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Stressless copper for superior semiconductor performance

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Figure 1. Finding the right electroplating materials doesn't have to be cumbersome with a great supplier. Source: Umicore

Integrated circuit (IC) reliability depends on many factors. In complex heterogeneously integrated packages, coefficient of thermal expansion (CTE) mismatch between the mix of packaging and chip materials creates excessive stress at material interfaces. Under large thermal excursions or repeated thermal cycling, stress on the packaging materials leads to fatigue and eventually to failure.

In addition to thermally induced stress, internal stresses due to defects in the crystal structure create additional reliability problems that may not appear until a chip or wafer is stressed. For example, when wafers are handled or when assembled packages experience mechanical shock, the copper film can experience cracking or delamination.

A solution to these potential failure mechanisms comes from new electroplating material options. A unique set of materials and processing steps can be used with existing processing equipment to produce stress-free copper materials. These materials and features are more reliable under thermally induced stress, and they will be easier to solder in heterogeneously integrated packages.

How defect-related stress appears in electroplated copper

Internal stress in electroplated copper is a well-known phenomenon caused by defects in the electroplated crystal structure. After electroplating, these defects attempt to self-correct via diffusion across grain boundaries, which induces either tensile or compressive forces on the deposited copper. When the electroplated copper is mostly on one side of the substrate, stress relief can lead to warping or curling in the substrate, which depends on the stress magnitude and the flexibility of the substrate.

Stress in the deposited copper film can also create insufficient adhesion of the film to the substrate. With weak adhesion comes peeling or cracking in the copper film. When a plated wafer or panel is handled with transfer tools, warping may occur, which then causes the aforementioned defects to appear. In addition, warped wafers will be difficult to handle with these transfer tools due to dimensional differences. When thicker electroplated copper is required, the magnitude of the stress is proportional to the thickness of the deposited film. This is more problematic in cases where higher thickness is needed to support smaller or narrower lateral feature sizes.

How to produce stressless copper

An alternative approach is to use additives in the electroplating bath that influence the material properties of the deposited copper. These additives can modify the grain structure and deposition rate of copper, indirectly affecting defect density and resulting stress in the deposited copper films. With an appropriate set of additives, a standard process can be used to produce a stressless electroplated copper film with smaller CTE mismatch between the copper and wafer.

Figure 2 shows the warpage distribution in a 20-micron thick electroplated copper film across an 8-inch wafer, illustrating a maximum deformation of less than 10 microns. This low-stress copper film was deposited with specially designed additives in the electroplating bath. The image shows warpage becoming more significant around the edge of the deposition region, but the low warpage near the center of the wafer indicates the low residual stress in the film.

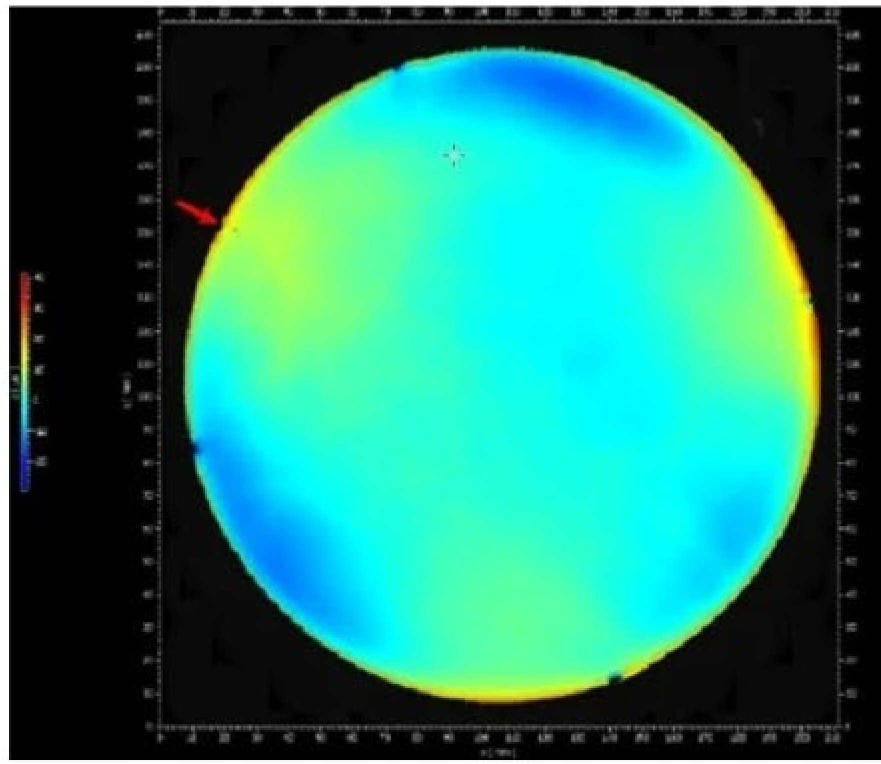

Figure 2: The warpage distribution in a 20-micron thick electroplated copper film across an 8-inch wafer. Source: Umicore

For electroplating with these additives, the typical process steps required are as follows: plasma cleaning, pre wetting with deionized (DI) water, plating (considering plating time and conditions), rinsing with DI water and drying. The key takeaway is that the use of stressless electroplated copper as a process step in advanced packaging manufacturing may reduce internal stress, difficulties caused by warpage and CTE mismatch.

Umicore's superior materials

Umicore is an industry-leading company that supplies innovative electroplating materials that can be used to produce stressless copper within existing processes. Equipment makers that want to enable copper plating processes with insoluble anodes will find high-purity copper(II) oxide for copper replenishment, or appropriate additives to circumvent copper replenishment, in Umicore's portfolio:

- Additives for copper electroplating
- Copper(II) oxide for dry metal replenishment (DMR)
- Anode/cathode materials for ECD equipment
- Sputtering and evaporation materials (TFP)

Umicore's deposition materials and additives are fully compatible with existing processing equipment and are offered in conjunction with the equipment vendor. This allows existing operations to be retrofitted to include stressless copper electroplating capabilities. These capabilities can also be added to new production facilities via standard equipment.

To learn more about Umicore's additives and processing requirements to produce stress-free copper materials, contact Umicore today.