Redistribution Layer Preparation on Glass Panel for Panel Level Fan Out Package by Photosensitive Polyimide

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We successfully developed redistribution structure by using photosensitive polyimide and all wet Cu plating processes. To obtain the structure, patterned Cu was obtained by non-electrical plating on photosensitive polyimide layer with a mask of photo-resist. Various types of surface treatments on polyimide layer were investigated to obtain good adhesion between Cu and polyimide. In this work, we coated the photosensitive polyimide by a slit coater and found a suitable wet surface treatment to obtain good adhesion to plated Cu. The all wet Cu processes are composed of wet activation process and electro-Cu plating process. By combining all these processes, 40 μ m line and space Cu pattern was obtained by using a 500–600 mm glass panel. In addition, 2 μ m line and space Cu pattern was obtained on an 8 inch glass wafer.

Keywords: Redistribution layer, Photosensitive polyimide, Cu plating

1. Introduction

Fan-Out Package (FO-package) is one of advanced packages due to its low profile, good electric properties, and good heat dissipation property [1]. The FO-packages are applied for application processor (AP), power management IC (PMIC), and high frequency device for smart phones [2]. Fabrication process of a current FO-package is composed of placing a semiconductor chip on a supported wafer which was coated a mold resin, and forming re-distribution layer (RDL) on the chip and the mold resin. This process is called mold-1st process. Another process is a RDL was formed on a supported wafer, then a semiconductor chip was placed on the RDL and molded on a chip. The process is called RDL-1st.

In addition, toward a cost reduction, the FO-package will be formed on a big glass panel [3]. In this work we report the RDL fabrication by combination of photosensitive polyimide and Cu plating processes on a 500 mm $\times$ 600 mm glass panel with 40 μ m line and space. And we formed the RDL structure on an 8 inch glass wafer with 2 μ m line and space.

2. Experimental

General procedure of redistribution layer preparation was shown in Fig. 1. Photosensitive polyimide was coated on Cu sputtered glass substrate (500 mm $\times$ 600 mm). Then Ni and Cu seed layer were plated on an activated polyimide surface. A photoresist was coated and patterned on the Ni-Cu layer. Then, Cu wiring pattern was plated on the Cu layer as a mask of photoresist pattern. Finally, Ni-Cu were etched. After removal from glass substrate, we obtained redistribution structure.

2.1. Photosensitive polyimide processes

Photosensitive Polyimide (LT-S8001, Toray) which was suitable for a slit coater was coated on a Cu sputtered glass substrate by the slit coater. After coating, polyimide solution was soft baked at 130 °C for 3 min by a hot-plate. Then the photosensitive polyimide was cured at 200 °C for 1 hr under N₂ atmosphere.

2.2. Surface Treatment

In order to decrease the residue on Cu surface and increase adhesive strength, polyimide surface was treated by plasma. In this work, we tried O₂

ashing, O₂ RIE, and Ar etching by PB-1000S (Yamato). Process conditions are summarized at Table 1.

Fig. 1. Process flow of sample preparation.

Table 1. Polyimide surface treatment conditions.

No.	Gas	Mode	RF Power	Gas Flow	time	Etching thickness
			W	sccm	sec	um
1	None					0
2	O ₂	PE	500	100	60	0.2
3		RIE	500	100	60	0.4
4	Ar	RIE	500	40	60	0.2
5		PE	1000	100	60	0.5
6	O ₂	PE	500	100	30	0.2
7		PE	500	40	60	0.4

2.3. Redistribution layer process

Prior to Cu plating, we investigated the effect of wet activation condition at Okuno-chemical. Then, Cu plating processes were fabricated at System Integration Platform Organization Standard's (SIPOS) at Fukuoka Univ. At first, polyimide surface was treated by wet processes to adhere with Ni and Cu seed layer. Then, Ni and Cu seed layer was formed by a plating. Photoresist (P-W-1000 Tokyo Ohka Kogyo) was coated on the Ni and Cu seed layer. After patterning of photoresist, electro Cu plating was executed at SIPOS. Finally, photoresist was removed by acetone.

3. Results and discussion

3.1. Polyimide formation

In this work, we use LT-S8001 (Toray) for insulator. The LT-S8001 is low temperature curable photosensitive polyimide having 3- μ m resolution at 7- μ m thickness. In addition, the polyimide shows good adhesion properties to Cu [4]. We examined the adhesion between copper and the polyimide by a previous report [4]. In the previous work, we

found that oxygen permeation in the polyimide film proceeds the Cu oxidation to decrease the adhesion strength. The adhesion strength did not decrease to add oxygen block layer such as sputtered Ti on the polyimide layer. We found some anti-oxidant was effective to maintain adhesion strength.

