Surface treatment of metals using an atmospheric pressure plasma jet for cleaning, oxidation, reduction and thin film deposition

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Abstract: In this contribution, we report the treatment of metal substrates using an atmospheric pressure plasma jet generated with different ionization gases at room temperature. Depending on the ionization gases, the process configuration and the plasma parameter, it is possible to induce surface modification of the metal surface such as cleaning of organic contaminants, oxidation, reduction of metal oxide and coating of a protective barrier layer with a controlled introduction of a siloxane precursor into the plasma discharge.

1. Introduction

Adhesive bonding is a reliable joining technique, increasingly used in the automotive industry to reduce weight and improve vehicle performance. Proper surface treatment is crucial for successful bonding. Atmospheric pressure plasma processes, like plasma activation, offer a green and cost-efficient solution by modifying the surface chemistry and enhancing adhesion [1]. Plasma jets, such as OpenAir plasma®, are particularly suitable for industrial applications, offering high-speed treatment and compatibility with various substrates. Moreover, in addition to surface activation, it is also possible to consider OpenAir Plasma processes for advanced cleaning of contaminants, reduction of metal oxide and thin film coatings. In this work, a detailed presentation of possible alternative solution to replace cleaning agent, acids or anodizing processes will be presented and discussed.

2. Methods

The plasma is generated at atmospheric pressure with a discharge frequency that can be set from 21 to 25 kHz. The plasma jet system is equipped with a double plasma control unit module M that can control at real time ionization gas flow and monitor plasma power. Depending on the plasma process considered, different ionization gases can be used. Air or nitrogen are commonly used to create reactive species and lead to oxidation of contaminants. For the plasma reduction, a mixture of forming gas containing 5% Hydrogen and 95% Nitrogen was used as the main plasma gas with flow between 40 to 65 L/min and a plasma power of 1350W. It is also possible to bring additional liquid precursor to the discharge and generate more oxidative species for plasma cleaning or thin film deposition for anticorrosion application.

3. Results and Discussion

To assess the effectiveness of plasma reduction with the use of N_2H_2 ionization gas, X-ray photoelectron spectroscopy (XPS) was employed. Figures 1 displays the XPS spectra of the reference copper sample and the plasma-reduced copper sample, respectively, after one hour of exposure to ambient air.

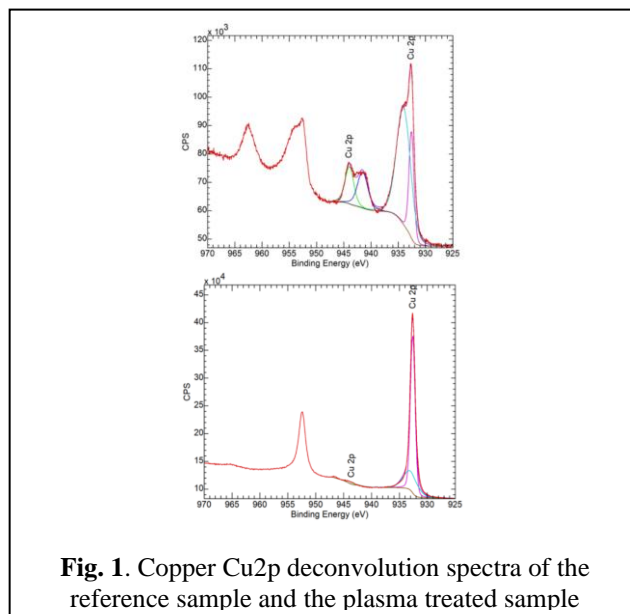Both spectra exhibit prominent copper peaks corresponding to Cu 2p3/2 at 930-940 eV and Auger Cu

Fig. 1. Copper Cu2p deconvolution spectra of the reference sample and the plasma treated sample

LMM triples at 916-920 eV, consistent with previous studies by Platzman et al. [2]. the oxygen concentration decreased from 35.8% for the reference sample to 21.1% after plasma treatment and one hour of air exposure confirming the reduction process.

4. Conclusion

In addition to plasma activation commonly used to increase surface energy and improve adhesion of metal, it is also possible to consider different gases and reduce metal oxide surfaces. These encouraging results indicate that atmospheric pressure plasma technology can be effectively applied in semiconductor and electronics manufacturing. Additionally, to the reduction of metal oxide surfaces, plasma thin film deposition can also be employed to enhance adhesion or protect the metal surfaces from corrosion. This newly developed plasma processes offer an environmentally friendly alternative to traditional chemical methods.

References

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