Exposing Cycolor Film using Telegen's New Linear Head

Joseph C. Camillus
Cycolor Incorporated
Miamisburg, Ohio

Abstract

A new linear head is being developed, using Telegen Display Corporation's HGED technology, to expose Cycolor instant photographic media in a compact digital printer. Some of the design criteria used in the development of the new head to optimize the quality of the final picture are reviewed in this paper. The spectral characteristics of the red, green and blue phosphor emissions need to be matched to the spectral absorption characteristics of the corresponding photo-initiators employed in the microcapsules of the Cycolor photographic media to minimize exposure cross-talk. The intensity of the phosphor emissions also needs to be high to obtain the required print speed of 20 seconds. The selection of each of the phosphors needs to take both of these criteria into account. Specific details in the selection of the red phosphor system are provided.

Introduction

Cycolor media provides a full-color, panchromatic, dry, single sheet, instant, photographic system. Its characteristics allow for the development, with a suitable exposing device, of a compact, fast, desktop or portable digital printer.

Cycolor media is panchromatic – it can be exposed by visible light. The exposing device can be either a mask (as, for example, an LCD) which modulates a source of light or a device (LED's for example) that actually emits light. Full-frame Black and White LCD's have been used to make 4x6 color pictures at print speeds shorter than 5 seconds. Cycolor has also shown that its media can be exposed by LED's (red, green and blue) in a scanning head that irradiate the media pixel by pixel to obtain an image.

The ideal exposing device would be a masking device (with an appropriate light source) or a light source (which can be appropriately modulated) which is flat and thin, with bright saturated colors, excellent contrast, and low cost, but without the size, weight, bulk or high voltages of traditional CRT's or the bulk and cost associated with projection LCD's.

Design criteria imposed on the product included compactness, minimization of exposure cross talk and a print speed of 20 seconds for a 4x6 picture.

Cycolor Technology

Cylithography[1,2] (Cycolor Technology) was developed in the Central Research Labs of Mead Paper (now Mead-WestVaco) as an offshoot of carbonless paper technology. In carbonless paper, an appropriate leucodye[1,2] is dissolved in an inert solvent, microencapsulated and coated onto a sheet of paper. When these microcapsules are ruptured (by writing on the sheet, for example), the solvent and the dissolved leucodye are squeezed out of the microcapsules. The leucodye comes into contact with developing chemicals with which it reacts to form color.

In Cylithography, instead of an inert solvent, a monomer that can be polymerized by free radicals is used in the microcapsules**.** Along with the leucodye, a photoinitiator is also dissolved in the microcapsule fluid to initiate the polymerization reaction.

When exposed to light, the monomer in the internal phase of the microcapsules reacts and hardens, turning from a liquid to a solid or gel state.[4,5,6] By selectively exposing the three basic colored microcapsules, cyan, magenta or yellow, millions of colors can be derived. Microcapsules filled with magenta dye are hardened by green light. Similarly, the cyan and yellow dye-filled microcapsules are hardened by red and blue light, respectively. Upon exposure, a latent image is formed of exposed and unexposed microcapsules. In order to develop an image, pressure is required to break the microcapsules and to release leucodye contained in the soft or partially exposed microcapsules, analogous to carbonless paper technology. Once the leucodye is released, color develops upon contact with adjacent developer resin particles. Heat is applied to accelerate the color development process and fix the image.

An image is recorded onto Cycolor digital imaging film in a three-step process, much like the conventional silver halide technology with the exception that Cycolor, being a dry process, requires no wet chemicals for color development. The entire image forming process consists of three simple steps: 1) exposure to light, modulated by image information; 2) application of pressure to break the microcapsules (similar to carbon-less paper); and 3) the application of a brief heating step to accelerate color development. The result is a continuous-tone photographic image.

Cycolor technology involves coating a polyester film with millions of microcapsules. In the manufacture of Cycolor media, a mixture of microcapsules and developer particles is precision-coated onto a thin, transparent polyester film. White polyester backing with adhesive is laminated against the coated film, producing a water-resistant, durable sheet.[7,8] Since the coating is applied from edge to edge, the film can be cut in any desired size depending on product requirements and can be supplied with either a bleed-edge or with a white pre-exposed border.

