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Laser-induced site-selective silver seeding on polyimide for electroless copper plating

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Abstract

Ag particles were generated on Ag^+-doped polyimide film by laser direct writing, followed by selective copper deposition using the metallic silver particles as seeds. Laser irradiation caused in situ reduction and agglomeration of silver on the polyimide film. The copper lines were less uniform and compact with higher scanning velocity and the width of the deposited copper line could reach 25 μm. Equations of the relationship between scanning velocity and connectivity of the deposited copper patterns have been derived. The process was characterised by AFM, XPS, SEM, and semiconductor characterisation system.

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Keywords: Electroless plating; Ion exchange; Laser; Lithography; Polyimide; Silver

1. Introduction

In the microelectronic industry, the long resistance–capacitance (RC) delay time has become a serious problem. The RC delay is caused by the reduction in metal line widths and pitches, and can result in low signal transmission speed [1]. The RC delay time must thus be reduced to allow for the manufacture of faster devices. Copper can reduce the RC delay time, and has better conductivity than aluminium, and so has become a preferred choice for the microelectronics industry [2]. To further reduce the RC delay time, the use of an insulating medium with a low dielectric constant (low-*k*) material is necessary. Hence, the combination of Cu-based metallisation and low-*k* materials is a good solution for the microelectronics industry [3,4].

Polyimide is a low-*k* material with high thermal stability and has been widely used in the microelectronics industry. Various efforts have been made to produce metallisation on polyimide surfaces. Copper electroless metal deposition is a primary choice because it is a relatively low-cost and low-temperature technology [5].

The conventional electroless plating procedure involves pretreatment, activation or seeding, and plating. Pretreatment can improve the interfacial adhesion between deposited copper and substrate [6]. The activation or seeding of the dielectric substrate is key to the subsequent successful electroless metal deposition. The traditional seeding process consists of either a two-step method using successively sensitization solution of $SnCl_2$ and then activation solution of $PdCl_2$ or a one-step method using a colloidal mixture of $SnCl_2$ and $PdCl_2$ [7–9]. The solutions are expensive and could cause environmental problems, so new activation methods are attractive.

Akamatsu et al. have developed a method for deposition of silver nanoparticles on PI film [10]. The PI surface was modified first by alkali treatment to hydrolyse the imide bonds on the PI surface to yield the corresponding potassium carboxylate, after which the K^+ ions were exchanged with Ag^+ ions. Subsequent UV lamp irradiation caused in-situ deposition of silver nanoparticles on the PI film. This method is relative simple and practical. Because Ag can also act as seed in electroless plating, this method provides a new possible route to seed polyimide for electroless plating.

Selective or patterned electroless plating has more applications than blanket electroless plating in the fabrication of microelectronics. Laser direct writing has been to use to create

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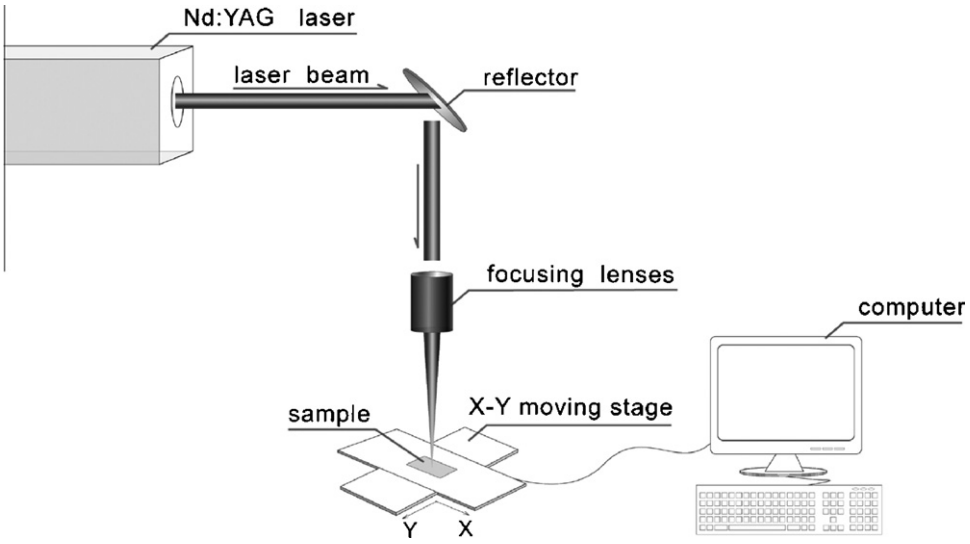


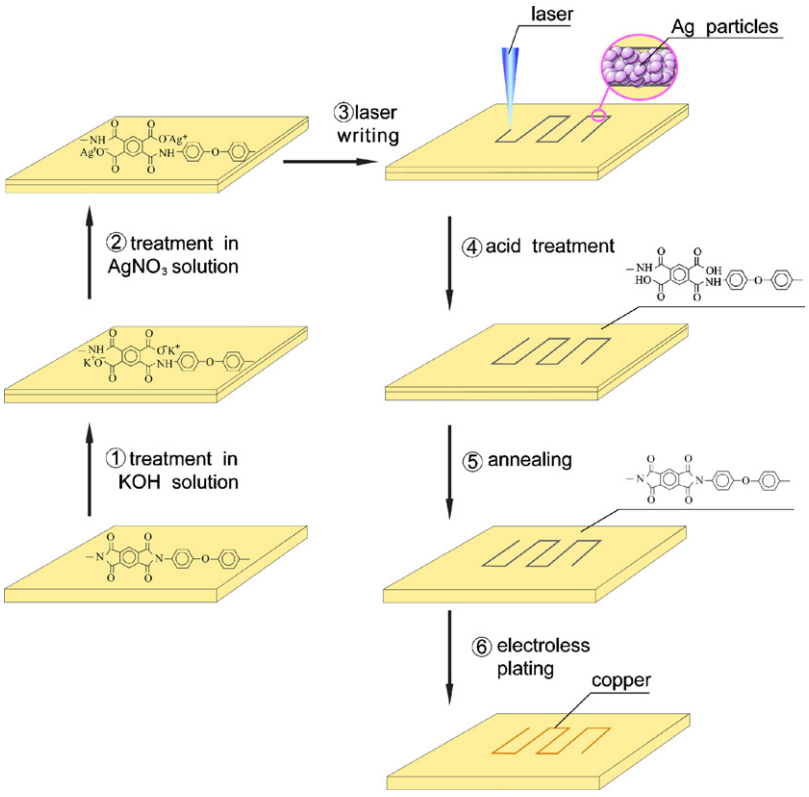
Scheme 1. Set-up of the laser system.

the selective seeds because it is a noncontact, maskless, low-temperature, and relatively simple process [11], and many efforts have been made in such laser-assisted electroless plating [5,12–17]. Laser irradiation causes deposition of silver particles on Ag^+-doped PI film more efficient than UV lamp irradiation due to the much higher light intensity of the former. Here, we report a method using laser direct writing on Ag^+-doped PI film to seed the polyimide for selective electroless copper deposition. We found that Ag particles were generated and agglomerated in situ efficiently by laser irradiation, the scanning velocity of the laser affected uniformity of the electrolessly deposited copper, and copper line-widths down to 25 μm were achieved.

2. Experimental

2.1. Materials

Commercially available PDMA-ODA polyimide films (Kapton) with a thickness of 50 μm were used as substrates.



Scheme 2. Diagram of the metallization process.