cluster speciation between the highly charge polarized TiOB and the less polarized EA. The possibility of using these titania networks as support for the MNPs as heterogeneous catalysts has also been investigated. The results clearly imply that these systems could be used as catalysts for many reactions including CO oxidation. We propose to undertake more controlled growth of the catalytic system and also effective control of the reaction conditions to improve its effectiveness.