MICROBUMP CREATION SYSTEM FOR ADVANCED PACKAGING APPLICATIONS

Andrew Ahr, DuPont Electronics EKC Technology, Albuquerque, New Mexico

Dr. Hao Yun, DuPont Electronics Advanced Packaging Lithography Business Group, Research Triangle Park, North Carolina.

Chester E. Balut, DuPont Electronics Advanced Packaging Lithography Business Group, Atkinson, New Hampshire

Alan Huffman, RTI International's Center for Materials and Electronic Technologies, Research Triangle Park, North Carolina.

Abstract

Recently, DuPont Wafer Level Packaging Solutions has developed a photoresist/remover chemistry system to address the micro-bump market with a new family of dry films capable of imaging the required less than 50 micron pitch, and cleanly remove them. The focus of the presentation will be twofold. The first part will focus on the process development and characterization of the 40 micron thick DuPont MXAdvance * 140 dry film candidate with 2:1 aspect resolution ratio on a 40 micron pitch application with 30 – 40 micron high pillars/micro-bumps. The second part will review the results of the DuPont EKC162™ remover tests and its impact on copper and lead free, and or solder electro-deposition processes. Together, the combination of a high resolution dry film and effective remover chemistry that strips the photoresist cleanly from the wafers offers customers a viable process for producing micro-bump technologies.

Background

Today, the electronics market is faced with constant pressure from designers who want to develop "leading edge" products and customers who want more functionality in smaller packages and lower prices. This has driven the need for miniaturized 3D packages to increase portability. With this trend, came increasing I/O density and further shrinkage of the bump pitches. At the same time, the lower processing costs/die of the 300 mm wafers format has driven the need for a photoresist system that not only meets the resolution requirements of the shrinking bump pitches, but is also cost effective.

The uniform coatability of dry film with minimal waste in the standard wafer bumping applications in the 80 – 100+ micron heights and diameters is a major reason for the industry interest in this alternative to liquid photoresists. In the thinner application, there must be a remover system that cleanly strips the dry film from the substrate and does not attack the microbumps or UBM. Together, these offer customers a full solution to their lithography needs.

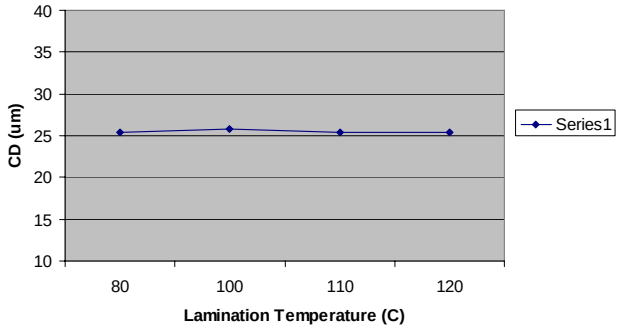
DuPont MXAdvance * 140 Lithography Process

The DuPont MXAdvance * 140 is a negative working, aqueous processable dry film photoresist that was specially formulated to enable the polymerization of fine features in thin dry film packages. In a typical photoresist system, there are photoinitiators that act as the catalyst in the presence of UV light to start the polymerization reaction. Depending upon the resolution aspect ratio that the dry film was formulated to image, an appropriate level or type of inhibitor package is added to prevent lateral growth of the dry film. For the typical microbump application, this combination of photoinitiators and inhibitors must allow adequate polymerization the large areas of dry film over the wafer surface that is surrounding the microbumps, while preventing the small 20 - 30 micron openings from being closed in. In addition to the dry film formulation, the exposure and development processes must be optimized to ensure that the openings clear out and the exposed dry film will survive the chemical attack from the electro-deposition chemistry.

The test matrix used to evaluate the impact of various process steps on the CD of the 25 micron openings was:

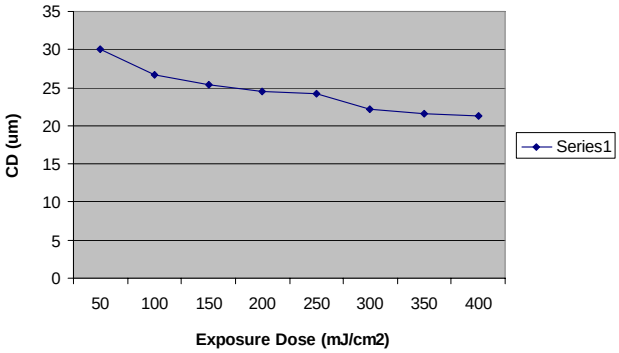
- Lamination temperature – 80, 100, 110, and 120 C,
- Exposure Energy – 50,100, 150, 200, 250, 300, 350 and 400 mJ/cm2,
- Development time – 60, 90, 120, and 180 seconds.

