Significant scientific and technological interest has focused on polymer-inorganic nanocomposites (PINCs) over the last two decades. The use of inorganic nanoparticles into the polymer matrix can provide high-performance novel materials that find applications in many industrial fields. The integration of inorganic nanoparticles into a polymer matrix allows both properties from inorganic nanoparticles and polymer to be combined/enhanced and thus advanced new functions can be generated to the PINCs. Research in functional hybrid organic–inorganic materials is being mostly supported by the growing interest of chemists, physicists, biologists and materials scientists to fully exploit this opportunity for creating smart materials benefiting from the best of the three realms: inorganic, organic and biological. In addition to the high versatility in chemical and physical properties and shaping, hybrid nanocomposites present the paramount advantage to both facilitate integration and miniaturization, therefore opening a land of promising applications in many fields: optics, electronics, ionics, mechanics, membranes, functional and protective coatings, catalysis, sensors, biology, medicine, biotechnology, etc. The present work is mainly focussed on the synthesis, characterization and various application studies of conducting polymer modified TiO₂ nanocomposites.
8.1. Summary

The present thesis comprises of 8 chapters including introduction, experimental, physico chemical characterization and application studies.

Chapter 1 deals with a general introduction about hybrid nanocomposites, their different synthesis strategies and their properties and applications. Also contains a general introduction to photocatalysis by TiO₂, thermal diffusivity measurement by thermal lens technique, nonlinear optics, and lasing studies.

Chapter 2 describes the synthesis procedure of TiO₂ conducting polymer nanocomposites. This chapter also gives a brief description about the various techniques used for physico-chemical characterization. Pure TiO₂ was prepared via P123 assisted hydrothermal technique and the precursor used is titanium tetra isopropoxide. The polymer modified nanocomposites were also prepared via hydrothermal route. Prepared nanocomposite systems were characterized by XRD, UV-Vis.DRS, FT-IR Spectroscopy, SEM-EDX, Thermogravimetric analysis, Raman spectroscopy, TEM, XPS and BET surface area. Conductivity measurements of the prepared systems were done using standard 4-probe method.

Chapter 3 describes in detail the results of various physico-chemical characterizations of the prepared nanocomposite systems. The phase purity and crystalline nature of the prepared systems were obtained from XRD analysis. All the prepared systems contain TiO₂ in the anatase phase. This is also confirmed by Raman analysis. Low angle XRD pattern shows that pure TiO₂ is mesoporous in nature and the ordering of structure is retained only on forming composite with polyaniline. But on composite formation with polypyrrole
and polythiophene the structural order is destroyed. From UV-Vis.DRS analysis it is evident that the conducting polymers acts as good sensitizing material for TiO$_2$ and on composite formation the resulting nanocomposite photocatalyst can be activated by absorbing both the ultraviolet and visible light ($\lambda = 190–800$ nm) to give a maximum visible light harvesting, and is a promising photoelectric conversion and photocatalytic material for the efficient use of light, especially sunlight. FT-IR spectroscopy confirms the incorporation of polymer with TiO$_2$. Thermal analysis TG-DTG reveals the thermal stability of the prepared nanocomposite systems. Surface morphology of the nanocomposite systems was obtained from SEM and TEM. N2 adsorption - desorption isotherms of all the samples show representative type IV isotherm which is characteristic of mesoporous materials. The elemental composition of the prepared systems was obtained from EDX and XPS analysis. In EPR analysis the TiO$_2$-conducting polymer composites, the spectrum shows a signal having ‘g’ value approximately equal to 2.004. Such a sharp symmetrical ESR signal, of which g value is close to that of free electron is typical in organic radicals or polaron species formed in conducting polymers.

Chapter 4 mainly discusses the photocatalytic degradation of cationic dyes such as Rhodamine B and malachite green, nitrophenol, phenol, endocrine disruptor bisphenol-A, antibiotic sulfamethoxazole and the photocatalytic antibacterial activity. In the degradation reaction reactions various reaction parameters such as effect of catalyst amount, effect of time, effect of lamp power and the effect of various catalytic systems were studied.
Chapter 5 discusses the thermal diffusivity measurements of TiO$_2$/polyaniline nanocomposite systems using thermal lens technique. The thermal lens technique is based on measurement of the temperature rise that is produced in an illuminated sample as a result of nonradiative relaxation of the energy absorbed from a laser. Because the technique is based on direct measurement of the absorbed optical energy, its sensitivity is higher than conventional absorption techniques. The composite material can be used as a good coolant material which will diffuse heat from the medium at faster rate as polyaniline component increases in the composite material.

Chapter 6 discusses the third order nonlinear properties of bare and polyaniline modified TiO$_2$ nanocomposite systems. Z scan technique is used to study the third order nonlinear optical properties. Thin films of the samples were prepared via tape casting technique. The polyaniline modified TiO$_2$ nanocomposites show reversible saturable absorption and they act as good optical limiting materials.

Chapter 7 presents the lasing applications of polyaniline modified TiO$_2$ systems. These nanocomposites act as a potential dye laser gain medium. The dye used is Rhodamine 6G. In this study lasing like sharp peaks are observed possibly due to the optical feedback process of the multiple light scattering induced by TiO$_2$ nanoparticles embedded within the hybrid polymer.

Chapter 8 presents the summary and major conclusions drawn from various investigations.
8.2. Conclusions

The conclusions of the present work are outlined below:

- Mesoporous TiO$_2$ was prepared by the cationic surfactant P123 assisted hydrothermal synthesis route and conducting polymer modified TiO$_2$ nanocomposites were also prepared via the same technique.

- All the prepared systems show XRD pattern corresponding to anatase phase of TiO$_2$, which means that there is no phase change occurring even after conducting polymer modification.

- Raman spectroscopy gives supporting evidence for the XRD results. It also confirms the incorporation of the polymer.

- The mesoporous nature and surface area of the prepared samples were analysed by N$_2$ adsorption desorption studies and the mesoporous ordering can be confirmed by low angle XRD measurement.

- The morphology of the prepared samples was obtained from both SEM & TEM. The elemental analysis of the samples was performed by EDX analysis.

- The hybrid composite formation is confirmed by FT-IR spectroscopy and X-ray photoelectron spectroscopy.

- All the prepared samples have been used for the photocatalytic degradation of dyes, antibiotic, endocrine disruptors and some other organic pollutants. Photocatalytic antibacterial activity studies were also performed using the prepared systems.
Chapter 8

Polyaniline modified TiO₂ nanocomposite systems were found to have good antibacterial activity.

- Thermal diffusivity studies of the polyaniline modified systems were carried out using thermal lens technique. It is observed that as the amount of polyaniline in the composite increases the thermal diffusivity also increases. The prepared systems can be used as an excellent coolant in various industrial purposes.

- Nonlinear optical properties (3rd order nonlinearity) of the polyaniline modified systems were studied using Z scan technique. The prepared materials can be used for optical limiting applications.

- Lasing studies of polyaniline modified TiO₂ systems were carried out and the studies reveal that TiO₂ - Polyaniline composite is a potential dye laser gain medium.