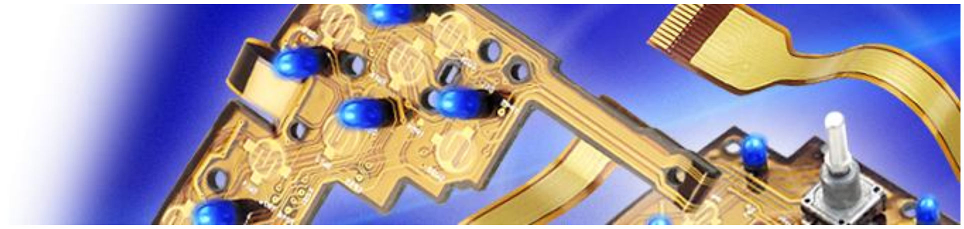
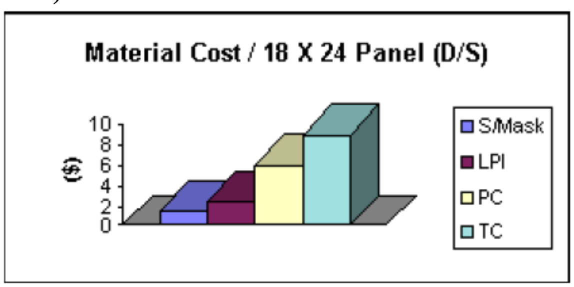


Flexible Circuit Cover Coating Techniques

Flexible circuit applications typically include designs where the circuit wraps around other electrical subsystems or rests against the inside of an instrument enclosure. This necessitates that in all but a few instances, a protective insulating layer is required to cover and isolate large areas of the conductive circuit pattern. The purpose of this layer may include some or all of the following; to protect conductors from the environment, to insulate conductors electrically or to dictate solder coating areas for component assembly.

The material options commonly available for these purposes break into two categories. The first is a cover layer which consists of an adhesive coated film. This film is laminated to the conductive pattern by way of temperature, pressure and time in a hydraulic press or autoclave. The second category is a covercoat, but is more often referred to as a solder mask. This can refer to screen printed solder mask, liquid photoimagable (LPI) soldermask (screen printed, roll coated or spray coated) or dry film photoimagable soldermask (semi-cured liquid mask supplied as a roll of film).



A more recent product offering, from DuPont is PC 1000 photoimagable coverlay which falls into a gray zone somewhere between the two categories. By process definition, it is a dry film solder mask but by performance and visual characteristics it is a coverlay.

To establish which technique is most suitable for a specific application, issues such as, operating environment, flexing requirement, circuit pattern density, copper thickness, circuit technology (i.e. thruhole, SMT) and overall cost must be carefully considered.

Conventional screen printed soldermasks are by far the most cost effective option. Though the performance is fair, the material price is low, the tooling cost is low and the manufacturing process is short. This method is intended for use on flex-to-install type applications and non-disk drive dynamic applications (such as CPU to display interconnect in a laptop computer). The major set-backs with this method are image definition. The coating is directly transferred through a photoimaged screen stencil which dictates the coverage pattern. Due to the flow characteristics of the liquid mask, the registration capability of the process and the saw toothing effect of the screen, it is not possible to accurately define openings around fine pitch devices or to hold tight pad to opening tolerances as required for bare board electrical test and automatic pick and place assembly. Screen printed soldermasks are therefore unsuitable for all but the most basic SMT boards. Additionally the moisture absorption characteristics of many screen printed soldermasks make them unsuitable for use in harsh operating environments such as automotive ‘under the hood’ applications.

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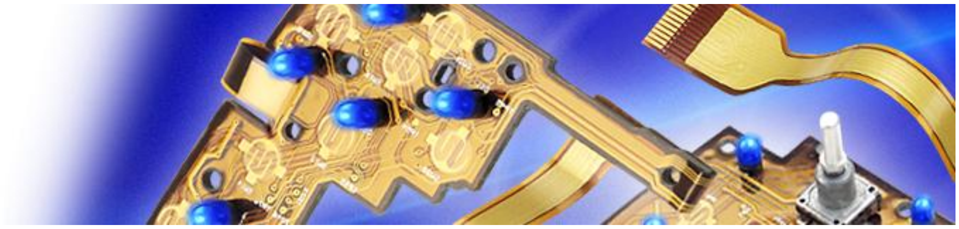

Thermally Laminated Coverlay Materials

Thermally laminated coverlay materials were the flexible circuit standard for many years. In this case the material purchase cost is high (press pad materials must also be considered), tooling cost is low (where drilling is used to produce openings) or high (if a piercing tool is utilized). The manufacturing process is long but the resulting performance is high. The finished board is suitable for flex-to-install applications (with extremely demanding bend radii) and in dynamic disk drive applications requiring many millions of flex cycles. One reason for such excellent results in dynamic applications is that the thermal coverlay thickness can be matched precisely to the base film thickness thus placing the copper conductor in the neutral axis. This minimizes stress and strain work hardening of the copper during continual flexing.