Measurements of the SEM's from the lamination temperature matrix showed no effect on CD. Graph 1. shows the measurement results across the test parameters.



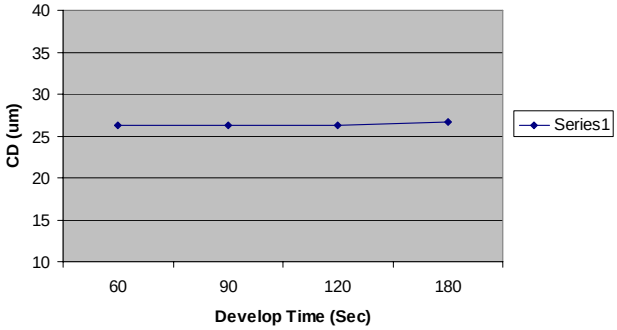
Graph 1. CD versus Lamination Temperature

Measurements of the SEM's from the exposure energy matrix showed that in the recommended 150 – 250 mJ/cm2 exposure range the CD for the 25 micron opening was +/- 1 micron. Graph 2. shows the measurement results across the test parameters.



Graph 2. CD versus Exposure Energy

Measurements of the SEM's from the developer time matrix showed that over the test matrix the CD for the 25 micron opening were within 1 micron. Graph 3. shows the measurement results across the test parameters.



Graph 3. CD versus Develop Time, secs

The results of the exposure testing of the DuPont MXAdvance * 140 revealed that the optimum exposure range was in the 150 – 250 mJ/cm2 range. SEM's of the sidewalls for the required 20 micron openings are shown in Figures 1 and 2.

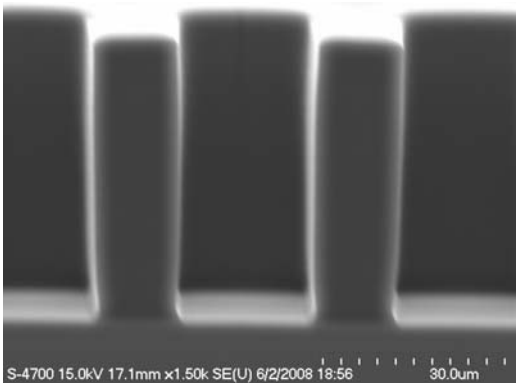


Figure 1. Energy 200mj/cm2 Opening 20um/Pitch 35um

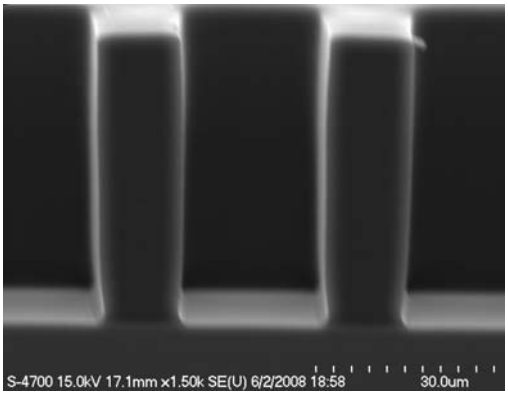


Figure 2. Energy: 250mj/cm2 Opening: 20um/Pitch 35um

The DuPont MXAdvance* 140 lamination through plating processes used for the tests were:

- Lamination – DuPont HRL-24 with Hot Roll Temperature of 100 C @ 1 meter/minute
- Exposure – Suss MA-6 Mask Aligner with soft contact
- Develop – Semitool Spray Etch Tool with 1% sodium carbonate @ 30 C for 60 – 90 seconds develop time and 60 seconds rinse time
- Descum – O2 Descum prior to plating
- Plating – NEXX Systems ShearPlate* tool with Copper Sulfate and Pb/Sn chemistries.

