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Improvement in surface characterisitcs of polymers for subsequent electroless plating using liquid assisted laser processing

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Abstract

Metallization of polymers is a widely used process in the electronic industry that involves their surface modification as a pre-treatment step. Laser-based surface modification is one of the commonly used techniques for polymers due to its speed and precision. The process involves laser heating of the polymer surface to generate a rough or porous surface. Laser processing in liquid generates superior surface characteristics that result in better metal deposition. In this study, a comparison of the surface characteristics obtained by laser processing in water vis-à-vis air along with the deposition characteristics are presented. In addition, a numerical model based on the finite volume method is developed to predict the temperature profile during the process. Based on the model results, it is hypothesized that physical phenomena such as vapor bubble generation and plasma formation may occur in the presence of water, and it is because of these effects that causes an increase in surface porosity.

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Keywords: Laser processing; surface modification; metallization; electroless platin; finite volume method

1. Introduction

Metallization of polymers and polymer-based materials is a widely used industrial technique for a variety of applications that include electric, electronic and mechatronic devices, and decorative purposes [Charbonnier and Romand (2003)]. Electroless plating is one of the most commonly used metallization techniques for polymers. The process involves surface modification of the polymers to improve adhesive properties and subsequent activation of the surface with an electroless catalyst (typically by submerging it in a Sn/Pd solution), and the activated surface is plated using electroless auto-catalytic process by immersing it in an electroless bath (Ni or Cu solution) [Yang et al.

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(2011)]. The other techniques of polymer metallization include chemical plating [Stremsdoerfer et al. (2003)], physical vapor deposition [Mittal (1991)], plasma and ion beam etching [Kupfer and Wolf (2000)] and chemical vapor deposition [Duguet et al. (2013)]. In comparison to other processes, electroless plating is economically cheap as it uses very simple equipment. In addition, electroless process offers a large flexibility of the thickness and volume of metal deposition with a uniform surface finish.

Nomenclature

T	Temperature (K)
T_b	Normal boiling temperature (K)
T_c	Critical temperature (K)
k	Thermal conductivity (K)
c_p	Specific heat (J/kg-K)
ρ	Density (kg/m^3)
I	Laser Intensity inside the substrate (W/m^2)
α	Absorption coefficient (m^{-1})
t_p	Pulse duration (μs)

The deposition quality and the interfacial bond strength between the polymer and the metallic layer is mainly governed by the surface characteristics of the polymer. Therefore, surface modification plays an important role in the metallization of the polymers. Surface modification based on plasma, wet-chemical or mechanical methods can be used to generate a rough surface to facilitate metallization of the polymer [Oher (2003); Penn and Wang (1994); Dayss et al., (1999)]. However, these processes are not area-selective and rely on the usage of a mask. One of the most superior techniques of polymer surface modification is the photo-chemical treatment by using a laser radiation. The laser radiation causes photo-thermal or photo-chemical decomposition of the polymer surface, generating a highly rough surface. The process is not only fast, but is also area-selective.

Frerichs et al. (1995) carried out surface modification of polymers for subsequent metallization with three different processes viz. laser radiation, wet-chemical and plasma etching processes. The authors observed an evident improvement in surface roughness with laser radiation that resulted in superior adhesive properties between the polymer and the metallic layer. The surface characteristics of the laser modified surface are largely influenced by the laser parameters such as wavelength, intensity, number of pulses and pulse duration. Zhang et al. (2013) carried out laser polymer surface modification process using several industrial lasers and did a comparative study. The authors measured the surface characteristics in terms of surface porosity function. Higher surface porosity was observed to result in a superior metal deposition. Based on the porosity function, the authors experimentally identified the suitable lasers and the range of operating conditions that can result in optimal surface characteristics for better electroless deposition. Horn et al. (1999) performed electroless copper deposition on an excimer laser pretreated poly-butylene terephthalate and observed very strong adhesive properties between the polymer and the deposited metallic layer.

In this work, experiments are carried out to compare the surface characteristics obtained in the presence of air vis-à-vis water and the subsequent deposition characteristics for both the cases. The experiments were carried out using Nd:YAG laser on a polycarbonate surface and the resulting surface characteristics were measured. In addition, a numerical model was developed to estimate the temperature variation during the laser heating process. The study is aimed at understanding the possible reasons that results in improved surface characterisitics for laser processing with ambient water.

Section 2 presents the experimental work. The modeling approach is described in Sec. 3 and the results are discussed in Sec. 4. The important conclusions of the work are summarized in Sec. 5.