Superior Polymer Processing for Wafer Level Packaging

Bill Moffat – Founder & CEO
Ken Sautter – Senior Process Engineer
Yield Engineering Systems, Inc.
203A Lawrence Drive Livermore, CA 94551
925-373-8353 www.yieldengineering.com

As electronic devices become more consumer-oriented, production costs and efficiency become higher priority. Wafer-level Packaging (WLP) has the ability to enable true integration of wafer fab, packaging, test, and burn-in at wafer level in order to streamline the manufacturing process undergone by a device from silicon start to customer shipment. WLP basically consists of extending the wafer fab processes to include device interconnection and device protection processes. WLP involves attaching the top and bottom outer layers of packaging and the solder bumps to the integrated circuit while still in wafer-form, and then dicing the wafer.

An integral part of WLP involves the relocation of the Input/Output (I/O) pads used to communicate with the die to points suitable for the final package. The I/O pads may be located at the edge of the die or down the middle. The pads can be relocated using Redistributed Layers (RDL) which involves at least two layers of Polymer to separate the active circuitry from the new bond pads. An essential part of this Polymer separation layer is the need for uniform thickness and dielectric consistency.

High temperature ovens are required for the extended bake cycle to convert the polyamic acid precursor into the polyimide film. The high temperature is not only required for complete imidization, it drives off the N-Methylpyrrolidone (NMP) casting solvent and orients the polymer chains for optimal electrical and mechanical properties. Often ovens which operate at atmospheric pressure are used for the polyimide cure step. In order to prevent the inclusion of oxygen into the film, these systems must spend an extended period flushing the chamber with nitrogen. Once an oxygen-free atmosphere has been established, the system must ramp to temperature in steps to allow the casting solvent to evolve from the film. Dwell times of 30-60 minutes at 200°C must be included in the process to allow NMP time to migrate to the surface and evaporate. After the solvent has been removed from the film, the ramp can continue to the final cure temperature, usually 300-400°C depending on the polymer and the required film properties.

An alternative is to use vacuum or partial pressure during the cure cycle. This technique serves several purposes. First, using vacuum / nitrogen interchanges allows rapid achievement of an oxygen-free environment. Second, at a vacuum level of 50 Torr, NMP boils at 115°C. It therefore evolves out of the polymer well below any temperature that would promote a skin on the coating. Additionally, at reduced pressure, water boils at 25°C, so moisture is quickly removed from the polymer. Any Oxygen that has been included during initial processing steps at 760 Torr will be drawn out by the vacuum as well. Over 90% of the solvent, moisture, and Oxygen can be removed during an initial vacuum step.

The vacuum bake unit starts to heat up to operational temperature with a steady input of Nitrogen heated to the oven temperature and a vacuum pulling below. This laminar flow reduces any particles on the wafers and continuously removes solvent, moisture and Oxygen. At 250 Torr, the standard pressure for most of the remaining operation, NMP boils at 140°C. This is substantially below any temperature at which an inhibiting skin would form.

The net result of a vacuum bake compared to an atmospheric bake is the vacuum bake is designed to produce a wrinkle free, void free polymer with no discoloration. Since the entire polymer is imidized, the dielectric uniformity is constant anywhere on the wafer. These process steps assist in there being no problems outgassing at later metallization steps. True laminar flow with the reduction in particles leads to a process time about half of the atmospheric process time. Below are diagrams describing the stages:

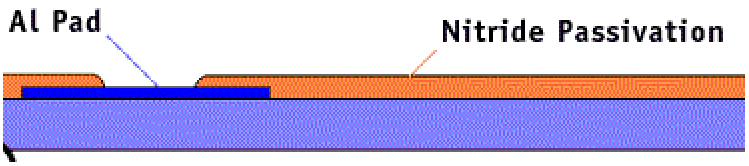

Fig 1 – Die cross-section showing original bond pad location and glass passivation.

