Until recently primary imaging of PCBs was carried out, almost exclusively, using dry film resists. However, as demand for finer track work grows, driven by the increasing application of surface mount technologies, board manufacturers are beginning to consider liquid photoimageable primary resists as a viable alternative to dry film resists for fine resolution work. The two groups of liquid etch resists available are the positive, light softening, resist and the negative, light hardening, resists. The positive resists rely on a polymer, which is rendered soluble in weak alkali solutions by the photo-induced breaking of bonds. The areas of resist, which are unexposed, define the circuit and may be stripped, after etching, using a stronger alkali solution, such as sodium hydroxide. The negative resists conversely work by photo polymerising the areas of resist, which will define the circuit during etching. This renders the pattern less soluble in the solvent of aqueous alkali developer solution than the surrounding unexposed resist. After etching, the resist can be removed as per positive resists with sodium hydroxide solution or a stronger organic solvent. Positive resists have never found extensive use in PCB primary imaging and are used in the main for printing plate preparation, photochemical machining and microelectronic photolithography. Negative resist technology is the basis of virtually all dry film resists and the newly emerging liquid primary imaging systems.

Wet photoresists vs dry film: What does what?

The advantages of liquid resists over dry film are both economic and performance based. Dry film has always been a wasteful process with any resist overhanging the board edges or in the space between boards being non-productive. Cut sheet lamination has gone some way to removing this problem by cutting the resist to fit within the lamination area, but the method still lacks the 100% recoverability of over-coated resist which many of the liquid coating systems have. The flexibility of many of the liquid coating systems means that infinite film weight variation is possible. Dry film users must tie up capital carrying a range of stock with varying film weights to cover all etching and plating operations.

The advantages which the liquid resists have over the dry films in performance are also closely related to the coating procedures. The resolution of dry films is limited by the polyester or mylar cover sheet which lies between the phototool and the photoreactive layer. This layer distances the image on the phototool from the resist layer and allows some light scattering causing halation or spreading and fogging of the image, thus losing resolution. Highly collimated light sources and the use of special thin cover layers have allowed dry films to resolve features of approximately the same dimensions as the resist thickness. These methods however do not lend themselves to volume production work. The UV sensitive constituents of dry films are, by their chemical nature, faster reacting to UV light than those which can be used in an ‘on-contact’ exposed liquid resist.

This means that the exposure times for dry film resists can be up to a third that of some liquid resists. This speed however also allows the spread of halation to occur much more quickly and so dry films are far more susceptible to loss of resolution through over exposure than the liquid resists. The liquid resists, with thinner coating capabilities than dry film and direct artwork to resist contact, have better resolution capabilities than the dry films. Thus etched structures of 40 microns can be regularly produced against 75 micron features using dry film. Another coating related problem with dry films is their inability to successfully fill nicks and deep scratches in the copper surface. This leads to etchant leaching beneath the resist, causing breaks in fine tracks. Dry film manufacturers have approached this problem
by adopting wet lamination. This process involves roller coating the laminate with a liquid, generally water, which locally solvates the dry film resist layer, allowing it to flow into the irregularities and give better conformity.

Liquid photoimageables however, do not have it all their own way and they are unable, on their own, to reliably protect plated through holes in double-sided and multilayer boards. Dry resists of a film thickness grater than 38 microns can protect the vias from etching by forming a resist ‘tent’ over the hole ends, preventing etchant entry.

Comparative processing

Both dry film and liquid resists require a rigorous cleaning regimen before coating can take place. The exact nature of the cleaning process varies from product to product, but all are a combination of physical cleaning and roughening with brushes or pumice sprays, and alkaline cleaner to remove greasy contaminants and an acid microetch to chemically clean and roughen the surface. Roughening is an essential part of the pre-coating process as it provides an irregular surface for the resist to key into improving adhesion between the copper and coating.

The major differences between the processes for dry film and liquid resists occur at the next stage in the line-coating. Dry film etch resists are hot laminated onto the substrate, which is fed to the laminator either at ambient temperature or pre-heated (generally to between 60° - 100°C). The dry film is pressed onto the laminate surface by two rollers heated to around 115°C, after the laminating machine has automatically removed the backing sheet from the resist. Dry film coats both sides of the board concurrently with resist. The boards are then cooled to the ambient temperature of the exposure shop to ensure dimensional accuracy in the exposed film. Cooling time is dependent on circuit thickness and complexity (i.e. number of layers). Liquid resists require no pre-heating of the laminate before coating which can be carried out using a number of application methods, spin-coating produces a very uniform thin coat of resist, but the laborious nature of the set up of this process make it unsuitable for volume coating work, it finds its main application in etch resist coating for silicon wafer production. A coating method which lends itself to low volume and prototype work is dip-coating. The boards are fully immersed in the resist solution and then withdrawn at a rate, which, with the viscosity of the liquid, determines the thickness of the coating. The film produced is marginally thinner at the top edge of the board than at the bottom, so this process is unsuitable for applications where and even coating thickness is critical. The process can be automated and it coats boards double-sided. Silk screen printing can also be used to apply thin, even films of resist for short production runs. The four remaining liquid coating processes all lend themselves to large production runs, they are; roller, electrostatic spray, electrophoretic and curtain coating.

