Cleaning and activation of aluminium metal using an atmospheric-pressure postdischarge

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Introduction

Due to its mechanic, thermal and electric properties, aluminium is one of the most used materials in industries as varied as automotive, construction or food vessel making. Alluminium is usually supplied to the industry covered with a film of hydrocarbons that avoids corrosion and/or adhesion [1], which must be eliminated prior to any further processing.

For that purpose, the use of plasmas constitutes an alternative to purely chemical methods or large ovens, especially at an industrial scale, where their use results in large energy consumption and substantial amounts of chemical pollutants. However, the effectiveness of plasmas is typically limited by the distance at which the discharge can act on the surface, as is the case of dielectric barrier discharges [2], or by other practical factors, such as the additional pumping required in the case of techniques based on low pressure plasmas [3].

In most atmospheric pressure plasmas, the application distance is also limited by the dimensions of the plasma, which typically lie in the 0.5 - 1.0 cm range. However, some discharges sustained in flowing gases exhibit an active zone characterized by a very low density of charged particles and lower temperatures which is usually referred to as *remote plasma* or *postdischarge* [4], where a significant amount of long-lived active species capable of acting on a surface can be found at distances up to several centimeters.

In the research presented herein, the effect of applying the postdischarge of an atmospheric pressure microwave discharge sustained in argon and argon-mixtures on an aluminium metal surface for cleaning and activating purposes has been studied.

Experiment Setup

The microwave (2.45 GHz) discharge was generated at atmospheric pressure using a surfatron [5] device (Figure 1) and sustained in high-purity (<99.999%) argon and nitrogen mixtures using a power of 150 W. Nitrogen contents were varied between 0 and 2%, keeping a constant flow of 1 slm (standard liter per minute). Under these conditions, a visible postdischarge can be obtained [6].

Aluminium samples obtained from a 400 μm thick commercial aluminium coil were placed on a movable sample holder and exposed to the action of the postdischarge at a displacement speed of 7500 μm/s. Several treatments were performed varying both the nitrogen content and the treatment distance, and changes in the hydrophilicity and free energy of the surfaces were studied using the sessile drop and Owens-Wendt methods [7]. Finally, the treated surfaces were analyzed by X-ray photoelectron spectroscopy (XPS) in order to understand the chemical modifications at the surface of the samples.

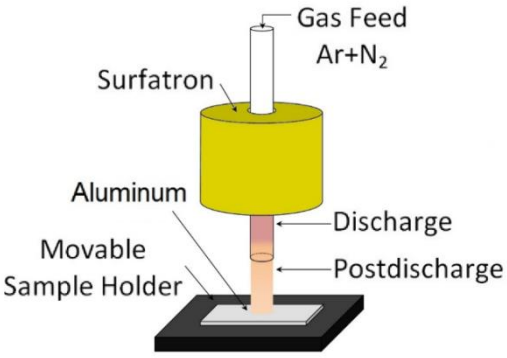

Figure 1. Experiment Setup.

Results and Discussion

The postdischarge treatment induced a significant increase in the hydrophilicity of the samples, related to an increase in the surface free energy to values of 77 mJ/m^2, much higher than those exhibited by untreated samples, which is about 37 mJ/m^2. This increase depends very weakly on the nitrogen content of the discharge (Figure 2a) and is affective to distances up to 5 cm measured from the end of the discharge (Figure 2b), much larger than those reported in other treatments based on the use of plasmas [7-8].

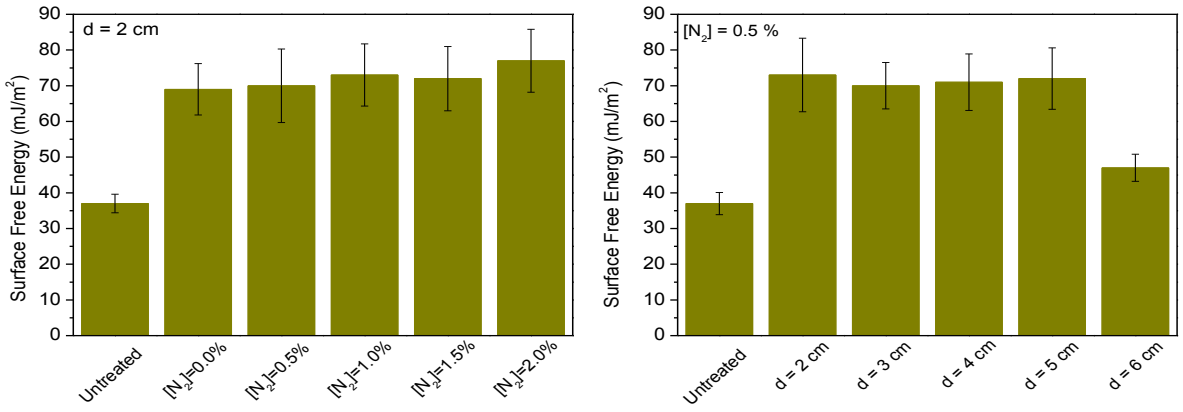

Figure 2. Surface free energy of the treated aluminium samples as a function of the nitrogen content of the discharge (a) and the treatment distance measured from the end of the discharge (b).

