Importance of Pigment and Dispersion Characterization

for Optimum Cure and Performance in UV-Curable Stains, Inks and Coatings

By Ronald Obie

Ultraviolet (UV) light-cured coatings are high-performance (essentially instantaneous cure) and environmentally friendly alternatives to conventional thermoset coatings technology. These characteristics are the impetus for continued growth of this technology.

The UV-cure process is an additional polymerization process which includes application of the coating on an article or substrate; exposure of the coated article to UV radiation of a given spectral distribution; absorption of UV radiation by specialized chemicals (included in the formulation, called photoinitiators), followed by generation of free radicals; initiation of polymerization; and subsequent curing of the coating (Figure 1).

Without absorption of radiation by photoinitiators, the cure process will not take place. Thus, from Figure 1 it follows that the spectral distribution of the incident radiation and the absorption characteristics of the photoinitiator package are critical components of the UV-cure process. Figure 2 displays an example spectral distribution of a medium-pressure mercury lamp and a gallium-doped mercury lamp. Figure 3 displays 12-micron pathlength absorption spectra of the photoinitiators 1-Hydroxy-cyclohexyl-phenyl-ketone, and Bis(2,4,6-trimethylbenzoyl)-phenyl phosphine oxide, both 3.85% concentration in an acrylate system.

The presence of pigments and colorants in UV-cured coatings—such

FIGURE 1

The UV cure process by addition polymerization

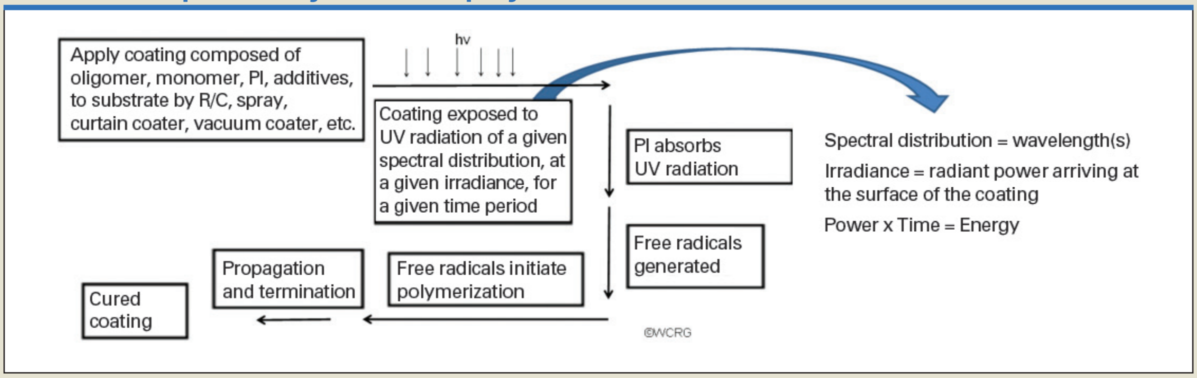
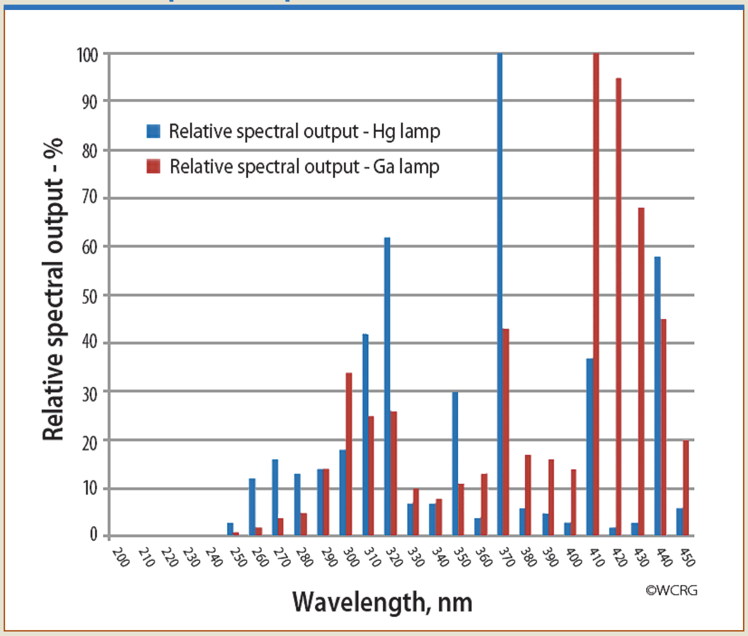


Figure 2

Relative spectral output of Mercury- and Gallium-doped lamps



as UV-cured wood stains or UV-cured inks and coatings—can greatly impact the cure and subsequent performance of UV-cured coatings compared to clear coatings. Therefore, when formulating pigmented wood stains, inks and coatings, it is imperative to understand the spectral characteristics of the pigments and colorants in the formulation, particularly with respect to the spectral characteristics of the UV lamp and photoinitiator system. Figure 4 displays the optical transmission of HR yellow, carbon black and titanium dioxide pigments as a function of wavelength and concentration.

