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Effect of Laminating Press's Opening-Stacking Position on Adhesive Thickness in Coverlay/Adhesive/Flexible-Printed-Circuit Sheet

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Abstract - **This study is to investigate the dependence of coverlay's adhesive thickness on the laminating press's opening-stacking position. Coverlays using acrylic- and epoxy-based adhesives were laminated onto similar size copper clad laminate (CCL) at 140 bars and 195°C for 150 min. Adhesive thickness measurements show opening-stacking positions near to the bottom of laminating press machine produced more consistent adhesive thickness as compared to the top positions.**

Keywords—Flexible electronics, adhesive layer, flexible printed circuit, Adhesive, copper clad laminate

I. INTRODUCTION

Recent flexible and stretchable electronics applications have created high demands for flexible printed circuit board (FPC) [1, 2]. Current FPC manufacturing process requires copper fill design on the copper clad laminate (CCL) to be protected by polyimide coverlay lamination. Optimization of lamination process parameters is important to pass the FPC according to the required standards, in particular to negate the delamination risk while in operation. Currently, acrylic- and epoxy-based adhesive have been widely used as the bonding materials between the coverlay and CCL layers.

In this study, we report the effect of opening-stacking position of FPC on the adhesive thickness after the CCL underwent the laminating press process. The change in adhesive thickness provides a good estimation on the shear strength of the coverlay lamination on the CCL.

II. METHODOLOGY

A. Laminating Press Process

Laminated FPC panels, each constitute a double-sided CCL laminated by two coverlays (with same adhesive type) were prepared. Both sides of each CCL were laminated using single polyimide coverlay with one-sided acrylic- or epoxy-based adhesive coating (i.e. as-received adhesive thickness is 25 µm, Model: HFBSX25X2-M, Aplus). Both types of panels (with same dimensions, 19.7 × 24 inches) underwent separate laminating press process using the same parameters.

6-opening laminating press (daylight BURKLE, platen size is 500 × 600 mm) was used for lamination of the FPC panels. A book of 10 FPC panels (i.e. in top stacking configuration) was fit into each opening of the lamination machine. Each FPC panel was sandwiched by a stack of steel plate, Kraft papers, PE cushioning film and HTRF release film (arranged in sequence). Lamination was performed at temperature of 195°C and pressure of 140 bars for time interval of 150 minutes. The parameters are set based on recommendation by the coverlay suppliers and circuit designs.

Sample characterization was done on the 1st, 5th and 10th FPC panels (i.e. the top panel was named as the 1st panel), collected from 1st, 3rd and 6th opening of the laminating press. The 1st opening considers as the top region (T) of the laminating press, while 3rd opening locates at middle region (M) and 6th opening locates at bottom region (B). All samples were labelled with the opening and stacking number for identification. For example, T5 sample was retrieved from the 5th stacked FPC panel of the 1st (Top) opening. Figure 1

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illustrates the arrangement of FPC panels in the laminating press.

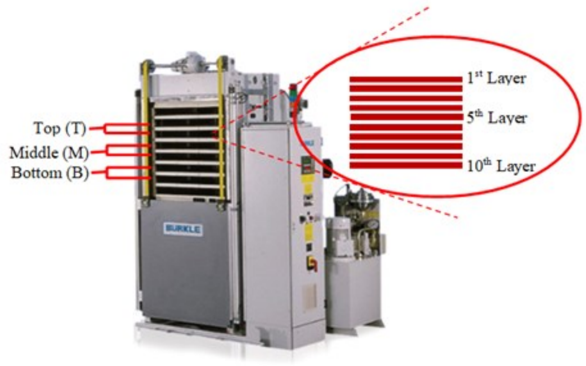

Fig. 1. Arrangement of FPC panels in the laminating press.

Five one centimeter-squared areas were cut from each sample. The areas were cut from the four corners and one centre region of the FPC panel to include 'edge effect' into the error calculation. Cross-sectional image of the sample's adhesive layers was captured using the 3D Laser Scanning Microscope (VK-X200 series, Keyence) and the adhesive thickness was determined using the VK-Analyzer software.

III. RESULT AND DISCUSSION

A. Cross-sectional Images of Post-lamination Press CCL Panels

Figure 2 shows the cross-sectional image of FPC samples. Each of the FPC sample consists of 7 layers: 2 layers of copper, 2 layers of adhesive, and 3 layers of polyimide (two of them are coverlays). The figure shows the CCL is laminated with the coverlay-adhesive at its top and bottom surface.

