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Selective metallization on copper aluminate composite via laser direct structuring technology

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ABSTRACT

This study focused on synthesizing copper aluminate and the compound's applicability to laser direct structuring technology. Since aluminum weighs less and costs less than chromium, this study investigated its potential as a substitute in copper chromate, the main additive of LDS materials. Copper aluminate was synthesized using a sol-gel method. The synthesized powder was then applied to two types of resin, polycarbonate (thermoplastic) and polyimide (thermosetting). After optimum processing at each laser parameter, the metal patterns are formed by electroless plating. Fabricated patterns were observed using optical microscopy. This study confirmed that copper aluminate can be used in LDS (Laser direct structuring) technology and that, furthermore, it supports the formation of conductive patterns with both thermoplastic and thermosetting resins.

1. Introduction

Due to the versatility of the injection molding and structured metallization process, mechanical and electrical functions can be directly integrated into a wide variety of molded interconnect devices (MIDs) [1]. The concept of molded circuit boards (MCBs) was introduced in the USA in 1983 and their industrial potential led to the development of MID technology in 1985 [2]. MCBs are made by combining the printing processes used to make classical printed circuit boards (PCBs) with injection molding [3]. MID fabrication is a multistep process. Most MID production starts with the injection molding of a thermoplastic part, and involves either single or two shot molding. In single shot molding, a single injection molding process of a thermoplastic material produces the MID, whereas in two shot molding, two successive injection molding processes are used, of which only the second layer is platable. The next steps of MID production are circuit structuring and selective metallization. Circuit structuring may be accomplished by various methods such as LDS (Laser Direct Structuring), LSS (Laser Subtractive Structuring) [4], two-shot molding [5], inkjet printing [6], hot stamping [7], and others [8].

Laser Direct Structuring (LDS) is a widely used and well known method of circuit structuring for MID fabrication, in which the circuit pattern is fabricated on molded thermoplastics through laser patterning and electroless plating. Fig. 1 shows the detailed steps of the LDS process. The molded part is subjected to laser activation, which activates the surface of the molded thermoplastic, allowing selective metallization to then form the conductive pattern [9] [10]. The advantages of this technology include great design flexibility, the possibility of making circuits on 3D surfaces and higher levels of product integration with improved quality and reduced costs. The technology also allows the production of ultra-fine structures with widths and gaps less than 100 μm [11].

Selective metallization takes place on composites doped with a LDS additive. The LDS additive is key to forming a conductive pattern. The LDS additive should initially be electrically non-conducting, thermally resistant to the injection molding process, well compatible with polymers, non-toxic and low cost for mass production. The preferred selective additive is a metal oxide or organic metal complex. The LDS additive is excited and separated into metal and organic residuals by laser irradiation [12]. This is called ‘activation’. In electroless plating, the activated filler acts as a plating catalyst [13] [14]. Examples of activation fillers include Al_2O_3, CeO_2, ZnO, AlN, SIC, CuO and a Cu-Cr complex [15] [16]. When a laser is irradiated on the composite surface, the polymer matrix is removed (photo-chemical ablation) or evaporated [17], and the filler is exposed and activated. The activated filler donates

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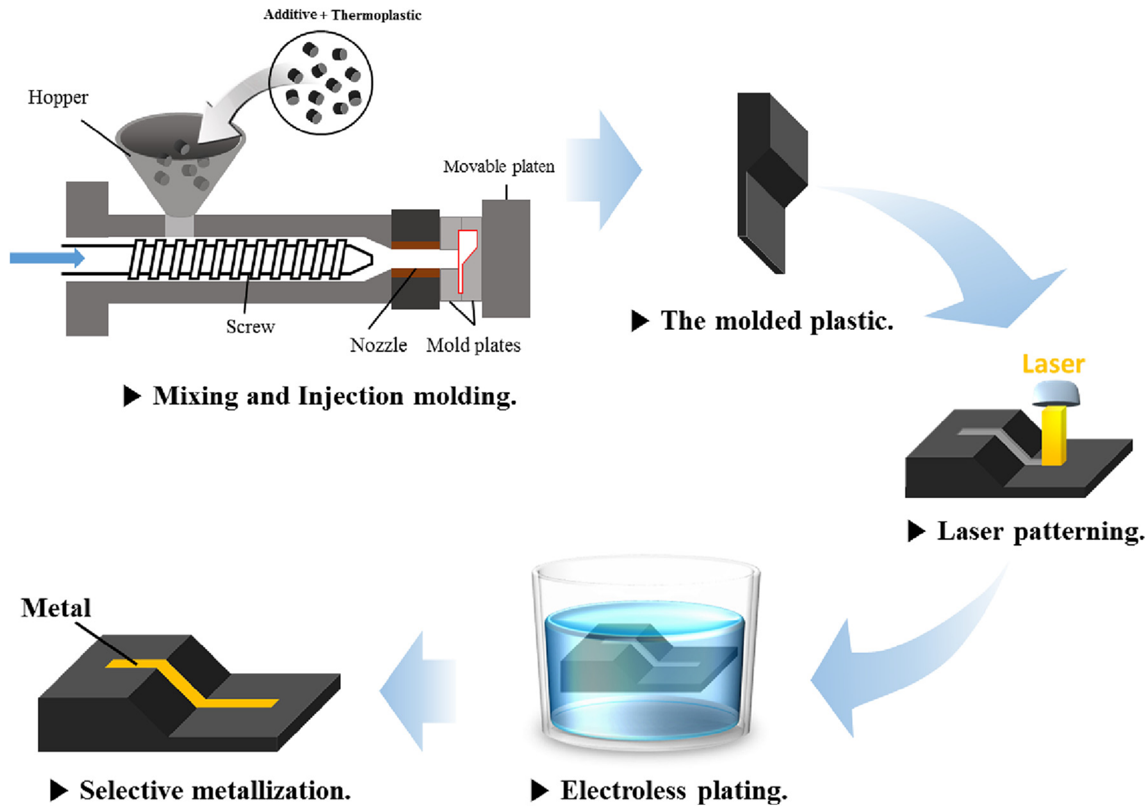

