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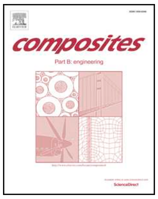

# Enhancing adhesion performance of sputtering Ti/Cu film on pretreated composite prepreg for stacking structure of IC substrates

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ABSTRACT

Successive pretreatments containing mechanical grinding, desmearing and $O_2/CF_4$ plasma were employed to modify the surface of polymer-based composite prepreg to improve the adhesion with sputtering Ti/Cu film. Surface morphology and roughness were characterized to find out the difference of microstructure change for pretreated prepreg. In addition, the variation of chemical bonding and surface wettability for pretreated prepreg were investigated for the possible explanation on the adhesion enhancement between Ti/Cu film and prepreg. The results indicated that the pretreatment of prepreg could lead to better adhesion performance of 6.54 N/cm between Ti/Cu film and prepreg, compared to the case for untreated prepreg with that of 1.77 N/cm.

## 1. Introduction

Electrical products call for various properties of polymer-based composites to carry out multifunctional and intelligent applications [1–6]. A stacking structure of IC substrates with conductive copper and dielectric composite is needed for the formation of high density interconnection [7–9]. In this way, chips packaged with integrated circuit (IC) substrates can act as important supports to improve the performance of electrical products but the connection between conductive copper and dielectric composite should be strong enough to contribute to reliable working of IC substrates.

Coreless processes of IC substrates from the stacking structure of electroplating copper pillars and patterns are designed to avoid traditional manufacture with microvia interconnection through complicated processes including laser drilling, desmearing and electroless copper plating, etc [7,9]. Conductive seed layer of sputtering Ti/Cu film on polymer-based composites plays a significant role on bottom-up plating of copper pillars and patterns for coreless IC substrates. Thus, the adhesion between sputtering Ti/Cu film and polymer-based composite prepreg should be well controlled to obtain good connection of conductive copper and dielectric composite.

Generally, the adhesion of polymer and metallic matrix is so poor that various surface treatments are introduced to improve mutual adhesion performance. Brown oxidation of copper surface was usually used to obtain good adhesion performance with the prepergs but the roughened surface of copper patterns could result in electrical signal attenuation to limit the signal integrity during high frequency transmission. In this way, surface treatments are attracted to improve polymer adhesion. Direct mechanical surface roughening are a simple method to change the morphology and roughness of polymer surface. André et al. reported that the interface adhesion between composite and aluminum was investigated to find out the difference of metal–composite adhesion after three surface treatments containing mechanical grinding, sandblasting, and sandblasting combined with plasma activation [10]. In addition, plasma treatment is another effective method for polymer surface modification. Plasma was employed to enhance the adhesion of copper layers with polyimide (PI) films [11,12]. The adhesion between copper foil and epoxy matrix of prepreg could be enhanced after plasma treatment of no-flow prepreg [13,14]. Surface roughening of metal layer can also lead to good adhesion with polymer structure.

In this work, the adhesion between polymer-based composite prepregs and sputtering Ti/Cu film was investigated to confirm a good pretreatment after successively mechanical grinding, desmearing and

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**Table 1**
Working condition of the plasma source.

| Plasma gases | Power (W) | Flow of gas (sccm) | Temperature (°C) | Time (min) |
|---|---|---|---|---|
| $O_2/CF_4$ | 1800 | 350/200 | 35 | 6 |

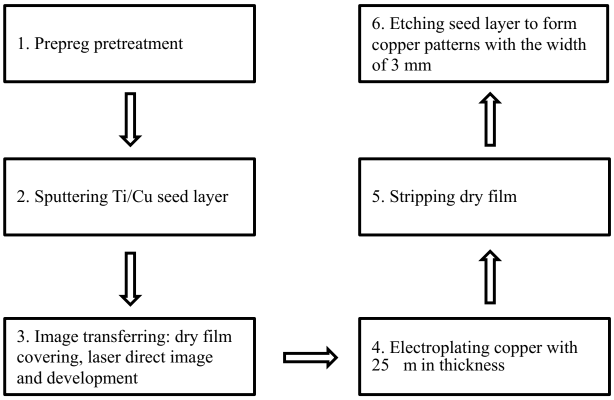

**Fig. 1.** The process to obtain required copper patterns for peel strength test.

$O_2/CF_4$ plasma treatment of prepreg surface. The surface chemical composition, surface morphology and roughness, and surface wettability of prepreg were measured to explain the cause of the adhesion difference.

