Tech Talk

Fine Lines in High Yield (Part CXXXIII)

Safe Lighting in Yellow Room Exposure Areas

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The subject of Safe Lighting has been previously covered in Tech Talk (No. 71, August, 2001). This Tech Talk includes some updates, mostly concerning sourcing. The PWB industry standard photolithographic process uses negative working photoresists that are exposed with UV radiation in the near UV range, whereby the photoresist UV-radiation sensitivity is peaking around 365nm. More correctly, the photoresist is not only sensitive to UV radiation but also to near UV visible light in the 410 to 430nm range which makes up the violet and blue light of the visible spectrum. This visible light is not "safe", i.e. it can lead to premature polymerization of the photoresist after the dry film has been removed from the box, and the black polyethylene cover has been removed from the film role. The unexposed resist needs to be protected from radiation to which it is sensitive to during lamination, before and after exposure, up to and through development. This is why suppliers of developer units often supply yellow safe light to check the developer break point or wash off point. The safe lighting area appears yellow for the following reason: the visible spectrum is made up of "complementary color" wavelength pairs which compliment each other in the sense that, when paired, they appear white. Yellow and blue are such a pair. Thus, filtering out the blue light makes the "yellow room" appear yellow. The question is often raised about the spectral sensitivity of the photoresist at shorter UV radiation wavelengths. The dry film photoresist actually does not "see" UV radiation below 320nm because the polyester coversheet that protects the resist during lamination, exposure, and post-exposure hold times absorbs UV radiation below about 320nm.

Then the question comes up: how do we know that safe lighting is indeed safe? This is a valid question since yellow lights are not always safe, and even safe yellow lights are not safe above a certain flux intensity. Traditionally, a flux intensity of less than 70 foot-candles (753 lux) has been recommended. The "flux" is expressed in foot-candles (fc) which is equivalent to the dimension "lumens per square foot". The metric equivalent is the "lux" (from Latin for light), or "lumen per square meter". The conversion factor is: lux = fc x 10.76ft^2/m^2 = 10.76 lumen/m^2. The 70 fc recommendation is nowadays often considered to be unrealistically low for a comfortable work environment, and many circuit board shops found 100 fc to be safe after minimizing exposure time to yellow light by optimizing work flow and characterizing the sensitivity of the photoresist. This is particularly important if high photospeed laser direct imaging (LDI) resists are in use. LDI resist that remains on a hot roll laminator after a short run is often protected by a black plastic cover to minimize yellow light exposure.

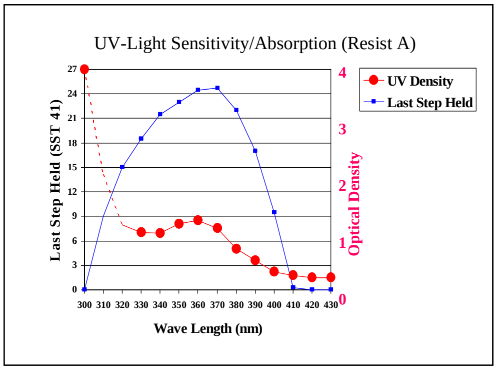

Fig. 1: Spectral Sensitivity Curve of Resist A

There is a good chance that LDI resists are also more sensitive to violet and blue radiation. Figures 1 and 2 illustrate different photo-sensitivities of Resist A and B in the visible range. The resists were exposed through filters that allow transmission in 10 nm increments. The UV (optical) density was then plotted against "steps held" that resulted from such incremental exposures. Remember: for a given radiation intensity (e.g. in mWatts) over an area (e.g. cm^2), one can adjust the exposure time (seconds) to arrive at the desired exposure energy (mW/ cm^2 x seconds = mJ/ cm^2) so that the "step held" falls into the functional range recommended for the resist.

The output of the study of Reference No. 1 was a series of curves that correlate "steps held" with the optical density (OD) of the resist at a given wavelength segment at equal (100 mJ/cm^2) exposure energy doses.

There are no optical density data below 300 nm because the polyester coversheet covering the dry film resist absorbs practically all radiation below 300 nm. Resist A shows less of a response in the near visible range than Resist B. This could be explained by the fact that Resist A and B have different colorants, and the colorant in Resist A siphons radiation energy away from the photoinitiator system. Resist A shows an optical density maximum around 370 nm, whereas Resist B's maximum is closer to 360 nm. Both resists show broad sensitivity in the 340-400 nm range which should be the target emission range for an effective light source, including UV lasers.

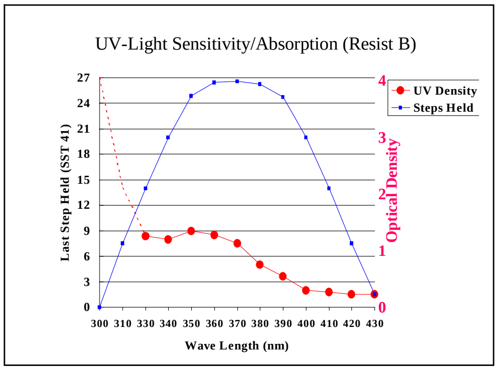

Fig. 2: Spectral Sensitivity Curve of Resist B

Safe lights/Filters/ Sleeves

Radiation sources shielded with "gold shield" or Photoresist Gold Lamps cut off radiation below 530nm and are considered very safe. The yellow or orange color of safe lights is not always an indicator that the light is safe: there are unreliable yellow-colored decorator tubes that sometimes find their way into yellow rooms; they may leak white light and don't meet safe light standards. There are also "Safe White Lights" that have gained popularity. They are generally not recommended unless their emission spectrum has been carefully characterized versus the spectral sensitivity of the photoresist. Resist B of Figure 2, for example, may show premature polymerization under such "safe white light". Safe lights can be obtained from a number of sources including Illumination Technology (www.illuminationtech.com) or EncapSulite® International (www.encapsulite.com). Non-safe lights can be made safe by covering them with safe light sleeves such as Olec's Accusafe sleeves (www.olec.com).

Unsafe light sources include direct sun from windows, skylights, doors, mercury street lamps, white fluorescent lamps, incandescent lamps, and high pressure sodium lamps. Unless they already have a safe light coating, one can cover windows with UV absorbing polyimide foil (e.g. Kapton®), or one can replace the windowpane with amber Plexiglas sheets (e.g. Atoglas® from Atofina Chemicals, Inc., Atoglas Division, 2000 Market St., Philadelphia, PA 19103).

Safe Lighting Check

The following is a practical test to check if the lighting is safe. Laminate two panels with photoresist and expose both panels with a fine resolution pattern. Then store one test panel in the dark while exposing the other panel to normal yellow light conditions for a realistic, longest hold time that is typical for the time elapsed between lamination and development. Develop both panels and subject them to flash tin plating (e.g. short immersion tin exposure). The presence of development resist residue due to unsafe light exposure will show up as incomplete tin plating in the developed areas. Light meters are also available to measure actual yellow light intensity directly. Suppliers of safe light also provide a useful tool for a quick, qualitative check for blue/violet radiation: it consists of a transparent foil, typically held in a cardboard frame. If you hold up this foil against the light source and you see a bluish color through the foil, this is an indication that the light source emits unsafe blue/violet light.

Lastly, the exposed, developed photoresist will continue to polymerize at a slow rate in white light. Long exposure to high intensity white light may cause slow stripping and resist embrittlement.

Reference:

1. UV-Light Sensitivity of Dry Films, M. Boudellal, DuPont Electronics, 6/13/85, unpublished information.