# Tech Talk

## Fine Lines in High Yield (Part CXLIII)

## Hot Roll Lamination - Heat input and Temperature Control

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In hot roll lamination, heat is applied to the rolls and transferred through the polyester film coversheet and the resist to the resist/copper interface to achieve good resist to copper conformation and adhesion (Ref. 1, 2). The rolls are heated by a variety of methods, including cartridge heaters and surface heaters applied to the inner surface of a hollow roll. Other laminators use an external IR source to heat the outer surface of the roll. Pressure is by far the more important variable than temperature when it comes to achieving conformation of the resist, but temperature plays an important role in reducing the resist viscosity for improved flow.

A more direct heat application is sometimes used to supplement roll heating: the board is preheated just prior to lamination. Such preheat units may use hot rolls, such as the triple hot rolls of the Hakuto Mach 610i, or they employ IR heat. Since these preheat units add cost to the lamination process in the form of capital expense, clean room floor space requirement, electricity consumption while heating the unit and more electricity consumption to keep the clean room at a comfortable temperature, one needs to carefully assess if such equipment is justifiable. One reason might be that the PWB fabricator is processing thick multilayers such as back planes that form a bigger heat sink than thin innerlayers. To achieve the desired resist/copper interface temperature at an acceptable lamination speed, the supplemental heat from the preheat unit may be justifiable.

It is also interesting to notice that resist suppliers whose dry film resists tend to have a high viscosity, i.e. harder resists, are more likely to recommend a preheat unit. Low viscosity dry films may have viscosities in the range of 20 to 60 m poise (milli poise = poise/1000) whereas high viscosity resists that benefit more from preheating may have viscosities in the range of 130 to 160 m poise.

The actual temperature at the resist/copper interface depends on the contact time of the resist with the heat source, the temperature of the heat source, the heat transfer coefficients of the materials between the heat source and the resist/copper interface, and the thermal mass and temperature of the board. The contact time, in turn, is a function of the lamination speed and of the roll/film "footprint" in the lamination roll nip. The lamination speed is set by the hot roll rpm and diameter of the rolls, while the "footprint", i.e. the width of the hot roll/board contact zone in the nip, is determined by the durometer and thickness of the roll covering, the diameter of the roll, and the roll pressure.

The actual resist/copper interface temperature is indirectly monitored and controlled. Controlled variables are the hot roll temperature, the lamination speed, and, where applicable, the preheat unit temperature. The board exit temperature, i.e. the temperature of the laminated board, just as it leaves the roll nip, is often used as an indicator of the desired resist/copper interface temperature during lamination. Since there are additional variables affecting board exit temperature, such as board thermal mass, room temperature, conveyor speed, i.e. the time to reach the temperature sensor, those variables need to be considered and controlled to make the reading meaningful.

The low end of the recommended board exit temperature range has been established empirically and is the result of extensive yield studies and DOE tests to find the lowest temperature that still guarantees good resist conformation and adhesion. The high end of the recommended board exit temperature range is established empirically, and it is the highest "safe" temperature at which one can run without getting into trouble, notably resist wrinkling (see below).The control logic for assuring the proper temperature at the resist/copper interface through the use of exit temperature monitoring might follow the following methodology: select the highest roll temperature that is

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“safe” to run (per resist supplier data sheet), set an initial conveyor speed within the typical range, e,g, two meters per minute, then check the board exit temperature, and adjust the conveyor speed to achieve the recommended board exit temperature. A “safe” roll temperature implies that there is no film wrinkling, no thermal polymerization of the photoresist, and that the resist out-gasing components at this temperature are known and can be vented safely. Etch retardation which is sometimes observed with certain innerlayer resists, can be an indicator that the lamination temperature is too high. Lowering the pre-heat temperature, or eliminating pre-heating altogether, or lowering the roll temperature will solve this problem.

The board exit temperature guidelines should depend on the board type. As a rule of thumb, aim for 60-70°C (140-160°F) for thin innerlayer boards. If the innerlayer boards feature drum-side-treated copper foil which has a rougher (outer) surface than standard foils and is therefore more difficult to conform to, aim for a higher exit temperature, e.g. 70-75°C (160-170°F). We measured the average roughness of standard copper foil and found it to be in the range of Ra = 0.1- 0.2 microns whereas reverse-treated foil gave a Ra of 0.38 microns (Ref. 3). For thicker outerlayer boards aim at 45-55°C (110-130°F). If the outerlayer resist will be subjected to a harsh nickel/gold plating cycle, go for the upper end of the outerlayer range, i.e. 50-55°C (120-130°F). Note that suppliers of harder, higher viscosity resists may suggest higher board exit temperatures than given here.

Heat-related resist wrinkles are an indicator that the board exit temperature may be too high and the roll temperature needs to be lowered. This could be the case in a wet lamination operation because wet lamination can be particularly prone to resist wrinkling. In another scenario, the tent and etch process, wrinkles may first show up in the form of wrinkled tents, especially in resist tents over large diameter holes. However, tent wrinkling may be cured by process changes other than lowering the lamination roll temperature such as changing the exposure, development or drying conditions after development. For example, the resist may be underexposed and weaker than expected. Here, one has to keep in mind that the resist tents are exposed to some oxygen during exposure, in spite of the polyester cover sheet which acts as an oxygen barrier, due to the trapped air in the tented hole. Since oxygen is an inhibitor to resist polymerization, it is often recommended to overexpose tent-and-etch boards by 10-20% vs normal exposure doses. Aggressive development conditions such as an early break point (wash-off point), high developer temperature, or high carbonate concentration may also contribute to tent wrinkling. Lowering the drying temperature after development from about 50°C to 40-45°C can also help avoid tent wrinkling.

References

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