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The Development of Dry Film Photoresist with 15um Lines and Spaces Resolution for Semi-Additive Processing

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Abstract
Next generation IC substrate designs will feature higher interconnect density and faster signal speed than current designs. Circuitization of these substrates uses copper pattern plating followed by differential etching, which is called “semi-additive processing”. Dry film photoresist is well suited for semi-additive processing because it is available at the proper resist thickness with excellent thickness uniformity.

The performance requirements for dry film photoresist for semi-additive processing are defined as process compatibility, environmentally friendly chemistry, ease of handling, and high yield. According to “voice of the customer”, key dry film attributes are high resolution, good adhesion to a variety of copper surfaces, good line reproducibility, high yield, and clean stripping after plating with conventional alkaline solution, that is compatible with existing aqueous waste water treatment.

A novel dry film photoresist for the next generation IC substrate substrates was developed with new polymer technology for binder polymer and monomer combinations and novel photo initiator systems. This paper covers dry film performance derived from requirements voiced in the VOC.

Introduction and Background
Dry film photoresist, coated on PET base and covered with polyethylene film, is mainly used for primary imaging of printed circuit boards and package substrates. Generally, the patterning of a printed circuit board is made with Tent and Etching method with Dry Film. Recently, the demand for IC substrates is increasing, and the density of pattern is becoming higher.

As Table 1 of technology roadmap showed, the pattern will be designed 15 um line and space in 2007.

In the area of 50um pitch, the pattern cannot be made by the tenting and etching method due to etching factor issues. When attempting to form fine lines of less than 20 um line and space by etching, the cross section of pattern couldn’t keep the top width. Today, there is a more capable process for fine lines, called “Semi Additive Process (SAP)”. Figure 1 illustrates the SAP process.

The copper surface will need to be smoother by 2007 to minimize the detrimental impact of the skin effect on signal propagation at higher frequencies. As Figure 2 shows, the depth of electric current was around 2um at 1GHz. . It is desirable to keep the copper roughness small relative to the skin depth of the electrical signal. Therefore roughness needs to be reduced as frequencies go up. However, the smooth surface of the copper weakens dry film resist adhesion to the copper, due to decreasing the anchor effect.

Table 1 - Technology Roadmap for Next Generation Package

	2003	2004	2005	2006	2007	2008
Design rule (Line & Space)	20um	15 – 20 um		15um		10um
Cooper surface	Electroless copper				Sputter copper	
Patterning methods	Semi additive Process					

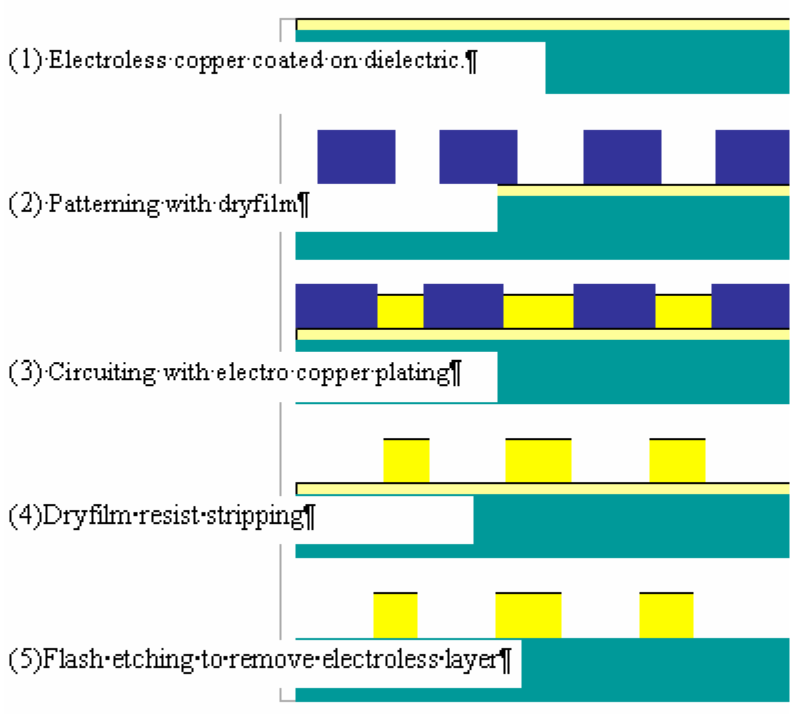

Figure 1 - Semi Additive Process (SAP)