Electrostatic spray is a coating process which enjoyed some popularity for solder resist application and which may find increased usage in etch resist application because of its ability to coat very thin, even layers of resist. The basis of the process is the atomisation of the resist by air pressure. The droplets formed are given a high voltage static charge which causes them to repel each other, maintaining the integrity of the mist of resist formed. A charged ‘halo’ of wires keeps the cone of spray to within the desired coating area, thus minimising overspray. The substrate to be coated can be passed horizontally or vertically through the spray. The latter allowing simultaneous double-
sided coating. Coating weight can be controlled by varying the viscosity (i.e. solvent content) of resist, feed rate of substrate beneath the spray and the speed of the turbine which produces the aerosol of resist (greater speed gives finer droplets and hence thinner films). Variation of these parameters allows the electrostatic spraying method to coat down to 5 microns dry film thickness with a feed rate of 1.5-2m/minute.

**Electrophoretic coating** of substrates with etch resist is also a new concept which is supplied by Shipley as their Eagle Dricoat™ resist system. This method uses an arrangement analogous to electroplating metals onto a substrate with the board being made the cathode of an electrophoretic cell. The resist molecules have an overall positive charge and are attracted and adhere to the board surface. The growth of the film is self limiting, as the resist layer is non-conductive, once sufficient resist has been deposited to insulate the board surface no further 'plating' occurs. This effect allows very consistent films of 10 microns to be deposited on both sides of the board at once.

**Curtain coating** is a solder resist coating method which can be used to coat liquid photoimageable etch resists. The liquid resist is pumped into a head from which the only exit is a thin nip on the head’s underside. The resist forced through this nip forms a curtain of resist through which the boards to be coated are passed. Pump rate, substrate speed through the curtain, nip width and resist viscosity can all used to alter final resist film weight down to a consistent 10 microns. This method can only coat single-sided and special support frames must be used for fine gauge inner layers. The resist used must also have low solids contents to yield thin resist films and so they involve the emission of large volumes of organic solvent.

**Roller coating** is a single or double-sided coating system which uses grooved rubber rollers to apply the resist, which is constantly fed into a nip between a doctor bar or roller and the coating roller. The pressure between the doctor and coating roller affects the final film weight of resist deposited, as does the pitch of the grooves on the roller, the non-volatile content of the ink and the coating roller-to-substrate pressure. Roller coating can produce very even coatings of low thickness using high solids solvent borne resists or emulsion resists, both of which limit volatile organic emissions on drying. Roller coating allows inner layer laminates down to 70 microns thickness to be coated successfully. Excess resist flows back to a sump for recycling through the machine via an automatic viscosity controller and filter unit, this limits wastage.

Once coated the liquid resists must then be dried, to produce a tack-free surface, if they are on contact imaging systems, off-contact imaging systems, like W R Grace’s Accutrace™ resist system do not require this stage and travel straight to exposure. Drying times vary from product to product but most weigh-in at under 10 minutes. Liquid coated boards, as with dry film laminated boards, must be allowed to cool to ambient temperature prior to exposure. Drying temperatures for liquid resists are close to those used for laminating dry films and so the degree of thermal stress on the system is comparable for either system.

Both liquid and dry film resists require a reasonably collimated light source but the importance of collimation increases with the distance between artwork and resist film, thus dry film requires a more collimated source than liquid resists and off-contact systems like Accutrace™ require a highly collimated, specialised exposure unit to give good resolution. Once exposed the coverfilm is removed from the dry film
resist prior to development. Some dry films also require a stand time in excess of 15 minutes prior to development to allow the cross-linking reaction to run to completion.

Solvent and semi-aqueous developing etch resists can still be found, but the environmental and health considerations of their usage have lead to fully aqueous systems becoming the norm. Both liquid and dry film resists develop in weakly basic aqueous solutions (1.2% w/w sodium or potassium carbonate solution at 30°-40°C), in which the uncrosslinked (i.e. unexposed) resist dissolves. The speed of development of the resist is heavily dependent on the temperature and pressure at which the developer runs and the type of spray pattern used, the age of the developing solution, etc., but the breakpoint, i.e. the at which the resist begins to fully strip from the board, is approximately the same for all resists under comparable conditions.

Some resists can then be used in the etch bath immediately, others require a short post-bake to improve adhesion and minimise undercut of the film or a brief UV exposure to give the film extra physical hardness prior to etching.

As with development, resist stripping is very similar for aqueously developable dry film and liquid resists both relying, as they do, on a 2-5% w/w aqueous solution of sodium or potassium hydroxide at 40°-60°C. The stripped resists do not dissolve in the stripping solution but form small flakes which can be filtered from the solution and disposed of.

At Coates Circuit Products our experience lies with curtain coating photodefineable solder resists and we have turned this knowledge to primary imaging resist application. Modern photodefineable solder resists are carefully formulated to meet the exacting resolution, standards, lack of resist undercut and straight sidewall definition that the densely populated printed circuit boards of today require. These attributes are also those required for and affective etch resist and it was this reasoning which has led us to develop the ‘AQUALINE’™ range of resists; the solvent borne XV750 and emulsion based H20/750, which may be used as etch of plating resists. Both resists can be applied using the new ‘AQUALINE’™ roller coating machinery specially designed by Coates for this purpose. This applies a coating of resist at 8-12 microns dry film thickness onto boards varying in width from 260mm up to 610mm and in thickness from 70 microns to 2mm. The handling system is also able to convey flexible circuit laminates without damage.

Once coated the laminate passed through a long infra-red drier (at up to 3m/min depending on film weight and laminate thickness), is cooled to within 1°C of ambient temperature by a cool air flow section, before exiting to a racking system. Both resist systems are fast exposing and contain a visual exposure indicator, develop in aqueous sodium carbonate solution and are resistant to acid and ammoniacaal etch solutions. The resists strip in hot sodium hydroxide solution or proprietary dry film strippers.