EKC Technologies EKC162™ Experimental Procedures and Results

A test matrix was devised that would require nine different tests runs using three different temperature settings (45°C, 50°C, & 55°C) and three different process times (10 min., 15 min., & 20 min.). The test matrix is shown in Table 1.

Table 1. Cleaning Test Matrix with EKC162™ on DuPont MX Advance* 140 Dry Film Wafers

Temp. Time	45˚C	50˚C	55˚C
10 min	X	X	X
15 min	X	X	X
20 min	X	X	X

The EKC162™ used in this evaluation was from a 10-gallon batch made in DuPont / EKC Technology's R&D laboratory on September 16, 2008. Approximately 300 ml of EKC162™ was poured into a 600 ml beaker and placed on a temperature controlled hot plate. A stirring bead was also added and set to 200 rpm.

Two wafer pieces, one with copper pillars and another with Pb/Sn solder capped pillars, were run together during the test runs.

After processing in EKC162™, each wafer piece was inspected with a Nikon optical microscope and a Hitachi scanning electron microscope. The SEM images of the copper microbumps at 45 C are found in Figure 3 - 5 and the solder microbumps at 55 C remover temperatures are found in Figure 6 - 8 of this report.

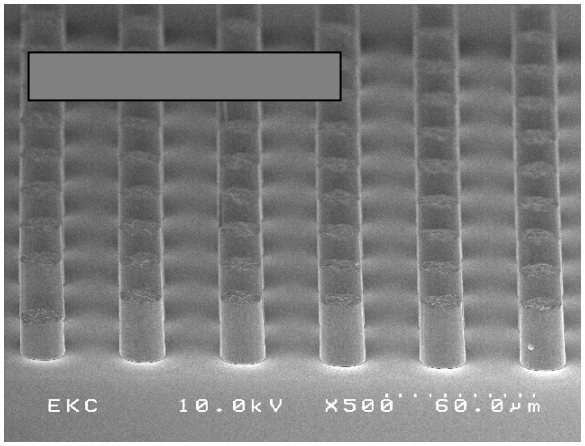


Figure 3. EKC162™ / 45° C / 10 minutes

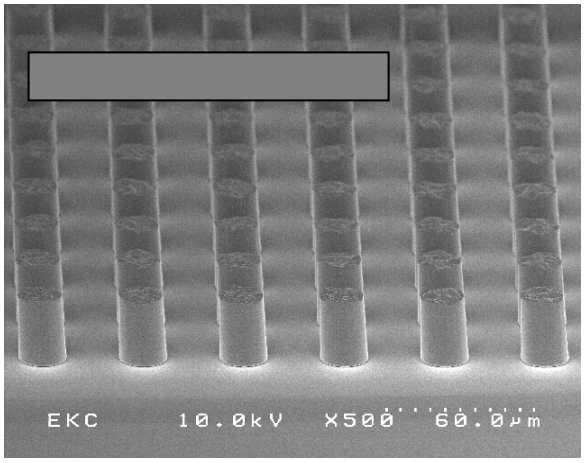


Figure 4. EKC162™ / 45° C / 15 minutes

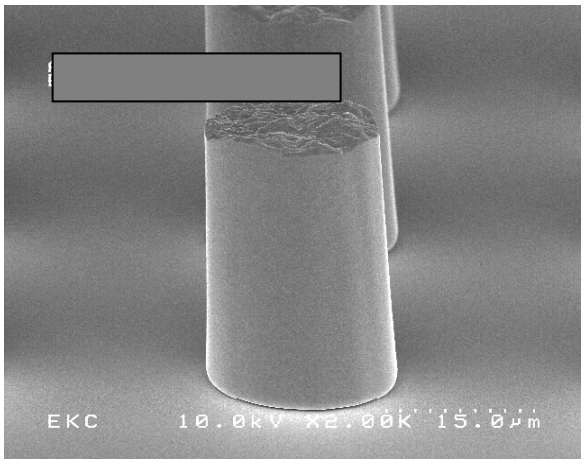


Figure 5. EKC162™ / 45° C / 20 minutes

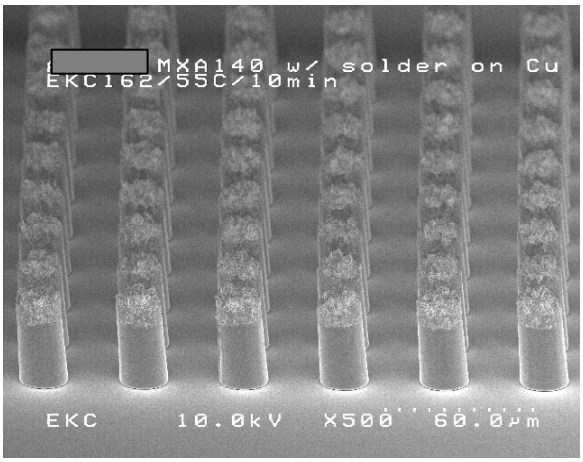


Figure 6. EKC162™ / 55° C / 10 minutes

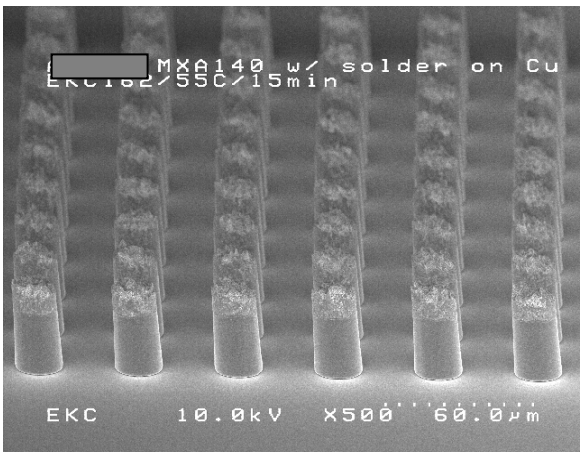


Figure 7. EKC162™ / 55° C / 15 minutes

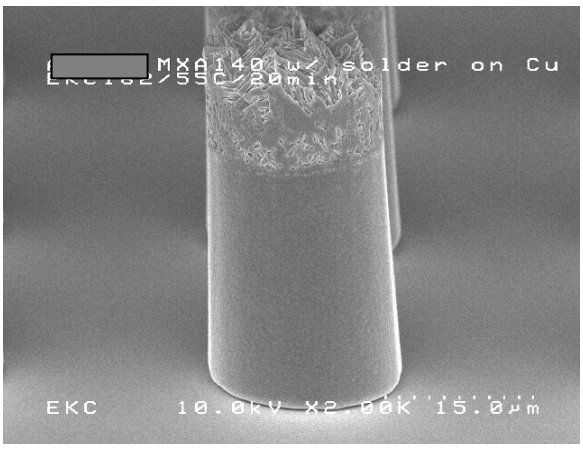


Figure 8. EKC162™ / 55° C / 20 minutes