Figure 2 shows that the gallium-doped lamp has greater light output at the longer wavelengths (400+ nm), whereas the non-Ga doped lamp has greater light output at the shorter wavelengths. Concurrently, Figure 4 shows that Rutile TiO2 displays greater light transmission at wavelengths above 300 nm, but tends to be optically dense at shorter wavelengths. Interestingly, HR yellow pigment displays somewhat of a low level window of transparency, exhibiting greater transparency between about 300 to 410 nm. Additionally, the amount of light transmitted by the pigmented film is dependent upon the concentration of the pigment as well as film thickness. Figure 4 shows that carbon black allows only very little light through a 25-micron film, even at only 2% concentration.

The data of Figure 3 indicates that the phosphine oxide photoinitiator would be the photoinitiator of choice between these two photoinitiators when using yellow and white pigments. The formulator must understand the output characteristics of the curing system; the absorption characteristics of available photoinitiators; and the spectral characteristics of pigments. Improper spectral matching of any of

Figure 3

Photoinitiator absorption spectra comparison

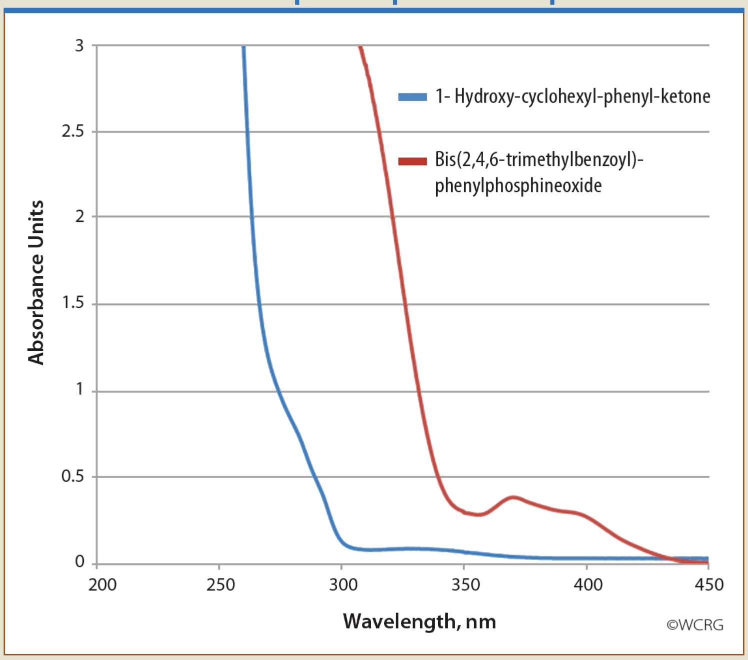


FIGURE 4

Percent transmittance as function of pigment, pigment concentration and wavelength

