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Study on thick film resistor and electrode fabricated by laser micro-cladding electronic pastes

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Abstract

Nowadays, electronic devices are required to be smaller, to have a high-density integration and to be of lower cost. In order to meet the developing demands, some new techniques have appeared in recent years. In this paper, a technique named laser micro-cladding electronic pastes is used to fabricate the thick film resistor and electrode units on insulator substrates without using a mask. The results demonstrate that the high-quality resistors could be fabricated by laser micro-cladding. However, the processing steps are very important since they have significant effects on the surface finish, the extent of diffusion between electrode film and resistor film, and on the reliability of the resistors. Laser micro-cladding electronic pastes may become a novel technique to fabricate high quality conductive lines (electrodes) and resistors with good properties that will come into industrial application in the future.

Keywords: Laser micro-cladding; Electronic paste; Direct fabrication; Resistor; Electrode

1. Introduction

In order to fabricate the conventional thick film circuit board, the following steps are usually adopted to get accurate resistors: firstly, the resistor pastes are pre-placed on ceramic substrate by means of screen printing; secondly, the ceramic boards are placed in a stove to sinter the electronic pastes on the boards; thirdly, the resistance value is adjusted by laser trimming until the required resistance value is obtained [1]. Although this method is rather reliable and is a low-cost route for large-scale production, it is a long production cycle because of a requirement of the mask. The minimum widths of the production lines are typically no less than 100 μm for this method. All these shortcomings limit its application in many situations. Nowadays with the development of subminiature electron components and high-density electronic packaging, the technical requirements of fabricating finer patterns on the substrate are higher, and the technical requirements are more rigorous. Therefore, it is important to develop new techniques to fabricate the electronic components and circuits on insulator substrates which should be low cost, short production cycle and manufactured to high precision.

A novel technique of laser micro-cladding electronic pastes (LMCEP), which combines conventional laser cladding technology with the recently developed direct writing technology suggested by Chrisey [2–5], has been proposed by our group to fabricate the conductive lines and electronic components directly [6–13]. Compared with the traditional thick film technology, LMCEP possesses many advantages such as high precision, flexible processing, short production cycle and it is contamination-free. In addition, other electronic components such as resistors and capacitors can also be fabricated by changing the composition of the electronic pastes. Especially, the resistors can be directly fabricated on the substrate with the different shapes and sizes according to the designed patterns with the help of CAD/CAM system [14].

In this paper, the use of LMCEP is illustrated for writing thick film electrode and resistor units directly on the insulator

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boards. The processing steps for fabricating the electrodes and resistors are very important, as the interfacial behavior between resistor and electrode may have a serious effect on the stability and reliability of the resistors due to the rather complicated interaction of the laser and materials. For example, resistance values will decrease and contact resistance values in the interface will increase because elements in the electrode materials may diffuse into the resistor film during laser heating. Therefore LMCEP has been studied systematically with different processing steps to fabricate the resistors and electrodes directly on ceramic substrates. The influence of interfacial behavior between resistor and electrode on properties of resistor is analyzed, based on which, the optimized process to fabricate the actual resistor patterns attached with the electrode by LMCEP is proposed.

2. Experimental materials and equipment

In the experiment, a fiber laser is adopted with the wavelength of 1.071 μm, the minimum spot diameter of 20 μm and the maximum output power of 50 W. The paste of resistor is mainly composed of Ruthenium system while that of electrode is silver system. A laser micro-cladding system (LMCS II) is developed to perform LMCEP on the electronic pastes on the 96% Al_2O_3 substrate with thickness of 1 mm.

Laser micro-cladding processing is done by optimizing laser processing parameters. After heat treatment at 450 °C, Nikon Eiphot optical microscope was adapted to record surface morphology and microstructure of the coatings. A scanning electron microscope (SEM) was used to observe the top surface and cross-section and surface profile-meter to analyze surface smoothness.

