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Evaluation of electrolessly deposited NiP integral resistors on flexible polyimide substrate

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Abstract

Integral nickel–phosphorus (NiP) resistors were fabricated on flexible polyimide (PI) substrates by electroless NiP deposition. The deposition process was first set up for standard rigid epoxy substrates and then modified for the flexible substrates. The effects of the PI surface modifications on the interfacial adhesion (NiP/PI) were measured experimentally by the pull-off method. The process parameters were optimised to give good adhesion. The mechanical durability of the electrolessly deposited thin film NiP resistors was tested by measuring the electrical resistance during cyclic loading. The results showed the resistors to be mechanically stable. The electrical resistance was also monitored continuously during exposure to corrosive gas environment. The corrosive environment had no significant effect on the resistance of either the electrolessly deposited resistors or the commercial integral resistors used as a reference. The results show that resistors can be fabricated on flexible PI substrate by the described method.
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1. Introduction

Flexible circuit boards are increasingly utilised in leading-edge portable electronics and medical instruments. So far, they have been used mainly for interconnection purposes [1,2]. However, as the portable devices become even more versatile, the component integration is beneficial for many applications. The integration improves the performance of electronic devices, while further reducing their size and power consumption [3,4]. The manufacture of totally flexible assemblies can be established on the basis of thinned chips and integral passive components [5,6]. For active component integration Chip-on-flex (COF) and flexible integrated module board (IMB) assembly techniques can be utilised [7–10]. It is expected, that the flexible assembly approaches will be especially important in wearable electronics, roll-up displays and products intended to operate at the human–machine interface, where lightness and flexibility are key factors for reliability and user-friendliness [11,12].

The fabrication of integral resistors can be realised by various thin and thick film methods. One well-known technique involves the use of dual metal foil laminate, which comprises a conductor metallisation on a resistive material [13]. These foils have been tested with use of various substrates including flexible polyimide [14]. An alternative approach is to take advantage of electroless deposition and to build up the resistors additively [15,16]. It is to be noted that the capital outlay for electroless deposition process is low in comparison with the

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vacuum processing and that the electroless deposition process is reasonably quick when thin (<500 nm) resistive coatings are fabricated [3,15].

Polyimide (PI) meets most of the requirements set for polymer substrates in advanced electronics. It has low dielectric constant, good chemical and thermal stability, low coefficient of thermal expansion and adequate mechanical properties. When a PI film is coated, it often is laminated with a metal foil using an acrylic or epoxy adhesive. Also adhesiveless laminates are available, based on either sputter-deposited copper or laminated foil [17]. The use of high-vacuum metallisation techniques ensures good adhesion between most PI substrates and metals [18–20]. Metallisation by wet processing has been widely studied for a number of polymer substrates [21–25]. The metallisation of PI in a wet process is particularly challenging, however. Copper diffuses into PI at elevated temperatures and causes polymer degradation at the metal/PI interface as well as compromised electrical performance [20,26,27]. Employing a diffusion barrier metallisation prevents the migration of copper. Unlike copper, nickel does not diffuse readily into PI [28]. A thin Ni metallisation can thus act both as a diffusion barrier to prevent the migration of copper and as an adhesion promoter for Cu metallisations prepared on PI substrate.

We investigated means to fabricate reliable integral NiP thin film resistors on flexible PI substrate. First the resistor deposition technique was studied and optimised for epoxy substrates. Then the interfacial adhesion between electrolessly deposited NiP and flexible PI was evaluated, and on the basis of the results, the process conditions were optimised. In a third step, reliability studies on resistors on flexible PI, that were fabricated under the optimised conditions, were carried out to understand better the structural integrity and the effects of corrosive environments on the electrical performance of the resistors. The performance of the electrolessly deposited NiP resistors was compared with that of a reference series prepared from commercial conductor–resistor foil material.

2. Experimental

2.1. Fabrication of NiP resistors on epoxy substrates

The fabrication process was initially set up for standard FR-4 epoxy substrates. The substrates were 1 mm in thickness with a copper foil laminated on both sides. The copper foil was etched away and a fairly rough ($R_A \approx 1\,\mu m$) epoxy surface was revealed. The surface was then catalysed using a palladium-based catalyst (Uniphase PHP) from Alfachimici and sensitised in hydrofluoric acid (10 vol%). The sensitisation step was applied to accelerate the nickel initialisation and to ensure that the film was built up homogeneously.

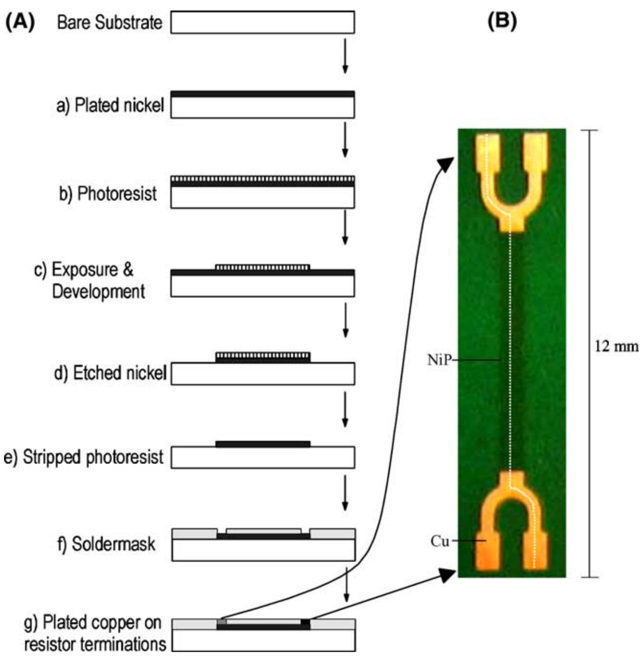

Fig. 1. (A) Schematic presentation of the integral resistor fabrication process and (B) a photograph of the integral resistor; the dashed line shows the cross-sectional plane portrayed in the schematic picture (A).

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