6.1 Summary

The focus of present thesis is to synthesize noble metal nanoparticles and nanomaterials using appropriate matrix and their extensive investigation using various techniques like UV-Vis., FT-IR, HRTEM, FESEM and Zeta potential measurement studies and used such type of nanomaterials for sensing of hazardous analyte like drugs used for critical diseases (anti-HIV drugs and third generation antibiotics).

There are various types of drugs which are used for the treatment of life-threatening diseases like Cancer, AIDS or HIV infection. Drugs specific to these diseases offers several side effects which are not manageable for example long-term adverse effects of anti-HIV drugs are bone or renal toxicity, dyslipidemia, insulin resistance, or accelerated cardiovascular disease. When their concentration in patient's serum is more than their toxic dose range, can cause adverse side effects. Therefore, recently it is realized by the medicos the need of a simple, sensitive and portable sensor for the onsite measurement of such drugs. So that, doctors can monitor the concentration of drugs and in patient's serum during the treatment.

In view of above, the focus of present thesis is aimed on development of novel functionalized nanomaterials for electrode modification and sensing of hazardous analytes like drugs. I have chosen anti-HIV drugs and antibiotics which are specific to certain diseases but their prolonged use can cause various adverse effects on patient's health. The thesis work is divided into seven chapters as follows.

Chapter 1 gives an introduction of basic concepts about sensors, types of sensors, advancement and generation of sensors. Importance of nanomaterials-based sensors and

need to develop portable low-cost sensors for drugs related to critical diseases. The extensive literature survey is made on these areas and reported in this chapter.

Chapter 2 deals with the development of Chitosan (Ch) stabilized silver nanoparticles (Ch@Ag NPs) hybrid materials as active materials for modification of screen printed graphite electrodes (SPGE) for electrochemical detection of Azidothymidine (AZT). AZT is an anti-retroviral drug used for the treatment of patients infected with HIV-1. Ch@Ag NPs have been synthesized successfully using one pot chemical synthesis approach. As-synthesized Ch@Ag NPs are characterized by various techniques like UV-Vis., Zeta potential, FT-IR, field emission scanning electron microscopy (FESEM), energy dispersive X-ray spectroscopy (EDAX), transmission electron microscopy (TEM) and cyclic voltammetry techniques. This hybrid material is used for the fabrication of sensing probes. Before making sensing probes of SPGE, first we modified commercial glassy carbon electrode (GCE) by Ch@Ag NPs (Ch@Ag NPs/GCE) in order to check the capability of this hybrid nanomaterials towards electro-reduction and detection of AZT. Thereafter, modification is extended using Ch@Ag NPs on SPGE (Ch@Ag NPs/SPGE) for making portable sensing probes. As-modified Ch@Ag NPs/GCE has been used for AZT detection in the wide range of concentration from 1.0 µM to 700 µM in 0.1 M phosphate buffer solution (PBS, pH = 7.6) using voltammetric techniques. After that, AZT is also successfully detected by Ch@Ag NPs/SPGE in the concentration range of 10 µM to 533 µM in phosphate buffer solution as well as in biological samples (human Plasma) using a simple cyclic voltammetric technique. The limit of detection (LOD) of Ch@Ag NPs/SPGE probes is found to be 1 µM in PBS and 10 µM in biological samples (human plasma) at S/N (Signal to noise ratio):3.

Chapter 3 deals with the detection of another recent anti-HIV drug Nevirapine (NVP) through a sensitive electro-oxidative method using efficient electro-active 2D materials Pd@rGO, MoS_2 quantum dots (QDs) and Pd@rGO decorated with MoS_2 QDs modified electrode. Nevirapine is an anti-retroviral against HIV-1, which is one of the representative members of class non- nucleoside reverse transcriptase inhibitor. The property of this drug is to inhibit the activities of both types of RNA and DNA dependent DNA polymerase by binding directly the catalytic site of reverse transcriptase enzyme and a recent drug used for HIV-1 treatment. This drug is detected using electro-oxidation and our earlier developed nanomaterials Ch@Ag NPs was not found suitable for electro-oxidation based sensing. We developed a novel nanomaterial and observed an interaction between the Pd@rGO and MoS_2 QDs in the composite based on FT-IR and UV-Vis. absorption studies. The interaction between the Pd@rGO and MoS_2 QDs in designed material leads to highly efficient electro-activity that is actually responsible for the broad spectrum quantification of frequently used anti-HIV drug Nevirapine. The electrochemical oxidation behaviour of NVP is studied using cyclic voltammetry (CV) over bare glassy carbon electrode and modified electrodes with alone Pd@rGO and MoS_2 QDs and finally over designed material Pd@rGO/ MoS_2 QDs. The excellent catalytic effect is observed over designed material as evident from oxidation at relatively lower potential of 0.65 V *vs.* Ag/AgCl and large peak current in comparison with others. The Pd@rGO/ MoS_2 QDs modified electrode exhibits a linear increase in oxidation peak current with an increase in NVP concentration in the range of 0.1 – 80 µM with limit of detection (LOD) of 50 nM at signal-to-noise ratio (S/N): 3. The developed sensing platform shows excellent stability and sensitivity to make it a suitable for the determination of NVP in the complex system.

Chapter 4 represents a novel sensor for electrochemical determination of NVP and AZT simultaneously based on Pd@rGO/ MoS_2 QDs modified GCEs and SPGE. The electro-catalytic activity of Pd@rGO/ MoS_2 QDs composite synergistically enhanced the oxidation of NVP and reduction of AZT resulted in the detection limit of NVP and AZT up to 10 µM concentration. The developed sensor showed a linear relationship between the peak current and drug concentrations in the wide range 10 µM – 80 µM under optimized conditions. Further, the proposed method is also employed for detection of NVP in complex system (human serum) samples.

Chapter 5 describe the synthesis of tetrathiafulvalene stabilized palladium nanocomposite (Pd@TTF) through one-step simple chemical route without using any external reducing agent. Prepared Pd@TTF was further used for the electrochemical determination of ceftazidime (CFZ). Ceftazidime is a semi synthetic and one of the third generation vaccines of β-lactam family. It is a broad-spectrum antibiotic and frequently used for the patients suffering from cystic fibrosis and urinary tract related infections. A possible interaction mechanism has been proposed for the formation of palladium NPs sandwiched between TTF radical cations (Pd@TTF). As-prepared Pd@TTF is characterized by using various techniques to investigate its structural, optical, and electrochemical properties. The interaction of drug molecules with Pd@TTF is utilized in sensing of the drug using voltammetric techniques. The limit of detection (LOD) of CFZ is achieved up to 0.5 µM. The Pd@TTF modified sensor probe is successfully used for the determination of CFZ in the commercially available CFZ injection.

6.2 Implication for future work:

In this thesis, electrochemical detection of AZT and NVP are performed simultaneously using disposable modified SPGE. But their commercial application using commercially available tablet Duovir-N

(combination of AZT, NVP and lamivudine) has not been performed. In a tablet, three drugs are combined we can detect all the drugs using the same sensing platform to control adverse effect of the commercially available tablet on patient's health. We can also develop some other efficient sensing platform to determine these drugs either alone or in combinations.

Portable sensor and modified screen printed sensing probes used for sensing of drugs:

Palmsens or portable sensing probe

Screen printed graphite electrode