Chapter 6

Overall Conclusion and Future Scope of Study

6.1 Conclusion of the study

The present thesis work is dictated for the investigation of various phenomenon of the plasma nitriding process on different grades of ferrous and non-ferrous alloys. To explore the importance of plasma nitriding technique, in the industrial market for the development of new alloys with modified properties, we have performed plasma nitriding process on different grades of ferrous and non-ferrous alloy. The main findings of the study are given below:

(i) The surface properties such as; surface micro-hardness and wear resistance of the ferrous and non-ferrous alloys can be increase after plasma nitriding process. The peaks of the different nitride phases are detected under XRD analysis after plasma nitriding process. Some mix peaks of epsilon (ε) phase with fcc (γ) phase of (111) planes at the 2θ position of 42.58^0 are detected in the study.

(ii) It is concluded that the diffusion of nitrogen is faster in ferrous alloys as compared to non-ferrous alloys. The calculated values of diffusion coefficients of nitrogen (D_N) in ferrous alloys are in the order of ~10^{-12} m^2/s, while it is ~10^{-16} m^2/s in non-ferrous alloys.

(iii) Alloying elements (e.g. Carbon, Chromium, Nickel, Aluminium, Manganese and Molybdenum) present in the alloys, strongly influenced the surface properties during plasma nitriding process. It is important to state that, if the steel has strong nitride forming elements (Cr, Al, Mo etc.) under low

concentration (~ 1-2%), the diffusion depth and surface micro-hardness will be more.

(iv) Some ferrous alloys are not possible to plasma nitride with the conventional plasma nitriding process. Plasma nitriding of high carbon low alloy steel (AISI 52100) is one of them. Plasma nitriding of this alloy is possible in the annealed condition only at higher temperature (>560 ^{0}C). During the conventional plasma nitriding process, the surface hardness and core hardness decreased after plasma nitriding process.

(v) The plasma nitrided layer is more efficient to protect the material surface below the plasma nitriding process temperature when plasma nitrided component was used for high temperature application. It is also observed that if heat-treatment (quenching and tempering) is carried out on the plasma nitrided samples, the nitrided peak is not observed on the surface during XRD investigation.

6.2 Future scope

The present investigations provide the basis for further in-depth investigation of plasma nitriding processes and can motivate for new theoretical, experimental or computational studies. Some possible areas for further investigations are discussed below.

a. Pulsed plasma nitriding have various advantages over the conventional and DC plasma nitriding. Fundamental processes occurring in pulsed plasma are entirely different from the former processes. Plasma nitriding process parameters such as gas compositions, process temperature and process time played a very crucial role in the formation of nitrided layer. The formation of nitrides such as; Iron-nitride, chromium-nitride, aluminum-nitride, titanium-nitride etc are depends on the process temperature and each compound has different solubility limit of nitrogen and reaction rate. From the results of metallurgical aspects, the present work can be extended for further investigations on more alloys.

b. Alloying elements (e.g. Carbon, Chromium, Nickel, Aluminium, Manganese and Molybdenum) presents in the alloy, strongly influenced the surface properties during plasma nitriding process. It is important to state that, if the steel has strong nitride forming elements (Cr, Al, Mo etc.) under low concentration (~ 1-2%), the diffusion depth and hardness will be more. A systematic study is needed to develop a theoretical model that explores the role individual alloying elements in nitriding process.

c. A large amount of metallurgical investigations have been reported for plasma nitriding processes. Several studies have been done to correlate the properties of nitrided surface with the plasma conditions. Many more steels which are industrially viable but are not investigate with the plasma nitriding technique.

d. Since, N2-H2 discharges are very complex, therefore it is very essential to combine the spectroscopic findings of other researchers to alter the surface properties. The new designs of the experimental setup with mixed power source are also the part of future study.