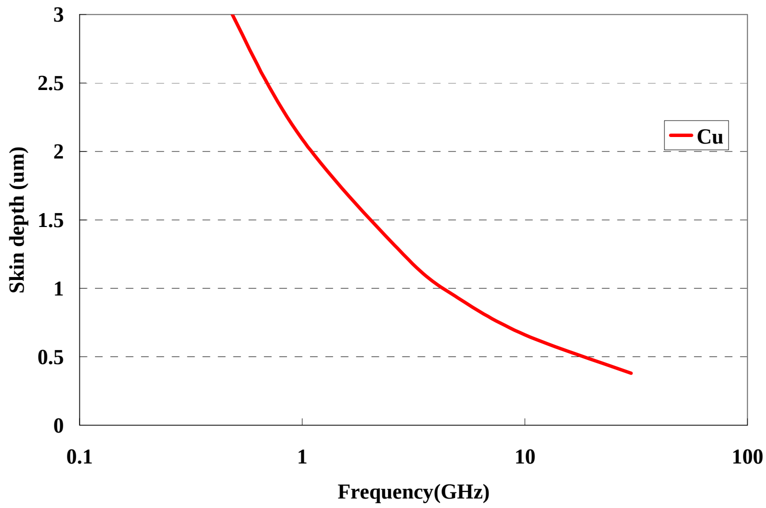

Figure 2 Skin Depth of Copper at High Frequency

Dry Film Specification and Development

According to voice of customer (VOC), we defined that the dryfilm for the next generation package patterning needs to have the following features:

1. High resolution less than 15um line and space at 25um resist thickness.
2. Good adhesion for smooth copper surface for skin effect.
3. Compatibility for SAP, such as wide development latitude, clean stripping and line reproducibility

Therefore, we developed new technology to achieve these 3 major VOC requirements through polymer technology for binder polymer and monomer combinations and novel photo initiator systems.

Dry Film Evaluation Results

Resolution and Adhesion Of New Dry Film

Figure 3 shows the results of the resolution (line and space) and the adhesion (isolated line) of the new dry film resist at 25um resist thickness. This dry film could resolve 15um line and space over a wide exposure range together with adhesion performance. It is believed that 15um line and space resolution could be reproduced, under the fluctuation of exposure intensity, when the board size is large such as 500mm x 500mm at manufacturing process.

Figure 4 shows the resist side wall of the dry film at 15um line and space pattern at 25um resist thickness after development. Since the copper surface was treated by soft etching solution, this roughness was about 0.2um Ra No resist foot or lifting at the edge of resist was observed. There was no resist residue in the space between traces. The shape of resist cross section is square.

