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Plasma surface modification of polyimide films by air glow discharge for copper metallization on microelectronic flex substrates

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Abstract

Surface modification of polyimide films such as Kapton E(N) and Upilex S by air plasmas were investigated for enhanced adhesive strength with sputtered coppers. Peel tests demonstrate this improvement, with the peel strengths of 0.7 g/mm and 1.2 g/mm for unmodified Kapton E(N) and Upilex S and 99.3 g/mm and 91.5 g/mm for air plasma-modified Kapton E(N) and Upilex S at certain plasma conditions. This study reported that the enhanced adhesive strengths of polyimide films with sputtered coppers by air plasmas were strongly affected by the surface characteristics such as surface morphology and surface energy of polyimide films. Atomic force microscopy (AFM) and sessile drop method indicated the surface roughness and the surface energy of polyimide films were much increased by air plasmas that result in much increased peel strengths of polyimide films with sputtered coppers. Electron spectroscopy for chemical analysis (ESCA) observed the increased surface energy on polyimide films by air plasmas were due to the increased surface composition of O and the increased chemical bond of C–O.

Keywords: Adhesion; Surface modification; Air plasma; AFM; ESCA

1. Introduction

The demands of electronics increasing day by day, not only light, thin, short and small but also performances are requested to improve. Therefore, the high density of electronic packages for portable electronics such as notebook, cellular phone and personal digital assistant (PDA) is needed. For diver integrated circuit (IC) of liquid crystal display (LCD) module, the flexible design of the packaging is needed. Tape carrier package (TCP) is the main package for the diver IC of LCD module so far. To meet the requirements of the light, thin, short, small and high performance for the electronics, the packages must keep on high density. The package of chip on film (COF) that use flip chip bonding to replace tape automated bonding (TAB) for TCP to provide chip connections to flex substrates by high-density connection [1]. Polyimide is the base substrate material for the flex substrates. The three layers type of flex substrate was used for TCP. Three layers of the flex substrates are Cu (18 μm)/adhesive (12 μm)/polyimide (75 μm). For three layers type of flex substrate, Cu metal layer was laminated to polyimide after adhesive was applied and partially cured. However, the adhesive layer creates certain disadvantages such as it (1) causes failure during higher temperature cycling, (2) could cause problems during hole drilling because of adhesive smear and (3) it is difficult to remove the adhesive from the copper after etching [1]. For finer patterning, a thick copper metal layer about 18 μm can be handicap because of under-etching during the etching process. These problems can be partially avoided by using an adhesiveless flexible laminate and a thin copper film. Adhesiveless flexible copper (8–12 μm)-polyimide (25–38 μm) thin film laminates. For two layers type of flex substrate for COF, Cu metal layers are coated onto polyimide by electrolytic plating, evaporation or sputtering. Proper adhesion between the copper and the polyimide film has

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to be assured even without an adhesion promoter (adhesive). Several studies indicated that the surface treatment on polyimide is needed to enhance the adhesive strength with coppers [2–9].

Egitto et al. [10] indicated that the plasmas can be used to modify polymer surfaces for adhesion enhancement by roughening surfaces, and/or introducing reactive chemical groups. The polymer surfaces were roughened to increase contact areas with coatings, enhance the mechanical interlocking with coatings, result in better adhesion with coatings [11]. The introduced reactive chemical groups on polymer surfaces were used to improve wetting that results in the spread of coatings to fill voids in the polymer surface for better bonding [12,13]. In this work, atomic force microscopy (AFM) was used to characterize surface morphology of the plasma-modified polyimide. The electron spectroscopy for chemical analysis (ESCA) was used to determine chemical compositions and functional groups of plasma-modified polyimide.

Menezes et al. [14] reported that a contact angle measurement technique can be used to estimate the interfacial energy between copper and polyimide. Based on the measured contact angle of copper cluster on polyimide, the work of adhesion of copper to polyimide is calculated. However, the contact angle of copper cluster on polyimide film is not easily determined for the industrial applications. The contact angles of three various surface tensions of liquids such as deionized water, ethylene glycol and diiodo methane on polyimide film can be easily measured in this study. Then, the surface energy of polyimide can be calculated as an indication on the wettability of polyimide. The wettability of polyimide is helpful to relate the adhesive performance with copper. In this study, the surface energy of polyimide film is calculated and discussed how to affect the adhesion performance with copper. The adhesion of copper to polyimide film, how to be affected by surface energy of polyimide film and related to the chemical compositions and chemical bonds of polyimide film is also discussed. The chemical bonds such as C–O, C=O and C–N how to play key roles for the enhanced adhesion performance of copper to polyimide film by air plasmas is investigated.

2. Experimental

2.1. Materials

Two polyimide films such as Du Pont–Kapton E(N) and Ube-Upilex S are used for this study. From the point of view on the chemical bonds of polyimide film for C–C/C–H, C–O, C=O and C–N are considered, the Kapton E(N) contains the chemical bonds of C–C/C–H, C–O, C=O and C–N and Upilex S contains the chemical bonds of C–C/C–H, C=O and C–N. The chemical bond of C–O is not found on Upilex S. To avoid the contaminations on polyimide films that affecting the adhesion of copper to polyimide, polyimide films were precleaned by wiping the surface 3–4 times with a Kimwipe that was moistened with 2-propanol.

2.2. Plasma modification

The plasma modification of polyimide films such as Kapton E(N) and Upilex S were carried out in a low-temperature glow discharge plasma chamber, as shown in Fig. 1. Air monomer was fed in the reactor, the plasma parameters were set as shown in Table 1. The reactor chamber was pumped down to a chamber pressure less than

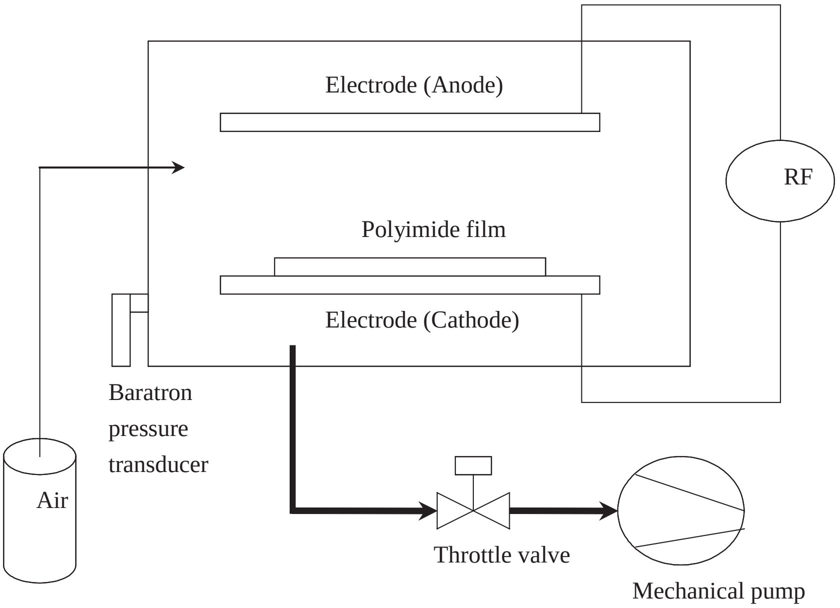

Fig. 1. The system for air plasma modification.