Abstract

In the present investigation, surface engineering of Interstitial Free (IF) steel has been carried out by plasma assisted surface engineering techniques to improve its wear and corrosion resistance properties. Plasma nitriding aims at development of a wear and corrosion resistant nitride layer on IF steel and understanding the effect of prior cold deformation, time and temperature of nitriding on kinetics and mechanism of nitriding. The detailed investigation included the effect of plasma nitriding on the microstructures developed, residual stress and phases and a detailed study of the effect of plasma nitriding on the wear resistance and corrosion resistance properties. The study also extended to develop sacrificial (Zn) and barrier coatings (Ti and Sn) on IF steel by DC magnetron sputtering technique and studying the effect of sputter deposition on characteristics of coating (microstructure, micro-stress, phase) and its properties (corrosion resistance). Finally, attempts have also been made to understand the effect of multilayering and co-deposition (developed by magnetron sputtering technique) of a combination of sacrificial and barrier coating on the corrosion behavior of sputter deposited IF steel.

Plasma nitriding has been carried out in pulsed direct current glow discharge mode at an applied voltage of 540-710 V with 3-6 A current in the temperature range 350-480 ˚C for a time period of 1-4 h. The phases formed after nitriding are mostly γ-Fe_4N with a small volume fraction of Fe_3N, embedded in ferrite matrix. Nitride volume fraction increases with nitriding time and temperature. The kinetics of nitriding is enhanced with the degree of prior cold deformation. Detailed characterization reveals that plasma nitriding of 80% cold deformed IF steel leads to significant improvement in hardness and wear resistance particularly after nitriding at 480 ˚C for 4 h. In addition, plasma nitriding also raises corrosion resistance of IF steel and the increment seems directly related to the increase in nitride volume fraction at the surface. Thus, plasma nitriding following prior cold deformation appears an appropriate surface engineering strategy to enhance surface hardness and resistance to both wear and corrosion of IF steel, which otherwise possess a fairly poor bulk strength and does not respond to usual bulk/surface hardening treatments. Twin target magnetron sputtering assisted deposition of two Sn-Zn alloy coating namely Sn-8.8 wt.% Zn and Sn-30 wt.% Zn on IF steel substrate with an aim to improve resistance to corrosion and

scratch has been studied. The study includes deposition from pre-alloyed as well as separate elemental (Sn and Zn) targets with independent control of sputtering current and voltage. Single magnetron sputtering gives finer deposition while volume fraction and size of the microstructure is higher in case of twin zinc target magnetron sputtering. Alloy composition achieved by controlling deposition rate using magnetron individual power. Film growth followed same angular direction as the angle between substrate plane and magnetron central axis. Sputtering using pre-alloyed target showed four-fold hardness increment as compared to as received IF steel substrate. Magnetron sputtering yields relatively smooth top surface of tin- zinc. Corrosion potentials for both the sputtered coated tin-zinc compositions as well as multilayered deposition found comparable with galvanized steel. A detailed investigation of sputtering of titanium (Ti) and zinc (Zn) on interstitial free (IF) steel for improving its corrosion resistance. Sputtering has been conducted on freshly polished and ion etched IF steel using a DC magnetron sputtering technique. Followed by sputtering, a detailed investigation of the microstructures, phase and composition of sputter deposited coating were characterized by scanning electron microscopy, energy dispersive spectroscopic technique and X-ray diffraction techniques. Finally, the mechanical and electro-chemical properties of the sputter deposited surface were evaluated. There is an improvement in average surface micro-hardness (350-700 VHN) due to sputter deposition as compared to as-received IF steel (190 VHN). For the sputter deposited titanium the average surface microhardness is 500 VHN, for zinc it is 350 VHN and for bilayered surface, the average surface microhardness is 700 VHN. Due to sputtering, there in improvement in wear resistance property of IF steel as compared to as-received substrate. The corrosion rate is marginally decreased (2.95 x 10^{-2} mm/year to 3.25 x 10^{-2} mm/year) in sputter deposited surface as compared to the as-received IF steel (3.55 x 10^{-2} mm/year). The corrosion rate is minimum is sputter deposited titanium (2.95 x 10^{-2} mm/year).

The thesis has been structured into five chapters. **Chapter 1** describes the introduction of the present work. **Chapter 2** provides a critical review of the earlier works reported in literature pertaining to different surface modification techniques as applied to IF steel with an aim to improve its surface properties towards tribological properties. **Chapter**

3 represents the experimental details illustrating: (i) procedure for different surface engineering techniques adopted in the present study, (ii) characterization techniques adopted for the modified surfaces, (iii) procedure for measurement of mechanical properties such as hardness, nano indentation, diffusion, grain size, interface, lattice strain and wear, (iv) methodology for evaluation of corrosion property. **Chapter 4** describes the results and discussions pertaining to as received and surface modified IF steel. This chapter also presents a summary of the major conclusions drawn from the present work. Finally, **Chapter 5** presents a suitable comparison of the adopted surface modification techniques, summary, major conclusions drawn from the present study and its future scope.

Keywords: *IF steel, plasma nitriding, sputtering, wear, corrosion*