Novel Wet Photoresist Strip for Wafer level Packaging

Steven Verhaverbeke, Jun Zhao

Applied Materials, Santa Clara, CA 95052, USA

An important module of the packaging based on flip-chip is the formation of solder or Cu bumps. Solder bumps are usually defined lithographically with a thick photoresist mask. After the solder bump is built up, the photoresist needs to be stripped. Solder bumps are not compatible with photoresist ashing and FEOL strip chemistries. Hence, traditionally, photoresist strip with solder bumps exposed has been carried out with solvent strip chemistries. Over the last decade, there has been a lot of research on the use of ozone for photoresist stripping. However, no real breakthrough has happened because of the limited solubility of ozone in aqueous solution and hence it's extremely slow strip rates. In this work, we are describing a novel way of using ozone in solvent chemistries that have very high strip rates. This process is widely applicable, but is extremely useful for stripping photoresist with solder bumps exposed.

Introduction

Novel packaging technology is rapidly becoming a differentiator for high end microprocessor performance and an enabler for extending Moore's Law through 3D integration. Wafer Level Packaging is defined as those steps of the advanced packaging technologies that are carried out before wafer dicing. These steps, even though belonging to the packaging side of the manufacturing line are akin to the Front End. Wet processing, which includes wet photoresist strip, wet metal etch and wet clean make up 30% of the Wafer Level Processing Line. Because of tighter pitch, currently a technology shift is happening with a transition of the use of thin positive photoresist to the use of thick negative photoresist for defining the solder bumps. Traditionally positive photoresist is limited in thickness to about 25 μm, whereas negative photoresist can easily be spun or laminated to thicknesses of the order of 100-200 μm. This technology shift creates an inflection point where new technologies are needed for stripping such thick negative photoresist layers. Currently no good existing technologies are available. Photoresist ashing cannot be used at this stage, since ashing needs temperatures >200°C and at these temperatures, the solder would melt. On top of that, the oxygen plasma causes excessive oxidation of the solder. Conventional Front End stripping chemicals, such as Piranha, cannot be used either, since these chemistries are corrosive to the solder bumps. Hence, we are limited so far to conventional solvent strippers.

Negative Photoresist

Negative photoresist allows for much taller bumps and a better definition of the bump location and pitch [1]. On top of that, negative photoresist also allows for better resistance against plating chemistries. Nevertheless, traditionally, positive photoresists have been used for this application. Since the positive photoresist was limited in thickness, the solder was overplated in a nail head shape, then the photoresist was removed and the nail head was reflowed into a ball shape. A comparison is shown in figure 1 where it can be seen that with positive photoresist (top) the solder is overplated and with thick negative photoresist (bottom) the solder remains in the photoresist pattern.

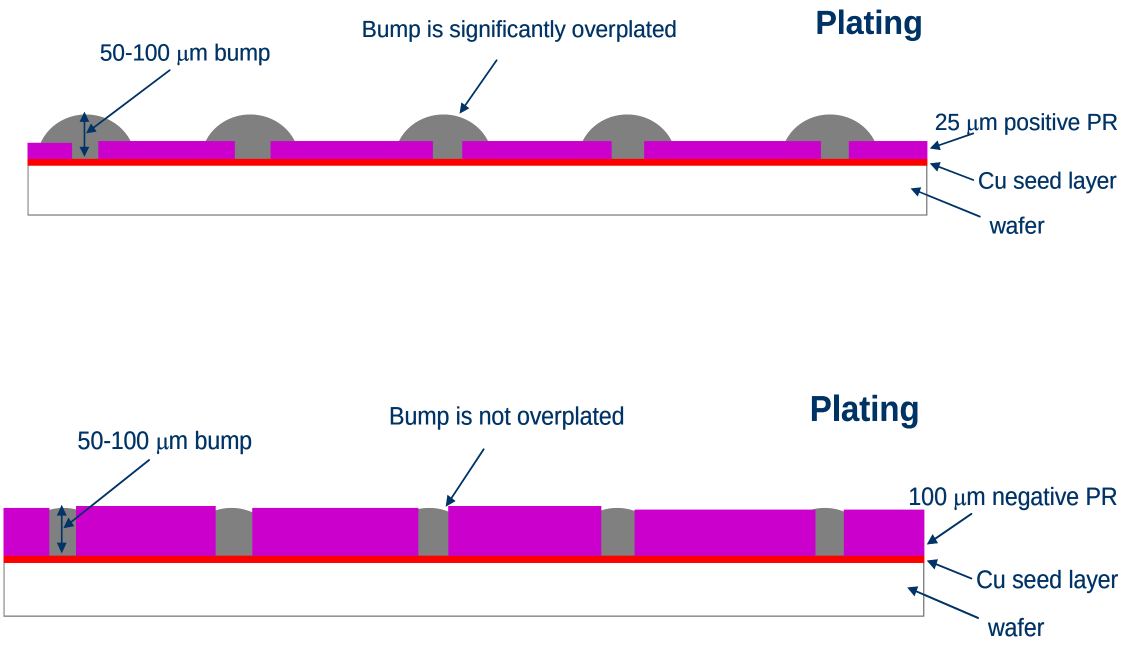

Figure 1. Comparison between positive (top) and negative (bottom) photoresist for Solder Bumping.