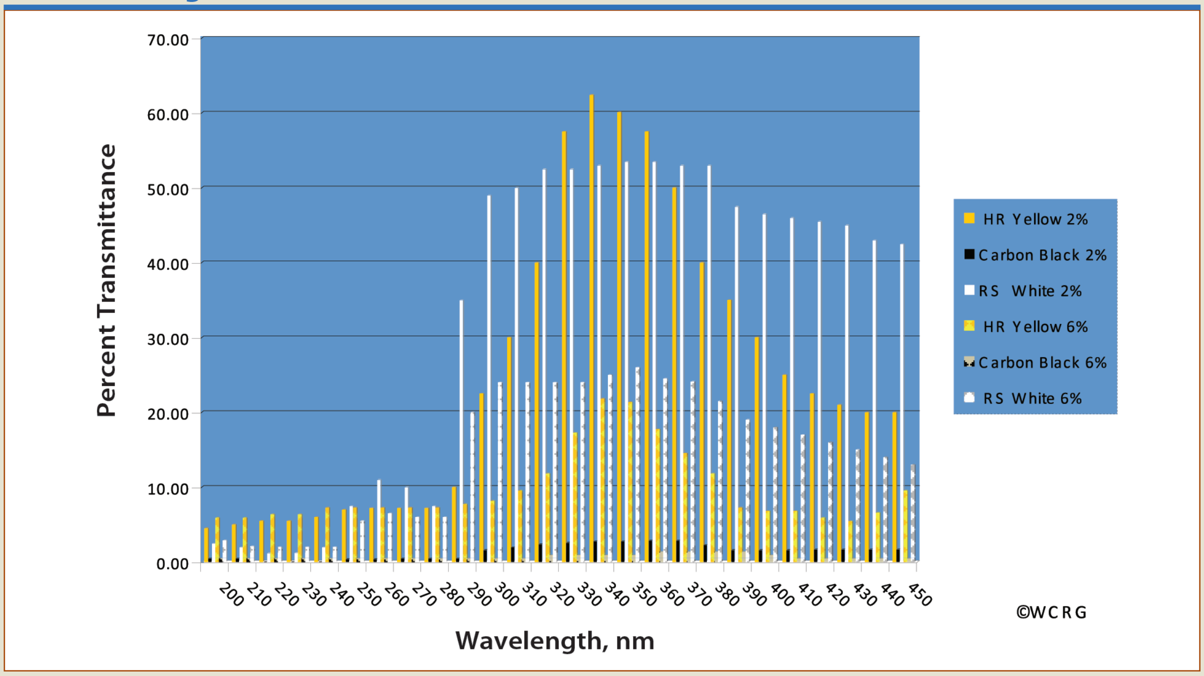
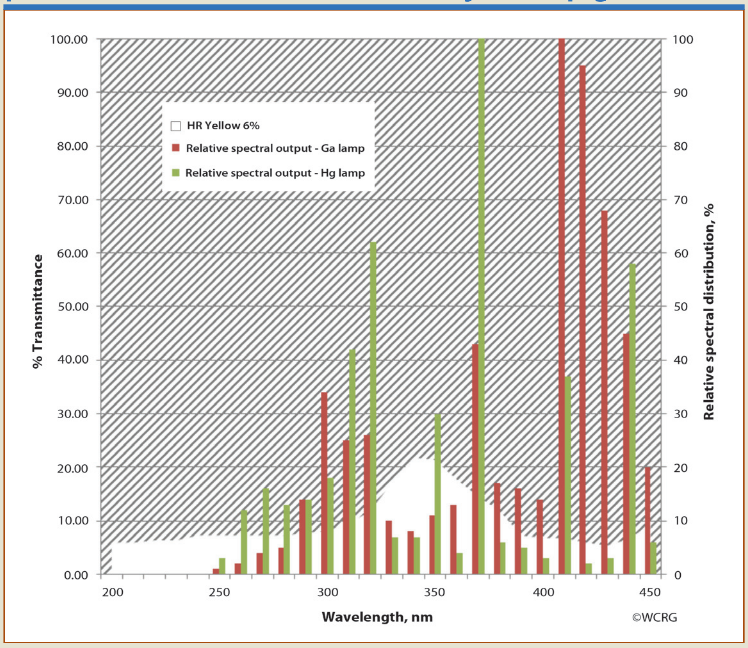


FIGURE 5

Overlay of lamp relative spectral distribution over percent transmittance of 6% HR yellow pigment

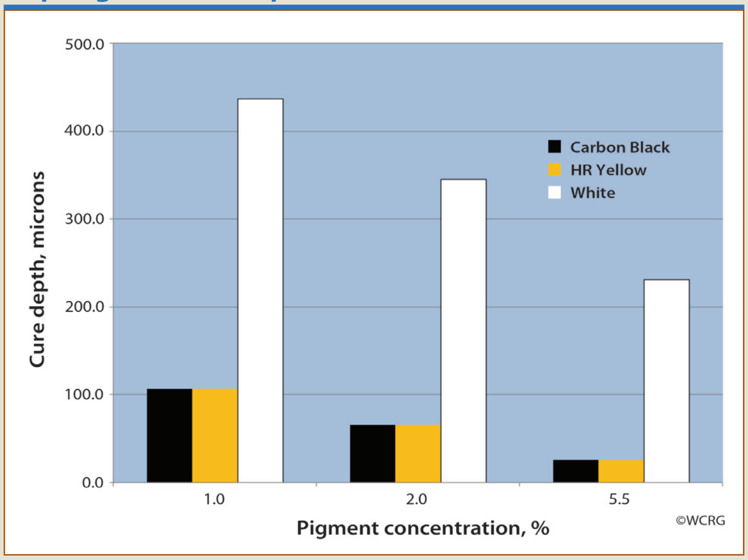


these parameters will result in reduced cure and performance. When utilizing pigments in UV-cured coatings, it is important to understand that only a certain amount of light will be available for curing.

Figure 5 displays how only a small portion of light is available (solid white portion of figure) for curing in a 25-micron film containing 6% HR yellow pigment. In fact, the data shows that for most of the radiation emitted at a given wavelength by the lamps, less than 10% of accessible light is available for curing the film. Indeed, film cure depth data indicates that HR yellow pigment is very similar in cure response as carbon black (Figure 6). This is apparently due to the fact that where HR yellow pigment is most transparent, the lamps have low light output.

Figure 6

Impact of pigment type and concentration on cure depth gallium lamp



Conclusions

Complete spectral characterization of pigment, photoinitiator and curing system is essential in order to develop optimized pigmented UV-cured coatings, stains and inks. Cure is dependent upon lamp spectral distribution and irradiance; pigment and PI type and concentration; PI quantum yield; film thickness; and oligomer/monomer chemistry.

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