Tech Talk

Fine Lines in High Yield (Part CXXXV)

The Effects of Lamination Roll Mechanics on Conformation

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Lamination roll strength and roll covering properties of hot roll laminators affect conformation of dry film resists because bending of the rolls causes the nip pressure to vary across the circuit board width. The roll covering helps keep the roll in contact with the panel the full width despite the bending. A spreadsheet model of the lamination roll nip was used to show how roll bending (see Figure 1) and roll covering compression affect conformation.

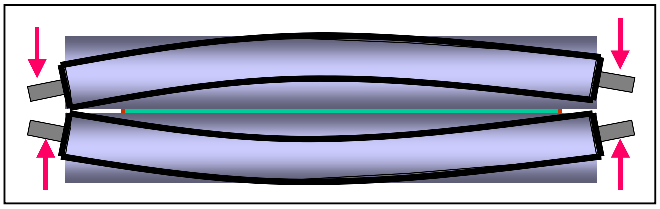

Figure 1: *Illustration of Roll Bending (exaggerated)*

Whether roll bending is negligible or whether it is a significant factor that affects lamination quality depends on a variety of parameters. Hot roll laminators that work at relatively low loads and feature large diameter rolls are less prone to roll bending. Roll bending affects outerlayer lamination more than innerlayer lamination because the thickness of the multilayer boards is great enough to allow roll bending. Thin boards or panels permit the rolls to touch on either side of the panel, reducing the tendency to bend. The model suggests that the thickness of the dielectric core, plus copper, plus resist thickness must be greater than 22 mils (550 micron) before roll bending defects are noticed. When roll bending occurs, the center of the panel is laminated at a lower pressure than the edges, and a higher abundance of open and dish-down defects will be noted in an print & etch application along the center of the panel in machine direction. We have also successfully examined the corresponding lamination defects or voids along the center by laminating the dry film photoresist to a thick plate of tempered glass.. When viewing the laminated resist through the glass, one can clearly see the resist/glass interfacial voids that will lead to the circuit defects after etching.

The use of "crowned" lamination rolls reduces the number of lamination defects considerably with thicker boards. The "crowning" is machined into the roll covering to give the center of the rolls a larger diameter than the diameter near the roll edges. This crowing should not exceed a diameter differential of about 3 mils (75 micron). The diameter profile should not be tapered (a straight line) but should be arced like an (American) football. Such crowned rolls have been used successfully with thin flexible substrates to avoid wrinkling of the resist.

Increasing lamination pressure reduces conformation defects. However, adding higher pressure capability to an existing laminator design without increasing roll bending strength will only cause bending-induced defects. This problem is even more acute with thin resist, because the thinner the resist, the higher the lamination pressure needed to achieve conformation. The key to successful lamination of thin dry film photoresist is the development of a relatively small diameter lamination roll, backed up by stiffening rolls to minimize bending.

The model developed to describe roll bending is relatively crude but was a useful research tool. The results were consistent, meaning that trends shown by the model are real. The main source of errors in the model was the adoption of simplifications to make the math simpler. The most significant error may be in determining the minimum panel thickness for which the model is valid. If the panel is too thin to keep the rolls separated beyond the edges of the panel, all the loading calculations are incorrect.

Table 1: Model Calculation

Roll Loading	Plate Width	"Rigid" Roll Loading	Actual Roll Loading at Plate Edge	Actual Roll Loading at Plate Center	Rubber Compression at Edge	Rubber Compression at Center	Roll Bend, Edge to Center of Plate	Total Roll Bending, End to Center	Estimated Minimum Panel Thickness
4 Bars 856 lbs	24"	35 lb/inch	41 lb/inch	32.5 lb/inch	0.0098"	0.0084"	0.0014"	0.0029"	0.022"
7 Bars 1498 lbs	24	62.4	78.1	53.6	0.0152	0.0118	0.0034	0.0050	0.032
4 Bars 856 lbs	18	47.6	51	45.5	0.0113	0.0105	0.0008	0.0033	0.028
7 Bars 1498 lbs	18	83.2	92.9	77.6	0.0169	0.0151	0.0017	0.0057	0.042

Table 1 shows the modeling results for a number of conditions. Rigid roll loading is the load per inch of plate width associated with the width and clamp pressure. The "plate" to which dry film resist was laminated was 0.188" thick (18" x 24") tempered glass. Actual roll loading at plate edge is larger that the rigid loading figure because of roll bending. The actual roll loading in the center is less than the rigid load figure because of roll bending. Rubber compression is the amount of compression of the 0.080" thick cover of the roll. At 7 Bars pressure on an 18" wide panel, the rubber will deteriorate eventually from the high (approx. 20%) strain. Rubber compression at the center is lower than at the edges because of roll bending. Roll bend from edge to center of the plate reflects the different widths of the plates. The 18" wide plate contacts less of the roll than the 24" plate. Total roll bending is the total displacement of the centerline of the roll from the ends of the roll to the center of the roll. Estimated minimum panel thickness is the minimum thickness for which this data is valid. For panels thinner than indicated, the rolls will touch at the ends, causing a reduction in the loading on the panels and a reduction in bending. This "estimated minimum panel thickness" column is accurate to about +/-10%.

The tabulation of model calculations is for two panel widths and two "clamp pressures" (i.e. the setting on the roll pneumatic cylinders) of 4 Bars and 7 Bars. We used a DuPont ASL (automatic sheet laminator) to test the model's conditions. The high pressure of 7 Bars was obtainable because of the available high air pressure in our laboratory setting but it is not generally recommended to run such high pressure on the laminator.

Conditions and results of the glass plate lamination tests

(by visual inspection of lamination voids between the resist and the glass).

The plates were laminated with a 1.3 mil thick dry film resists, at a lamination speed of 3 meters/minute, a roll temperature of 115ºC, and with the 18" plate dimension parallel to the nip. At both pressure settings (4 and 7 Bars) we saw the effect of roll bending (fewer voids near the edges than near the center). The 7 Bars setting showed better conformation than the 4 Bars setting. The difference in defect density between edge and center was significant. A "leading edge" problem (more defects near the leading edge) is superimposed onto this roll-bending defect pattern. This leading edge defect is due to lower resist temperature during lamination at the leasing edge. The leading edge defects are bubbles (voids) between the resist and the glass, the size of which diminishes further away from the leading edge toward the center of the board. Almost none of the bubbles seen under the high pressure condition would lead to actual open defects on a three-mil line and space pattern but might cause occasional nicks or dishdowns. The bubble size observed with the low pressure condition led a number of open defects and a significant number of nicks and dishdowns.

Acknowledgment

This work was conducted by my late colleague and friend Ed Hagan.