Tech Talk

Fine Lines in High Yield (Part CXLVII)

Dry Film Photoresist Coating Base Film and Coversheet Considerations

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When Jack Richard Celeste's "process for making (dry film) photoresists" (Ref. 1) was first introduced commercially by DuPont, it profoundly changed the fabrication of printed circuit boards. Compared to liquid photoresists in use at the time, the dry film enabled better yields due to the pinhole-free coating of uniform thickness it provided in a relatively simple, versatile process.

In addition to the photoresist layer, the dry film photoresist requires two more layers between which the actual photoresist is sandwiched: a base film, typically polyester, onto which the photoresist composition is coated, and a coversheet, typically polyethylene. It may be of interests to look at the functions served by these layers and to become familiar with the considerations in selecting the proper base and coversheet films.

One key aspect of Jack's invention is the notion of "differential tack". Since the polyethylene coversheet is removed first, before the lamination of the photoresist to the copper surface, the tack between the polyethylene and the resist has to be lower than the tack between the resist and the polyester. After the lamination of the resist to the copper surface, the tack between the copper and the resist needs to be higher than the tack between the resist and the polyester so that the polyester can be removed after exposure without pulling the resist off the copper surface. More specifically, the difference in adhesion between resist and copper and resist and polyester needs to apply to both, exposed and unexposed resist. On the other hand, the tack between polyester and resist can't be too low in order to prevent premature release of the polyester from the resist surface during the "tacky roll" cleaning of the polyester surface prior to exposure or during cut sheet lamination.

Polyethylene (PE) coversheet considerations

The role of the polyethylene is basically to prevent the photoresist layer from sticking to the adjacent, underlying polyester layer during roll formation and roll storage. There are a few quality considerations in the selection of the PE grade. Since the polyethylene is in contact with the resist composition, the manufacturing process for PE should not involve processing aids or adjuvants that could interfere with the function of any of the resist components, notably the photoinitiator system. Uniform thickness of the PE sheets seems to be an obvious requirement to avoid "telescoping" of the roll and to avoid uneven pressure on the photoresist layer during roll formation and storage which will lead to photoresist thickness variation. The problem due to localized thickness non-uniformity in the PE film is less obvious. One example of such a nasty problem are so called "gel slugs", protrusions from the polyethylene surface due to the presence of small gelatinous polyethylene domains during the film formation. Such protrusions will imprint into the photoresist layer and form small dimples. These dimples will face the copper surface after lamination and form a void between the resist and the copper. If such a void happens to be located at the fringe of a resist line after exposure and development, etchant can get under the resist and cause dish-downs on the copper trace, or in general, a ragged etched line.

Polyester Coating Base Film Considerations

The selection of the polyester film thickness is a compromise between conflicting requirements. The film needs to be thick enough for safe web movement during the coating operation. Next to web handling, the hot roll lamination process also introduces a minimum polyester thickness requirement to avoid lamination wrinkles. From a cost viewpoint, one would like to make the polyester film as thin as is practical. Other considerations that favor a thin polyester base are resist conformation to the substrate topography and good resolution in contact printing. Since the polyester film acts like a spacer between the phototool and the resist layer, it creates "off-contact" between the phototool and the resist. Since the exposure light is not perfectly collimated, such off-contact allows angled radiation to get under the opaque areas of the phototool and expose areas that should not be exposed. This effect increases as the space between the phototool and the resist increases (see Figure 1). Taking all of these consideration into account, the typical polyester thickness has historically been a little over one mil (about 28 micron), and it has been reduced over the years to about 0.9 mil (22 micron