Because negative photoresist cross-links when exposed to UV light, these thick negative photoresist layers are extremely difficult to strip with traditional strippers that work by swelling and dissolution. We have developed a new technology that strips negative photoresist not by dissolution, but by breaking the organic polymer chemically. This can be done with ozone. Ozone has traditionally been shown to break polymer bonds by oxidation. Ozonated water has been used before to remove photoresist [2]. However, the problem with this approach is that water has a very low solubility for ozone and hence the strip rates are extremely slow. We have solved this fundamental problem by using a solvent that has high solubility for ozone and is itself not reactive with ozone. On top of that, the solvent is not corrosive to metals and specifically to the solder materials.

Ozonated Solvent

Hence, at first, the ozonated solvent was evaluated for corrosiveness to metals used for UBM (Under Bump Metallization) and for the metals used in the solder. It was found that this ozonated solvent mixture is not corrosive to any of the metals used and is not corrosive to the solder. In fact, we have yet to find a metal that is corroded at a significant rate by the ozonated solvent.

TABLE I. Metal Corrosion rates in ozonated solvent at room temperature

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Metal	Corrosion rate of ozonated solvent
Al	0
TiN	0
W	0
Cr	0
Mo	0.0006µm/min
Cu	0.002µm/min

Following the corrosiveness study, the ozonated solvent was evaluated for its stripping capability. Both conventional positive photoresist, spun-on thick negative photoresist and laminated negative photoresist was evaluated. Positive photoresist of 10 µm thickness was easily stripped in less than 15 min at room temperature. Negative laminated photoresist of 70 µm thickness was stripped in 15 min and thick annealed negative spun-on photoresist of 80 µm thickness was stripped in 20 min. In all cases, the stripping was done at room temperature. Conventional solvent strippers operate typically at 60-70 °C. The time used for this novel process is slightly faster than the conventional high temperature strippers. A SEM picture of a typical solder bump before strip is shown in figure 2 and the same solder bump after resist stripping is shown in figure 3. Conventional strippers based on solvents cannot dissolve the negative photoresist completely. Typically, they dislodge the photoresist and the resist comes off in flakes. This then floats to the surface, where it is skimmed off. This makes conventional photoresist stripping of negative photoresist in a spray technique difficult. Indeed, the photoresist flakes can easily deposit back on the wafer and on the chamber walls. A wet bench approach in this case is preferred. The ozonated solvent photoresist on the other hand, decomposes the photoresist into soluble fragments. Even though the fragments continue to decompose after dissolution into the photoresist, surface skimming is not necessary. Hence, this chemistry allows the use of a spray technique

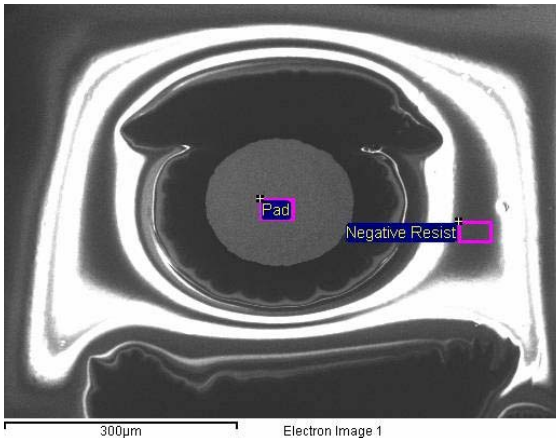

Figure 2. Solder in Negative Photoresist before strip.

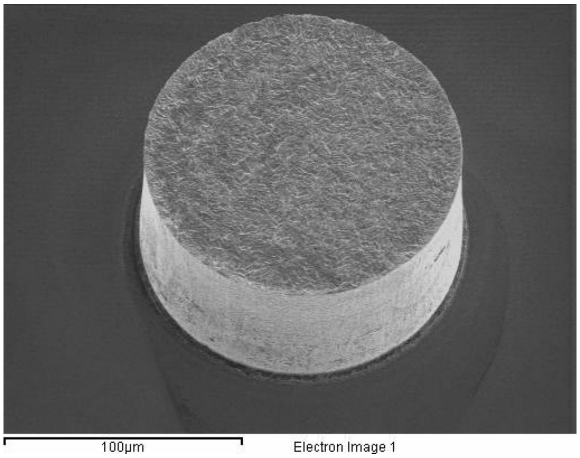

Figure 2. . Solder bump after stripping the thick negative photoresist with ozonated solvent.

Conclusion

Currently, a shift from thin positive photoresist to thick negative photoresist is taking place in the packaging process. The drivers for this shift are higher resolution on one end end the move to more economical squeegee solder paste processes on the other hand. The thick negative photoresist layers however are much more difficult to strip compared to the thin positive photoresist layers. On top of that, during the stripping process, the solder is exposed. We have developed a novel wet photoresist strip process using ozone dissolved in solvents, which is non-corrosive to solders and can be used for thick negative photoresist stripping. This process proved excellent at removing the thick negative photoresist layers without affecting the solder.

Acknowledgments

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References

1. K. Doki, “Advances in thick photoresists for flip-chip bumping”, Solid State Technology Magazine, August 2005, p.34.
2. S. De Gendt et al., Solid State Phenomena, **65-66** (1990, Scitec Publications, Switzerland, p. 165.