Electrodes and resistors were fabricated by four kinds of processing steps. The main principle of processing is as follows: the laser scans coating after the electronic paste is evenly coated on substrate by rotating machine. The laser gives rise to complex chemical reactions in the coating so that the resistor or electrode film is strongly bonded to the substrate on the areas scanned by the laser. The areas of the coating which are not scanned by the laser retain their intrinsic properties and can be cleaned off from the substrate using an organic solvent while those coatings scanned by the laser remain on the substrate, and the defined pattern of electrode or resistor is formed after heat treating at 450 °C.

3. Experimental results

3.1. Surface morphology and microstructure of the resistors and electrodes fabricated by LMCEP

3.1.1. Processing procedure 1

This processing procedure is as follows: firstly, the electrodes are fabricated; then, the resistors are fabricated; finally, both resistors and electrodes are sintered together. The surface morphology and the microstructure of the sintered resistor and electrode are shown in Fig. 1.

As shown in Fig. 1(A), the surface morphologies of the electrode and the resistors on the ceramic boards, which show that the microstructure of film is homogeneous and dense (Fig. 1(B)) after the coatings, are scanned by laser beam. The conductive particles are diffused into the resistors in the interface area between the resistor and electrode after heat treatment because of the heat diffusion, as shown in Fig. 1(C). The boundary is irregular between the resistor and electrode. The diffusion distance of conductive particles gradually weakens along the resistor body, just as shown from Fig. 1 (C–F). However, the composition diffusion between resistor and electrode is relatively slow. The microstructure is changed gradually from the pure conductive particles to the mixture of

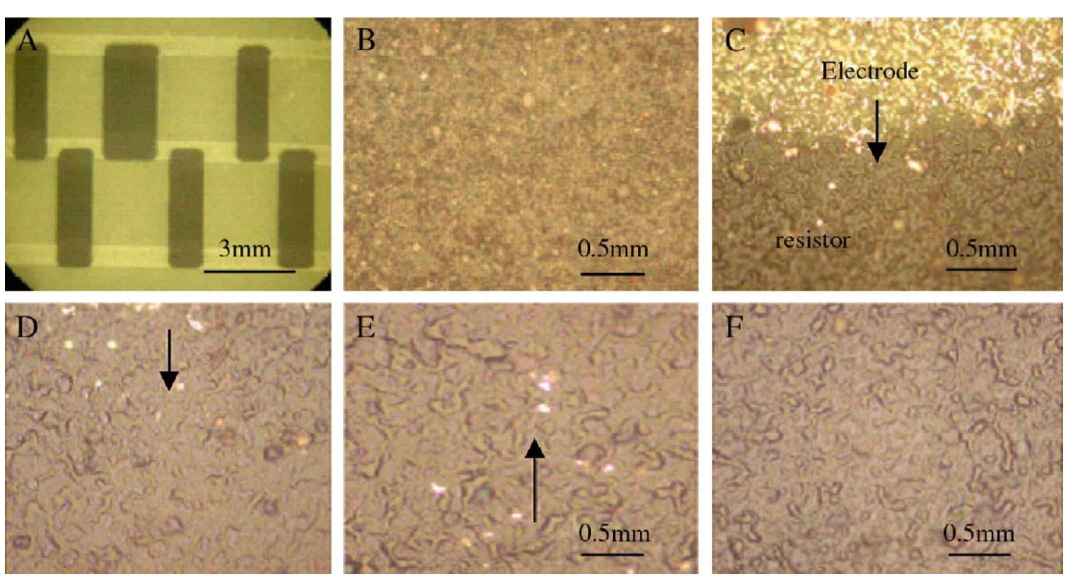

Fig. 1. Morphology and microstructure of resistor and electrode by processing procedure 1. (A) Morphology of interface between resistor and electrode after sintering; (B) microstructure of film after laser irradiation; (C) microstructure of interface between resistor and electrode after sintering; (D), (E), (F) are microstructures of resistor film moving down along resistor long side of (C).