Chapter – V
Summary
In the present thesis of my research work, I have made an attempt to synthesize, characterize and study an interpenetrating polymer network (IPN) and metal oxide doped interpenetrating polymer network films. Thin films do play a vital role in many branches of materials science and engineering, and what we study in this course can be directly transferred to the variety of applications in science and technology like sensors, antireflection coating on lenses or solar cells, reflection coatings for mirrors, insulating/conducting films, capacitors, semiconducting and piezoelectric devices etc.

IPNs have found enormous use in various biomedical applications due to their unique properties of specificity, swelling capacity, mechanical strength, nutrient and oxygen permeability, durability in the body and sensitivity. IPNs with metal or metal oxide nano particles are new generation materials useful for a wide variety of applications such as the stimuli-responsive sensors and actuators, coatings, fuel cells, solar cells, food packaging material and semiconducting devices. Thus IPNs grasp many advancements and future applications which will be of immense help to mankind. Maghemite (γ-Fe₂O₃) is an interesting and very important metal oxide due to its non-toxicity, chemical and thermal stability and favorable hysteric properties. It has got a chemically active surface where a variety of bonds can be formed allowing for coating to which a diversity of bio-active molecules may be attached. NiO an important ceramic oxide has attracted much interest due to its novel optical, electronic, magnetic, thermal, mechanical properties and potential application in catalyst, battery electrodes, gas sensors, electrochemical films and photo electronic devices.
Different advanced analytical instruments are used to study the morphology and thermal property of these films which includes UV-visible (UV-vis) spectroscopy, Fourier transform infrared (FTIR) spectroscopy, scanning electron microscopy (SEM), X-ray diffraction (XRD) spectrophotometer, and Thermal analyzer. Interpenetrating polymer networks with metal and metal oxide nano particles are attractive materials in various applications. The properties such as optical, electrical mechanical and thermal of IPNs can be effectively controlled by adjusting the monomer, oxidant and metal salt/metal oxide concentration. New properties can be anticipated by using polymers with active functional groups.

We envision here the new simple and efficient method of preparation of highly stable interpenetrating polymer network and IPN-metal oxide films. The synthesis of polymer IPN and IPN-metal oxide at room temperature will be the better method that may be employed for the synthesis of other polymer IPNs and IPN-metal oxide composites on industrial scale, thus making useful in various areas of science and technology.

The formation of PANI-PVA-Ag IPN composite by the \emph{in situ} polymerization of aniline in the PVA matrix in the presence of silver nitrate was indicated by the formation of dark reddish brown color. The UV-visible spectrum shows surface plasmon resonance peak at 448.0 nm due to the formation of silver nano particles. XRD pattern also confirms the formation of silver nano particles in the polymer matrix. SEM images clearly show globular shaped silver nano particles uniformly distributed within the PANI-PVA IPN matrix. It can also be seen that these Ag nanoparticles are clearly mono dispersed in the polymer matrix which is essential for uncovering their specific properties and for achieving their practical applications in various fields. These results are published in the journal “Advances
in Applied Research” entitled “Mono dispersed silver nano particles (Ag NP) in polyaniline-polyvinyl alcohol (PANI-PVA) interpenetrating polymer network (IPN)”.

The synthesis of PANI-PVA, PANI-PVA-γ-Fe₂O₃ and PANI-PVA-NiO IPNs were achieved successfully at room temperature. The FTIR spectrum confirms the formation of interpenetrating network between PANI and PVA. From XRD studies it is observed that with increase in concentration of PANI in IPN films, the intensity of the characteristic peak of PANI is decreased thus increasing amorphousness in the films. IPNs have shown good film forming ability on glass plate and best storage ability. The increased thermal stability of PANI-PVA-Metal oxide IPN films is observed due to the presence of metal oxide nano particles. The films are moisture resistant and show appreciable conductivity at room temperature. At high resolution SEM images of PANI-PVA films clearly show rod shaped PANI particles. XRD pattern of PANI-PVA-γ-Fe₂O₃ shows a prominent peak due to cubic spinel structure of γ-Fe₂O₃ nano particles which is confirmed by SEM images. These particles due to strong inter-particle interaction are closely packed to form the flakes. SEM images of the PANI-PVA-NiO IPN film show the amorphous sheet like structure. The surface of the film is not homogeneous and shows voids and unevenness. The results of the PANI-PVA films are published in “International Journal of Science Research” entitled “Studies on Polyaniline-Polyvinyl Alcohol (PANI-PVA) Interpenetrating Polymer Network (IPN) Thin Films” and that of PANI-PVA-NiO IPN film are published in “Indian Journal of Applied Research” entitled “Synthesis and Characterization of Polyaniline-Polyvinyl Alcohol-NiO Nanocomposite Film”.
Hence, the single step synthesis of PANI-PVA and PANI-PVA-Metal oxide IPNs at room temperature has made a successful step towards the processing difficulties of polyaniline. This synthesis provides a new method for preparation of highly stable films on large scale of polymer and polymer-metal oxide IPNs with uniform metal oxide dispersion.

The IPNs described here presents a system fundamentally different from those reported earlier. ICP-based IPNs prepared by chemical oxidative polymerization of aniline or pyrrole in presence of a cross-linked matrix gives rise to some microfiber like morphology and can provide the mixing of the components only to a limited extent. In other words, these are examples of pseudo-IPNs. On the other hand, the present IPN was synthesized by polymerization of aniline in the presence of cross-linked PVA matrix. Considering the simplicity of the synthetic method followed, the present single-step method is much more advantageous with respect to the earlier multi-step methods for the synthesis of IPNs. Consequently this method proves to be a forward step in the research field and further investigations and developments in IPN.