Fig. 1. Schematic of LDS process steps.

electrons in electroless plating [15] [18].

This study evaluated the characteristics of copper aluminate as the activation filler and investigated its potential in LDS technology applications. Copper aluminate was formed into nanoparticles using a sol-gel method [19] [20] [21] as nanoparticles are expected to be better able to form fine conductive patterns. Overall, this study confirmed that copper aluminate can form conductive patterns using LDS technology.

2. Experimental

2.1. Synthesis of copper aluminate

The copper aluminate was synthesized using a sol-gel method. Copper nitrate trihydrate ($Cu(NO_3)_2 \cdot 3H_2O$, 99–104%, Sigma-Aldrich) and aluminum nitrate nonahydrate ($Al(NO_3)_3 \cdot 9H_2O$, ≥98.0%, Sigma-Aldrich) was used as received. Citric acid ($HOC(COOH)(CH_2COOH)_2$, anhydrous, Sigma-Aldrich) was used as a complex agent. Firstly citric acid was dissolved in distilled water, followed by copper nitrate and aluminum nitrate. The molar ratio of citric acid to metal ions was fixed at 13:1 and that of copper nitrate to aluminum nitrate at 1:2. The solution was stirred until complete dissolution was achieved. The color of the solution was clear blue after 30 min. The solution was heated at 110 °C for 6 h to remove excess water. After excess water removal the solution became viscous indicating formation of the precursor had formed. The precursor was calcined at 600 °C for 5 h to remove organic matter, and, to finalize crystal structure formation, heated further at 900 °C

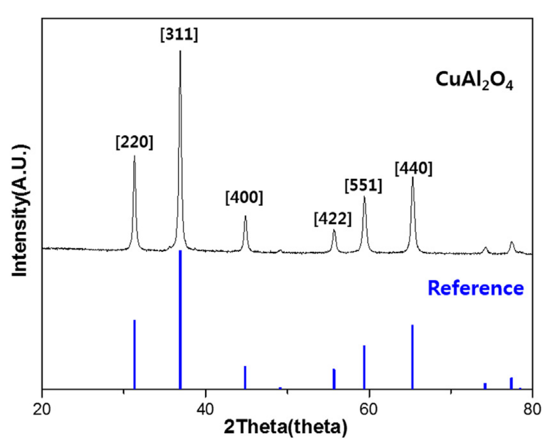

Fig. 2. XRD analysis of synthesized $CuAl_2O_4$ powder.

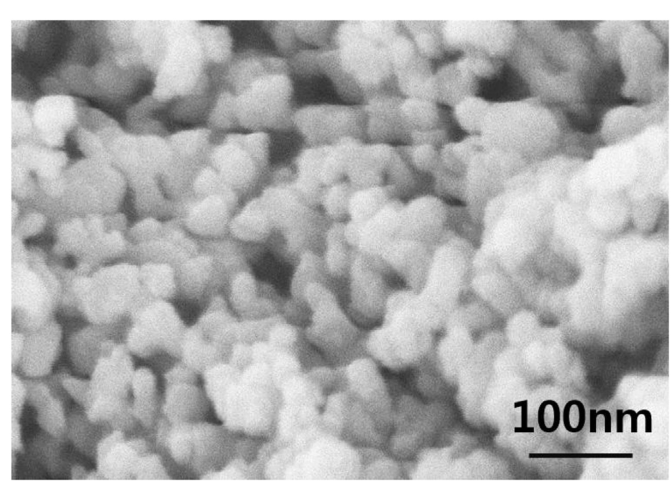

Fig. 3. High resolution scanning electron micrographs of synthesized $CuAl_2O_4$ powder.