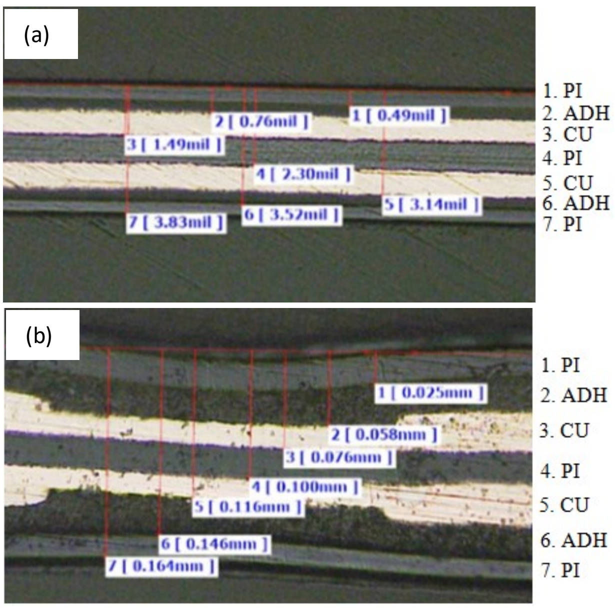

Fig. 2. Cross-sectional image of (a) acrylic- and (b) epoxy-based M5 FPC sample cut from FPC sheet corner region. Thickness was measured in mm. PI, ADH and CU are polyimide, adhesive and copper layers.

B. Adhesive Layer Thickness Measurements

Figure 3 shows both acrylic and epoxy sample's adhesive layer thicknesses decreased with the lower opening-stacking position. For example, adhesive thicknesses of B10 samples are 0.19% and 0.32% thinner than the T1 samples for the respective acrylic and epoxy samples. Furthermore, acrylic samples exhibited smaller adhesive thickness variation than the epoxy samples. The adhesive thickness of epoxy samples showed only a slight reduction from the original thickness (i.e. before laminating press) at 25 µm.

Adhesive layer shrinkage was due to adhesive curing during the laminating press process [3, 4]. First reason of the shrinkage is the chemical crosslinking between polymer chains and evaporation of water or volatiles from adhesive [5]. Secondly, an existence of difference thermal expansion between the adhesive and the CCL [5]. Currently, adhesive thickness is used by manufacturer as an important indicator of degree of cure of the particular adhesive layer between coverlay and CCL.

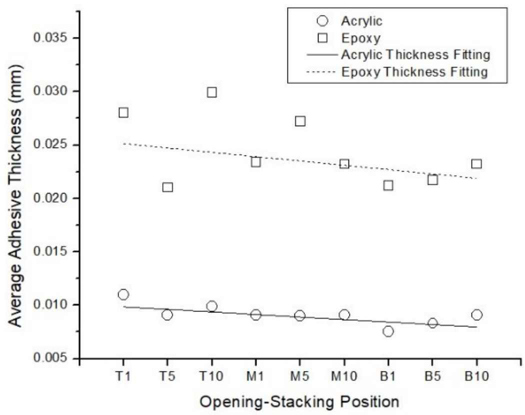

Fig. 3. Average adhesive thickness (5 data points from each sample) of post-lamination press sample as a function of opening-stacking position.

Interestingly, a significantly lower thickness shrinkage was observed in epoxy than in the acrylic samples. The occurrence is attributed to larger contact area with copper layer of the former samples. The cross-sectional images in Fig. 2(b) show the epoxy sample has uneven adhesive-copper interface, as compared to flat interface in the acrylic sample (refer Fig. 2(a)). Previous study showed dimensional contraction of adhesive was found to be linearly proportional to the decrease in copper filled percentage on flex panel [3]. Thus, it could be concluded that a difference in CCL circuit design of epoxy and acrylic contributed to different adhesive thickness shrinkage.

Larger deviation of adhesive thickness data point was clearly observed for epoxy samples as compared to acrylic samples, particularly for opening-stacking positions nearer to the top laminating press (see Fig. 2). Cross-sectional image of the epoxy samples (Fig. 2(b)) indicates thickness deviation may be created by thickness measurement error at the bent laminate region. The reduction in thickness deviation of epoxy samples near the bottom of laminating press shows less occurrence of bent laminates, thus implies a more consistent spread of epoxy adhesive thickness on the copper filled surface. The bent regions carry higher shear and bending stress, thus are prone to coverlay delamination failure [6].

IV. CONCLUSION

Opening-stacking position of post-lamination pressed CCL panels affects the adhesive layer spread on copper filled surface. The bottom opening-stacking position of laminating press produced adhesion thickness with less deviation from linear fit as compared to the top position. This suggests coverlay-laminated CCL panels with consistent adhesive strength value along the lamination interface could be produced from the lower opening-stacking position. A uniformly distribution of adhesive strength minimizes the premature delamination risk. Future work requires the study on the effect of acrylic- and epoxy-based adhesives on the lamination of CCL with similar copper fill design in order to eliminate the effects of copper-polyimide interface. It is important to identify the response of the two adhesive types on the lamination process in order to produce FPC with mechanical properties that are customized to the customer needs.

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