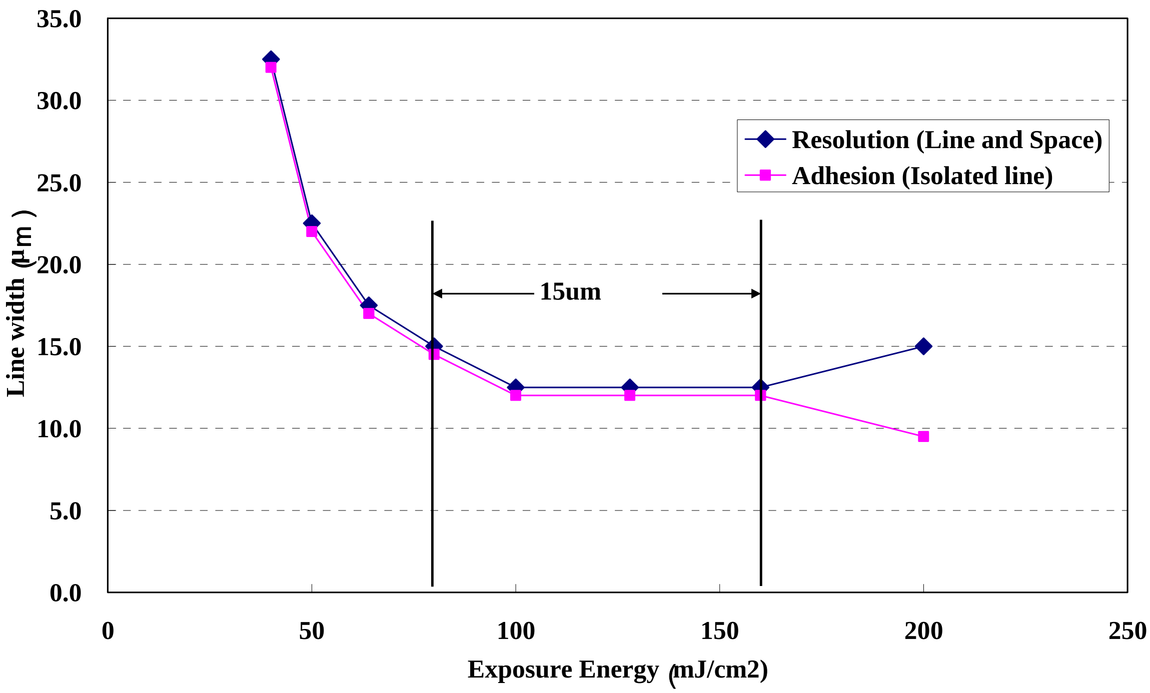

Figure 3 - Resolution and Adhesion of Developing Dry Film

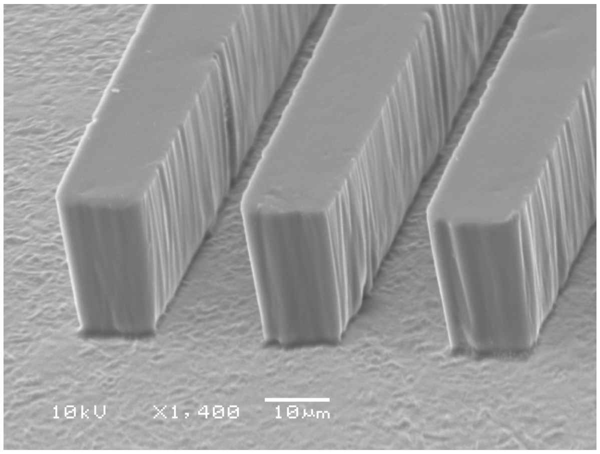

Figure 4 - Resist Side Wall of Developed Dry Film (15um Line and Space)

Adhesion to Smooth Copper Surface

It is necessary to enhance chelate chemical bond strength to adhere to smooth copper. Figure 5 showed the side wall shape of 25um resist thickness on smooth copper surface at 15um L&S. The roughness is about 0.1umRa. The adhesion of dry film resist comes from two effects. First, there is a chelate bond between copper and resist, which is a chemical bond. Second, there is a mechanical anchoring effect due to the rough surface. In this case, the developed dry film needed an improved chelate bond because there was little roughness.

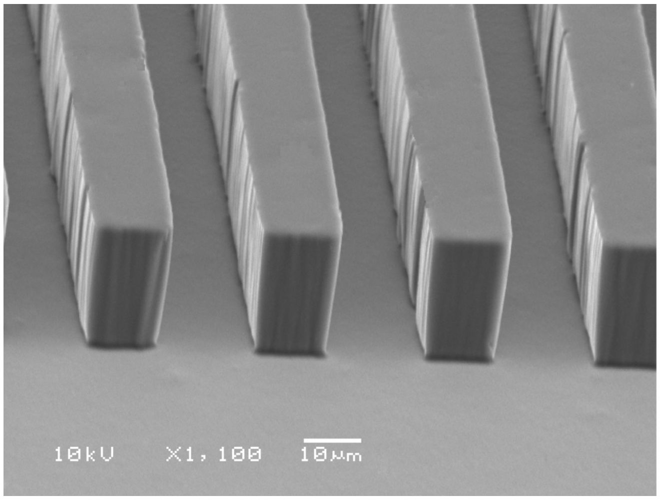

Figure 5 - Resist Sidewall on Smooth Surface (15um Line and Space)

As Figure 4, it was not observed the lifting and foot and the shape of resist cross section was square, it showed that the dryfilm resist had good adhesion performance for high frequency substrate design to eliminate skin effect.

Compatibility for SAP

Wide Development Latitude

Development latitude is a very important performance characteristic for SAP. In most cases, developing condition are severe to clean the resist in the micro via, and therefore the dry film resist needs good adhesion under aggressive over-developing condition such as 25% break point.

Figure 6 shows the resist sidewall shape at 50% break point and 25% break point conditions. There is no change of sidewall shape at 2 times longer dwell time, so this resist has a wide latitude of development.