Thermal covercoats are an excellent choice for elevated temperature or harsh environmental conditions. As with screen printed soldermasks, the major setback is one of coverlay to circuit definition, this time due mainly to adhesive in-flow around the drilled or punched opening (typically .003"-.005") and dimensional distortion during the lamination process. Also note that unless an expensive punch tool is used, the shape of the openings in the coverlay are limited to circular drilled holes or round ended slots.

Material Type	Minimum Pitch	Flex-to-install	Dynamic (max cycles)	High Temperature	Harsh Environment
Soldermask	Poor	Good	<100,000	Fair	Poor
LPI	Excellent	Good	<100,000	Good	Fair
Thermal Coverlay	Fair	Excellent	>1,000,000	Excellent	Excellent
Photoimagable Coverlay	Excellent	Excellent	<500,000	Good	Fair

For SMT boards, Liquid Photoimagable soldermasks can be very cost effective from a material standpoint, but, the process can be long winded depending on the application method. The basic options are screen printing or spray coating (roller coating is not capable of reliably handling thin flexible panels). Spray application is the shortest processing option but the initial capital start-up cost is high. Spraying does offer some distinct advantages over screen printing in that greater copper thicknesses can be coated (i.e. pattern plated images) and the mask thickness variation from conductor knee to non-conductor is significantly less.

This is critical when flex performance is considered because an increased mask thickness will crack and peel during even limited bending. Screen printing flexible LPI on dense circuit patterns can only really be successful in high volume over 1oz (or less) copper for this reason. The conductor thickness from a typical 1 oz base copper / pattern plated process will yield conductors varying from 3.0 - 4.2 mils thick (in isolated high current density areas). With a dense, random conductor pattern it is impossible to keep all conductors out of the plane parallel to the squeegee direction.

Given a group of 8 mil lines and 8 mil space conductors in this configuration, single pass coverage is practically impossible to achieve without leaving voids between the conductors. Reliability necessitates the use of a two-pass process. By using excessive pressure on the squeegee a two-pass process can be used without adding mask thickness to the top of the conductors but additional thickness is added between the spaces with each consecutive pass.

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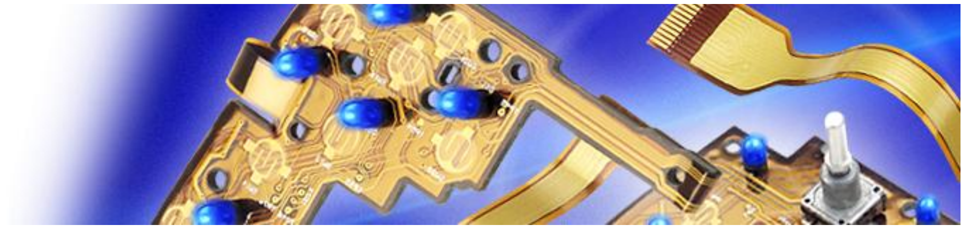

The choice becomes variable single pass coverage or dual pass coverage which will add thickness and may be susceptible to cracking and peeling?

You can see that the Cpk bandwidth with this process is extremely narrow, and that is before you even consider the potential variability of the in-coming material from the supplier!

When the correct process is chosen (based on the above criteria) and the coating is thin and uniform the resulting circuit is extremely durable and has excellent image definition. It is suitable for most flex to install applications but not for dynamic applications.

Photoimagable coverlay (DuPont PC 1000) is essentially a flexible dry film soldermask. It is supplied as a roll of film which is applied to the circuit panel using heat, pressure and vacuum in an SMVL (soldermask vacuum laminator). Panels undergo a pressurization stage after film application to ensure full encapsulation of conductor features, after which they are processed like a conventional LPI (image, develop, cure).

PC 1000 is an excellent choice for the most demanding flex to install applications and also for all but the most demanding dynamic applications (disk drives). The major setbacks with this product are it’s lack of UL 94 V-0 rating, it’s cost (compared to LPI) and in some cases the film thickness (2.5 mils typical) which can be a problem to ultra low profile components with short leads.

Processes such as HASL (hot air solder level) must be carefully analyzed by DOE to determine optimum processing parameters without which severe damage may occur to the relatively soft PC surface. With good process control this material exhibits excellent yield and performance.

When considering the cost trade-off between Photoimagable Coverlay and LPI, ease of processing and overall process yield must be compared to establish a true comparison. A more recent trend has manufacturers utilizing two techniques on the same board. A good example of this is the flex circuit in a disk drive. Due to inductance and noise, disk drive manufacturers place active components as close to the read/write head as possible. This dictates that a photoimaged material be used to accommodate the SMT or COF (chip on flex) components, however this material is not capable of achieving the flex endurance characteristics in the dynamic portion of the circuit. To overcome this problem, manufacturers apply a conventional thermally laminated coverlay in the dynamic section and utilize an LPI or dry film type in the component section. By incorporating a designed overlap between the two materials (with the thermally laminated coverlay either over or tucked under the photoimaged portion) total isolation of the conductors is ensured. Of course this type of hybrid process adds significantly to the amount of processing steps and will become inhibitive to cost sensitive products.

In summary, the choice of mask or coverlay should be carefully considered from both a performance and processing stand point. Whenever possible the circuit design should be optimized for a given process. For instance, if LPI is required but the volume is too low to justify the investment for a spray process, minimize the copper thickness to ensure that an acceptable yield will be achieved.

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