Using a wet bench-like application, both types of wafers (Cu pillar & solder capped Cu Pillars) coated with 40 micron thick DuPont MXAdvance* 140 dry film were successfully cleaned using EKC162™ at all process times and temperatures. Both wafers types with copper pillars and solder capped Cu pillars proved very easy to clean. Even a mild cleaning process consisting of EKC162™ at 45˚C for 10 minutes was able to fully clean both types of wafer pieces. This short dwell time and low temperature would minimize any potential etch loss issues.

Very few problems were found on the wafer pieces when inspected optically or with the SEM. A few pieces of dry film were occasionally seen when inspecting the wafer pieces optically at low magnification. It is believed that these residual pieces of dry film were re-deposited onto the wafer pieces during the cleaning process. The recommended remover tool would require a skin filtration system to remove the skins.

The finest dimensions of copper pillars and lead free solder capped pillars defined by DuPont MXAdvance*140 dry film and fully cleaned by EKC162™ as observed from the SEM photographs were as follows:

- Lead free solder capped Cu pillars: 30 microns high by 19 microns across
- Copper pillars: 25 microns high by 17 microns across

Conclusions

The results of this study show that the DuPont MXAdvance* 140 and EKC162™ provides a system for producing 20 micron diameter microbumps. The excellent resolution capability of the DuPont MXAdvance*140 in thinner versions is being developed for smaller diameter and lower microbump heights. The EKC162™ offers customers to achieve clean dry film removal with minimal attack to microbump or sputtered metals.