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Plasma Based Diffusion Processes for Enhancement in Properties of Steel Surfaces

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Low pressure plasmas have been used extensively for surface modification in the last two decades. The modification is primarily done by the ions from the plasma, where the ions are preferentially energized to impact on the material surface. The ion energy and flux to the surface determines the degree of surface modification. The ion energy is controlled by the bias applied on the substrate and the ion-neutral collisions that occurs in the ion sheath. The sheath dynamics plays a very important role in determining the properties of ions.

When the plasma forming gas is a mixture of nitrogen and hydrogen at pressure of few mbar and the substrate is biased negative with magnitude ~ 1 kV, intense plasma is formed around the substrate. The plasma alongwith ions also supplies excited radicals and energetic neutrals to the substrate surface [1,2]. If the substrate is heated the diffusion of nitrogen takes place to large depths leading to formation of nitrides. For steel substrates, the iron and chromium nitrides take place. These nitrides increase the hardness, wear resistance and for most steels also the corrosion resistance simultaneously. This process is commonly known as glow discharge plasma nitriding (GDPN).

Incorporation of nitrogen can also be done if the plasma is formed at a low pressure using auxiliary plasma sources, and the substrate is biased negative to high voltages. Such pulsed high voltage can increase the ion flux leading to high amount of ion incorporation in the substrate. This is the process of plasma based ion implantation (PBII), which for stainless steels leading to the formation of a novel phase formed called expanded austenite. Expanded austenite gives rise to enhancement in wear resistance without decrease of corrosion resistance [2,3].

PBII can be mixed with deposition leading to the process of implantation and deposition simultaneously. Using a judicious mixture of pulse on time, duty cycle and bias magnitude, the compressive stress in the coating can be controlled, without increasing the bulk temperature. Such coatings are more adherent to the substrate. Such duplex coatings can be used on a wide variety of steels, especially for orthopaedic applications. The presentation will cover all the processes described above alongwith case studies. It will also cover aspects of design of large scale plasma systems based on basic equations that define the plasma and sheath dynamics.

References

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