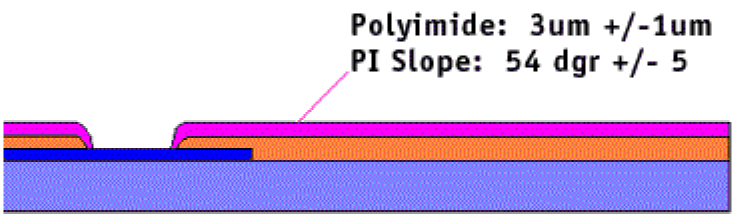

Fig 2 – Polyimide dielectric layer is deposited and patterned to open bond pads while sealing fuse openings. *(Care must be taken to remove all trapped solvents/moisture and oxygen for uniform wrinkle-free polymer.)*

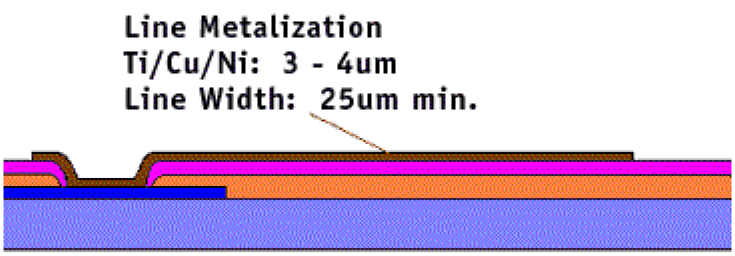

Fig 3 – Conductive metal layer connects old bond pad to new pad location. *(If any trapped solvent/moisture and/or oxygen, the polymer will outgas for a long time at metallization and it will wrinkle.)*

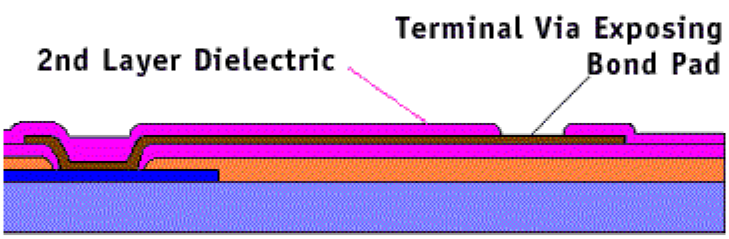

Fig 4 – Second layer of polyimide protects the metal trace. New bond pad location is opened up.

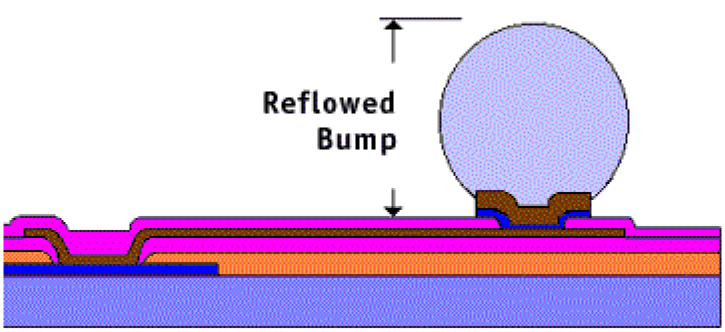

Fig 5 – Solder bump or wire bond can be attached in the usual way.

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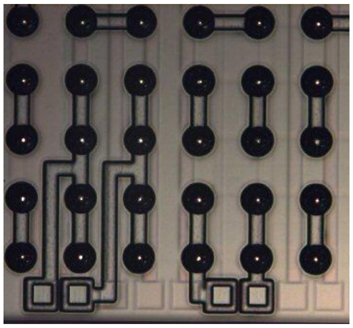

Fig 6 – Example of an old bond pad locations, RDL and solder bumps.

How can Yield Engineering Systems (YES) help with my process? YES builds several pieces of equipment that are particularly suited for RDL processing.

YES-VertaCure

Central to the RDL process is the curing of the polymer dielectric. YES polyimide curing systems, such as the YES-PB and YES-VertaCure Series tools, have several distinct advantages over conventional baking systems.

First, YES uses a series of vacuum / N_2 cycles to create an oxygen-free environment for the curing. Incorporation of oxygen in the polyimide can lead to a dark brittle film. YES ensures an environment of less than 10 ppm of O_2 before heating the substrates, leading to a stronger polyimide film.

Second, YES cures at partial vacuum. The vacuum draws the solvent out of the film of polymer leading to a faster more complete cure. During the curing process, the system flows a low volume of filtered, pre-heated nitrogen which pulls the solvent away from the substrates and helps remove particulates. Programmed temperatures with controlled ramp rates lead to low stress films. This is especially critical when employing multiple layers of polyimide. After the first metallization layer, temperature control of the cure is even more important. Improper curing can lead to the first polyimide layer softening and wrinkling the metal traces due to imparted stress.

YES-450 PB Series

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