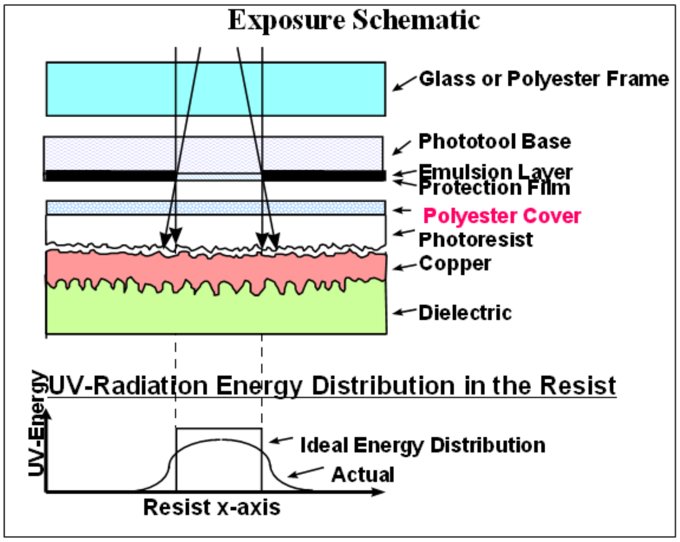

Figure 1: Exposure Schematic

The polyester has an additional important function. It serves as a barrier against oxygen diffusion into the resist. The oxygen concentration in the resist needs to be kept low because oxygen is a potent radical scavenger. It reacts with the acrylic monomer radicals before they have a chance to induce polymerization. Thus, the first acrylate radicals formed in the exposure process react with the oxygen that is present in the resist and a lost as polymerization initiators. Once the oxygen is depleted, and the polyester oxygen barrier prevents the oxygen concentration in the resist from building up again, then the radical induced polymerization can begin.

Since this oxygen barrier function requires the presence of the polyester cover during exposure, the coversheet needs to be UV-transparent in the 340-400nm wavelength range. Polyester absorbs UV radiation at wavelengths below this range so that there is no problem.

Lastly, the clarity or transparency of the polyester needs to be considered. The polyester films used for dry film resists typically have added particles ("matte") on the surface or throughout the bulk of the film. The function of this "matte" material is threefold: it allows air escape during the formation of the polyester film roll, avoiding pockets of trapped air to imprint on the film. It serves the same function during roll formation of the dry film photoresist after the resist is coated on the base. And thirdly, it allows good vacuum drawdown in the exposure frame during exposure to minimize off-contact. However, since these particles are opaque to UV radiation, they block and scatter light. If the light is highly collimated, the particles actually image on the resist, leading to pockmark dimples on the resist surface and causing a "fluted" appearance of the resist sidewall (see Figure 2). Thus, the size and level of particles in the polyester (see Figure 3) is a compromise between the need for good air escape and image quality.

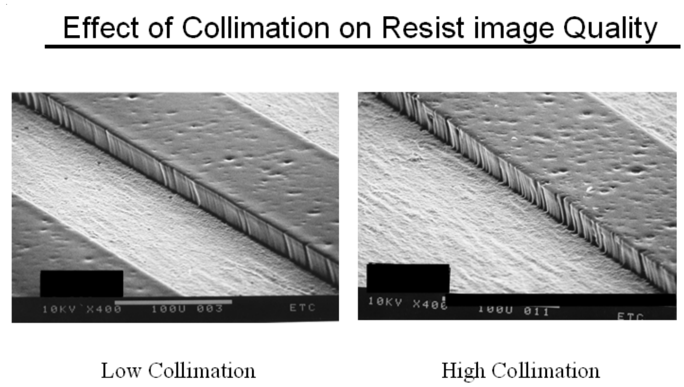

Figure 2: Effect of the degree of collimation on Image Quality

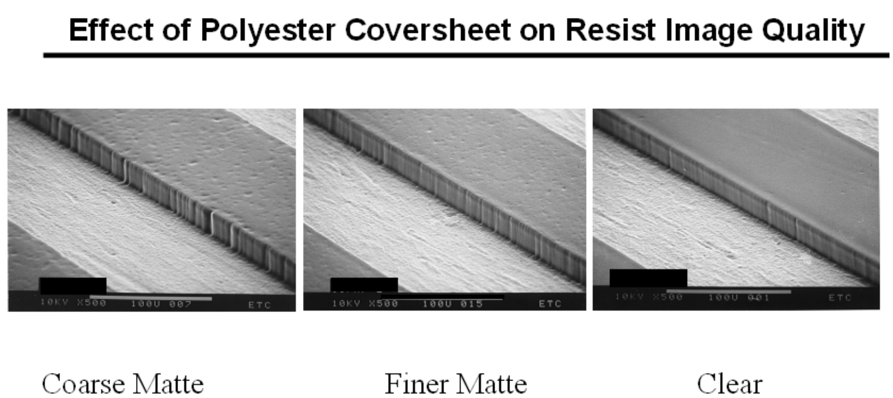

Figure 3: Effect of Matte Particle Size in Polyester on Image Quality

References

1. Process for making photoresists, Jack Richard Celeste, US patent 3,469,982 (Sept. 30, 1969)