In the silicon wafer, coatings of the photosensitive polyimide are usually applied using a spin coating machine, but when I use glass substrate, it may be difficult to rotate a large glass panel. So we choose a slit coater to coat a glass panel. It is necessary to apply uniform quantity to a glass interview without protruding from a slit nozzle with the varnish which came out on the substrate when it is a slit coating machine and applies it. For a slit coating, it lowers viscosity at the time of the coating, and it is necessary a solvent dries after a coating, and to raise viscosity. In addition, it is necessary to raise wetting property to raise coating uniformity. I manufactured photosensitive polyimide suitable for a slit coating machine coating in Toray and I utilized this technique and designed the photosensitivity polyimide suitable for a slit coating. I show the result that I applied, but X-Y direction achieves less than 1% of coating uniformity together (Fig. 2).

Fig. 2. Thickness uniformity by slit coating.

3.2. Cu plating

Prior to Cu plating, polyimide surface was treated by plasma. In addition, polyimide surface was treated by wet activation process. Then, thin metal seed layer, such as sputtered Ti, Ni or Cu was formed. In order to make a good adhesion between polyimide and Cu and make a good electrical contact, we studied a plasma treatment on the polyimide surface.

The results were summarized at Tables 2 and 3 and Fig. 3. Ar treatment or O₂ ashing with small O₂ flow are effective to improve Cu adhesion. Those

surface treatments might modify the surface roughness. On the other hand, O₂ RIE did not improve the adhesion, The O₂ RIE was damaged the polyimide surface deeply.

Then polyimide surface was activated by wet chemical treatment performed at Okuno chemical. Those results were also summarized at Tables 2 and 3 and Fig. 3.

Table 2. Cu adhesive strength for various polyimide surface treatment (without UV exposure).

No	Surface treatment	UV	Activation		Cu adhesion (N/cm)
			Conc (ml/L)	Temp (C)	
1	None	None	100	30	< 0.5
			250		< 0.5
			300		< 0.5
2	O2 Ash 1000W		100		< 0.5
			250		< 0.5
			500		< 0.5
3	O2 RIE		100		< 0.5
			250		< 0.5
			500		< 0.5
			500	40	1.1
				50	1.3
4	Ar plasma		100	30	< 0.5
			250		< 0.5
					< 0.5
			500	40	< 0.5
				50	< 0.5
5	O2 Ash 2000W		100	30	< 0.5
			250		< 0.5
			500		< 0.5
6	O2 Ash 30sec		100	30	< 0.5
			250		< 0.5
			500		< 0.5
7	O2 Ash 40sccm		100		<0.5
			250		<0.5
					1.3
			500	40	2.9
				50	1.1

First, UV process prior to activation treatment was effective to increase adhesion between Cu and polyimide. However, color of metal after UV treated polyimide was something dark. On the contrary, color of metal on UV untreated polyimide was shine metallic color. We expected that UV treated polyimide might be decomposed. So we choose

surface treatment No.6 (low O₂ flow O₂ ashing) without UV for this RDL formation pre-treatment. By changing wet activation process condition, high temperature treatment gave better Cu adhesion. By using the process, we obtained 40μm line & space on 500 mm × 600 mm glass panel, and 2μm line & space on an 8 inch glass wafer.

Table 3. Cu adhesive strength for various polyimide surface treatment (with UV exposure).

No	Surface treatment	Activation		Cu adhesion (N/cm)
		UV	Conc (ml/L)	
1	None	1min	100	0.5
2	O ₂ Ash		100	2.3
3	O ₂ RIE		100	2.2
4	Ar plasma		100	3.1
5	O ₂ Ash		100	2.4
6	O ₂ Ash		100	1.1
7	O ₂ Ash		100	0.5

Fig. 3. Adhesive strength between Cu and polyimide by various polyimide surface treatment.

In addition, UV process prior to activation treatment was effective to increase adhesion between Cu and polyimide. However, color of metal on UV treated polyimide was some dark color. On the contrary, color of metal on UV untreated polyimide was shine metallic color. We expected that UV treated polyimide was decomposed

So we choose surface treatment No.6 (low O₂ flow O₂ ashing) without UV.

By changing wet activation process condition, high temperature treatment gave better Cu adhesion. As a result, I handled whole area using condition 2 and formed copper electric wiring.

Fig. 4. Redistribution pattern on 8 inch glass wafer.

Fig. 5. Redistribution layer structures on glass panel and 8 inch glass wafer.

By using the process, we obtained 40 μm line and space on 500 mm $\times$ 600 mm glass panel, and 2 μm line and space on an 8 inch glass wafer (Figs. 4 and 5).

4. Conclusion

Redistribution layer with combination of photosensitive polyimide and plating Cu was successfully obtained. O_2 ashing with low flow rate of oxygen is suitable to obtain strong adhesion to metal. UV may improve the adhesion also, but metal surface was modified. By using these things, we can make 40 μm line and space at 500 mm $\times$ 600 mm glass substrate, and 2 μm line and space at 8 inch glass wafer.

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