Given that the postdischarge can show temperatures in the 100 to 300 ºC range, aluminium samples were also exposed to the stream of a heating gun to discard that exclusively thermal effects were responsible for the increase in surface free energy due to hydrocarbon vaporization. The test resulted in surface free energy values of 39 mJ/m^2, only slightly higher than those of untreated samples.

In order to understand the mechanism responsible for the increase in surface free energy, aluminium surfaces were analyzed by XPS. Figure 3a shows the atomic composition of untreated samples, samples exposed to the postdischarge of Ar and Ar+N_2 mixtures and for those heated as explained above. The analysis of the results reveals that the increase in hydrophilicity and surface free energy are partly due to a decrease in the carbon content at the surface [8] (surface cleaning), as well as due to an increase in the amount of OH radicals existing at the surface (surface activation), which according to literature [3] is related to a more hydrophilic behavior of the surfaces.

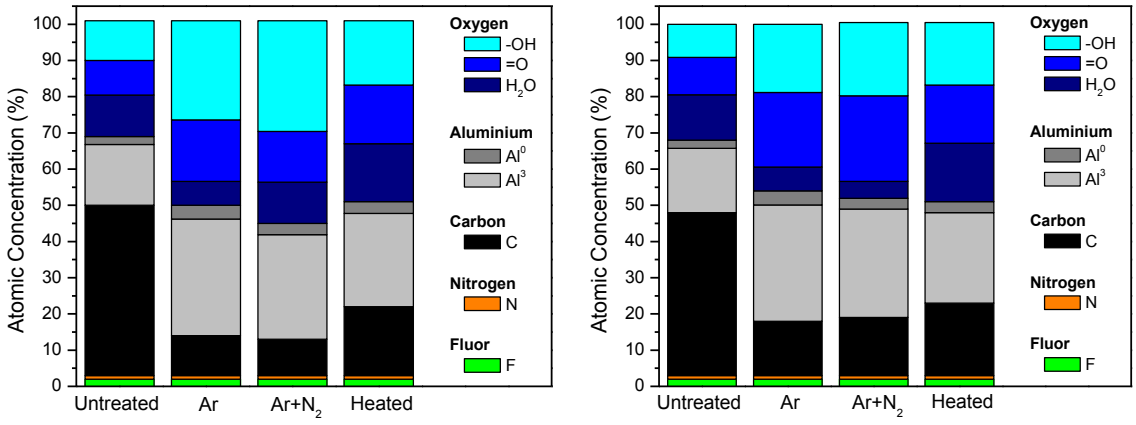

Figure 3. XPS quantification results of the elements and components existing in the surface after the treatment (a) and after 48-hour ageing in air ambience (b).

As it happens with other surface treatments based on plasma technology, the activation effect is reverted within the following 48 – 72 hours when the samples are stored in air [9] (Figure 4). From Figure 3b, where the chemical composition of the surfaces is examined by XPS 48 hours after the treatment, it can be concluded that this recovery of the hydrophobicity of the aluminium surfaces is not related to an increase in the carbon content, but rather to a decrease in the amount of OH radicals existing at the surface [10].

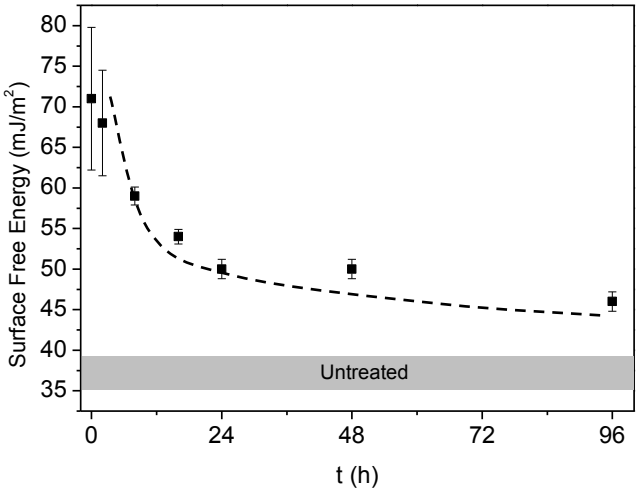

Figure 4. Ageing effect on surface free energy of aluminium samples treated with an argon-nitrogen postdischarge.

Acknowledgements

This work has been subsidised by the Consejería de Economía e Innovación (Junta de Andalucía) through project P11-FQM-7489 (FEDER funds cofinanced)

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