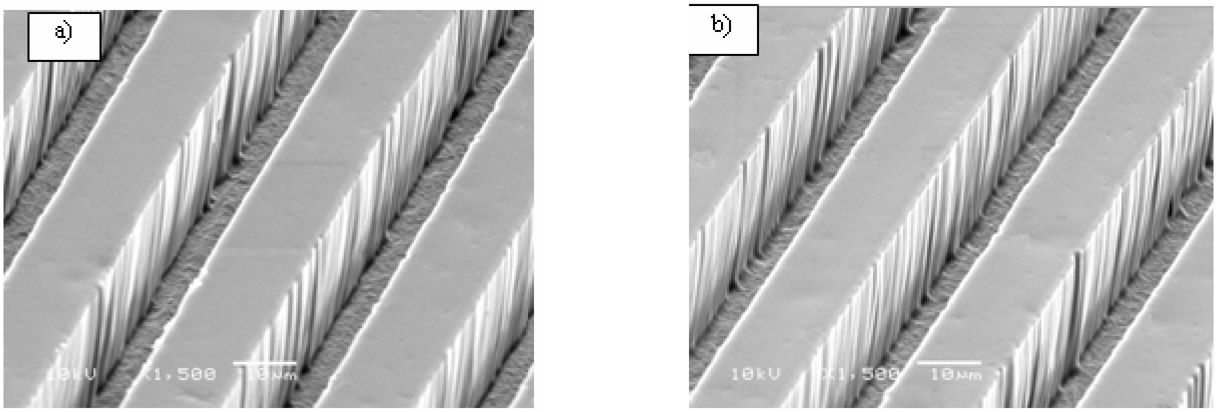

Figure 6 - The Resist Sidewall at a) 50% Break Point, b) 25% Break Point (1% Na_2CO_3 Solution, 0.15MPa)

After Plating
When dry film resist is stripped, stripping solution diffuses into the resist and swells it. This causes stress between resist and copper. In the SAP, there was a problem to strip the resist after plating due to resist swelling. In these cases, amine-based stripping solution to increasing stripping performance can be used. However, there are concerns about cost, and environmental issues. Therefore, the dry film resist needed the clean stripping performance after plating with sodium hydroxide- type stripping solutions.

Figure 7 shows the pattern shape after plating, stripped by 3% NaOH solution. Since no stripping residues were observed under these conditions, the dry film resist had good stripping compatibility with sodium hydroxide- type solutions.

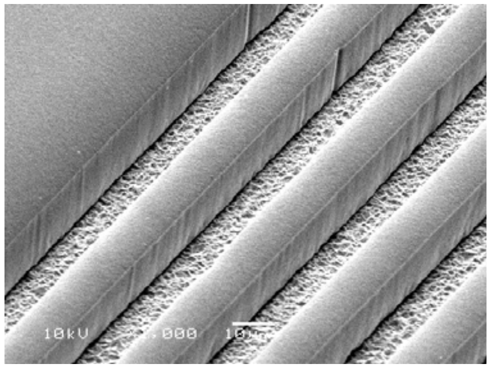

Figure 7 - The Pattern after Plating and Stripping (15um Line and Space (Plating Thickness: 15um, Stripping Condition: 3%NaOH 50C)

Line Reproducibility
Line reproducibility is an important performance criterion for SAP. Resist space width determines conductor width after plating. Stability of line width was needed for package substrate design.

Figure 8 showed the results of line reproducibility with exposure energy at 20um line and space. When the line width of the resist is increased by increasing exposure energy, the line width growth was less than 1um from 10SST to 18SST. This shows that this dry film has good line width reproducibility over a large exposure range.

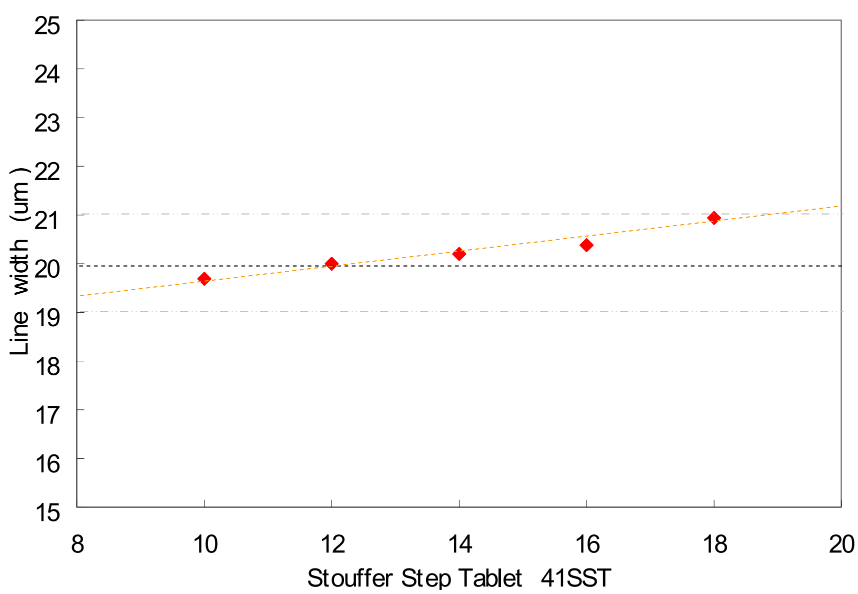

Figure 8 - Line width Reproducibility (20um Line and Space)

Summary
This novel dry film photoresist has good compatibility with the requirements for semi additive processing of next generation electronic packaging, such as good resolution, adhesion, wide development latitude, clean stripping after plating and line width reproducibility. It allows fabrication of package substrates with finer designs as needed for higher frequencies, while maintaining ease of handling and manufacturability.

References

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