## 2. Experimental

### 2.1. Pretreatments for adhesion test

Composite prepregs containing 73 wt% epoxy and 27 wt% $SiO_2$ microsphere particles were purchased from Hitachi Chemical Co., Ltd. The prepregs with a dimension of 515 mm × 419 mm × 58 μm were mechanically grinded using an automatic brush machine (GSH-MABB, Zhuhai Goal Searchers Co.) with the working parameters of 2 A and 2.5 m/min. After desmeared under potassium permanganate solution, above grinded prepregs were dried to remove water vapor under argon atmosphere at 120 °C for 60 min. Thereafter, $O_2/CF_4$ plasma pretreatment was employed to further activate and clean the surface of prepregs using a plasma device (MKII-1.5, Shanghai Risun Instrument Co.) with the working parameters listed in Table 1.

The prepregs with each successive pretreatment were respectively dried under argon atmosphere at 160 °C for 60 min for the subsequent sputtering Ti/Cu film as a plating seed layer. The sputtering deposition of Ti/Cu film was carried out under argon atmosphere at pressure of $5 \times 10^{-6}$ mbar at the power of 13 kW for Ti and 8.5 kW for Cu, respectively. The seed layer on the pretreated prepreg surface contained the former sputtering Ti with 0.1 μm in thickness and the latter sputtering Cu with 0.8 μm in thickness. Fig. 1 presented the processes of the required plating copper patterns with 3 mm in width and 25 μm in thickness on Ti/Cu films for peel strength test according to the standard of IPC-TM-650 2.4.8.

### 2.2. Characterizations

The surface microstructures of the prepregs were observed using a scanning electron microscope (SEM) (SIGMA 300, Zeiss). Surface roughness with the evaluation of the arithmetic mean surface roughness (Ra) was measured using a non-contact surface profilometer (GTK-15-0221, Bruker). Chemical bonding of pretreated prepreg films were characterized using a Fourier transform infrared spectroscope (FTIR) (iS50, Nicolet). The contact angles were measured by water contact angle analyzer (JY-PHa, Chengde YouTe Instrument Manufacturing Co.) with the ellipse fitting method to determine the wettability of the surface for pretreated prepregs. The adhesion between Ti/Cu film and prepreg was investigated using a 90° peel-off tester (PT-800, Guangdong XUYO Co.).

## 3. Results and discussion

### 3.1. Surface microstructure of pretreated prepregs

Surface treatment of polymer and polymer composites plays a significant role on the performance modification to improve the deposition of conductive particles for multifunction application of electronic products [13,15–17]. Fig. 2 presents the surface morphology of composite prepregs with successive pretreatments. As displayed in Fig. 2a,

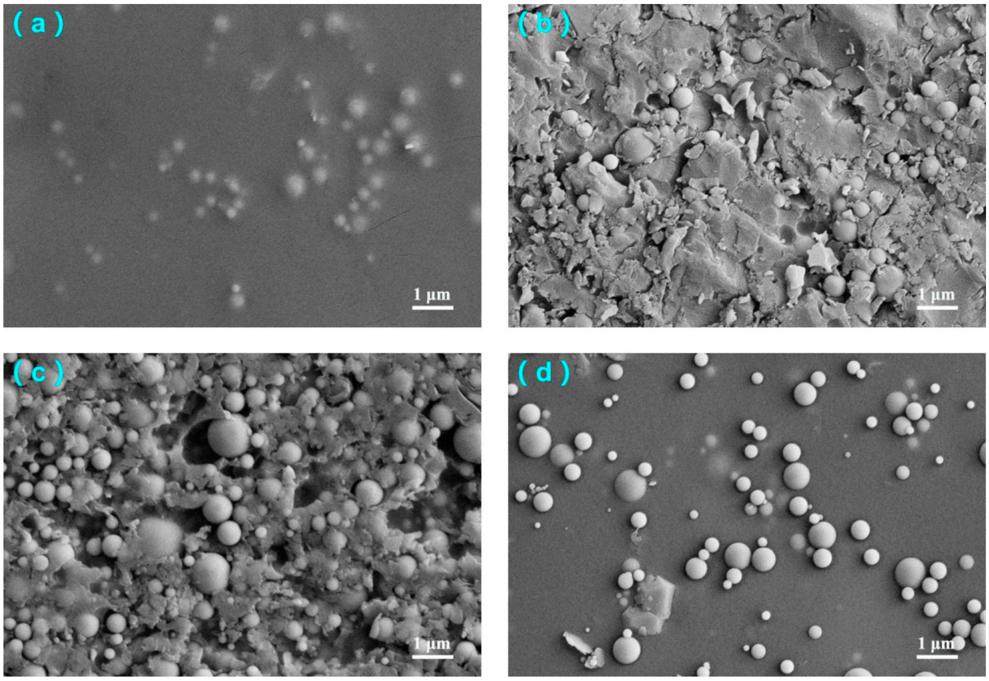

**Fig. 2.** Surface morphology of prepregs with different pretreatments: (a) no pretreatment; (b) mechanical grinding; (c) desmearing; (d) plasma treatment.