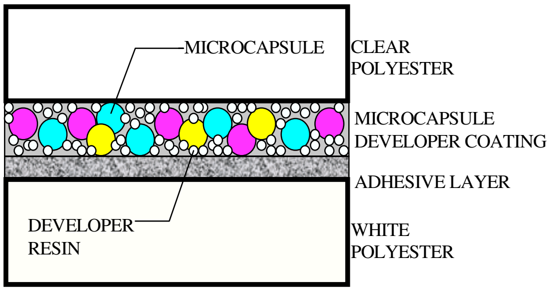

Figure 1. Cycolor Film Structure

Telegen's HGED Technology

High Gain Emissive Display (HGED) is a patented emissive display technology[9] from Telegen Display Corporation which utilizes a new type of electron focusing structure, a unique grid control structure, enhanced high brightness low voltage phosphors and proprietary electronic driver systems to construct a simple, flat, low voltage CRT type display. This type of device seems to meet many of these requirements.

In a standard CRT, a single electron gun assembly located in the rear of an evacuated (high vacuum) glass bell housing shoots a beam of electrons through the CRT neck. A series of magnetic deflection coils direct the electronic beam to a particular phosphor spot on the front screen. The entire image is "painted" across the front screen, dot-by-dot at over 60 times each second. However, for all of its apparent simplicity and performance, the CRT suffers from a number of deficiencies. First, it is big, bulky and heavy, necessitated by the high vacuum and the need to position the electron gun assembly far back from the front screen.

Additionally, the CRT utilizes very high voltages (>25,000 volts) to accelerate and control the electron beam, potentially causing harmful x-rays. The CRT is also susceptible to external magnetic fields, which can affect image quality as well as color purity.

The HGED, on the other hand, controls dozens of small, low powered, close-in beams, creating a display less than one inch thick. Because the multiple electron "guns" are located very close to the front screen rather than one high powered gun located far from the front screen, HGED displays operate at much lower voltages and with less heat than CRT's.

The heart of the HGED display is a new type of patented electron "gun" called the Compressed Electron Gun or CEG.[10] Electrons emitted by the CEG travel a short distance and are directed to a single line of the display by steering charges on the Deflection Grids, where they impinge upon proprietary low voltage phosphors, "painting" the visual image one line at a time.

Linear Head Design

In the new printer, Cycolor media is exposed by the image wise excitation of red, green and blue phosphors arranged as three separate lines in a flat, glass chamber.[11] The media is scanned under this chamber and thus exposed line-by-line with each of the colors. The drivers write the appropriate information on each of the red, green and blue lines of phosphors, according to the data contained in the digital file and after appropriate image processing for proper color matching.

The phosphors, of course, have to be first selected for use on the basis of two criteria: the spectral characteristics and the intensity of the light produced.

Spectral Characteristics

The spectral characteristics of the emissions from the excited phosphors need to be matched carefully with the spectral absorption curves of the photoinitiators used in the microcapsules. If this is not done, then the green-sensitive magenta capsules, for example, may be affected by red or blue light leading to unwanted polymerization of the green-sensitive magenta capsules and consequent reduction in the magenta density developed.

To minimize cross-talk in general, both the photoinitiator (for its absorption) and the corresponding phosphor (for its emission) need to have narrow-band spectra. However, the amount of light that is absorbed is low because of these narrow bands and the sensitivity of the system therefore is low – leading to long print speeds. So a proper balance needs to be found between the potential for cross-talk and the sensitivity of the system.

The spectral absorption characteristics of the blue-sensitive, green-sensitive and red-sensitive photoinitiators used in current Cycolor media are shown in Fig. 2. It is obvious from the curves that there is considerable overlap between the absorption curves of each of the photoinitiators. It is difficult then to obtain a system with no cross-talk – whatever the light source.

The red-sensitive capsules (containing cyan leucodye) peak in sensitivity, as can be seen in the attached spectral curves, around the 650 nm range. To maximize the efficiency of light absorption, the peak wavelength for the red phosphor emissions should also be as close to 650 nm as possible. Shown in Fig. 3 are the emission spectra, of two of the red phosphors (R-1 and R-2) that have been evaluated overlaid against the absorption spectra of the photoinitiator in the red-sensitive capsules.

The spectral emission curve of the red phosphor identified as R-2 in Fig. 3 is a very good match for the spectral absorption curve of the red-sensitive photoinitiator. This will result in an efficient utilization of the absorption band in the photoinitiator. The spectral curve of R-2 on the other hand is narrow band and seems to utilize only a small portion of the absorptive capability of the photoinitiator.

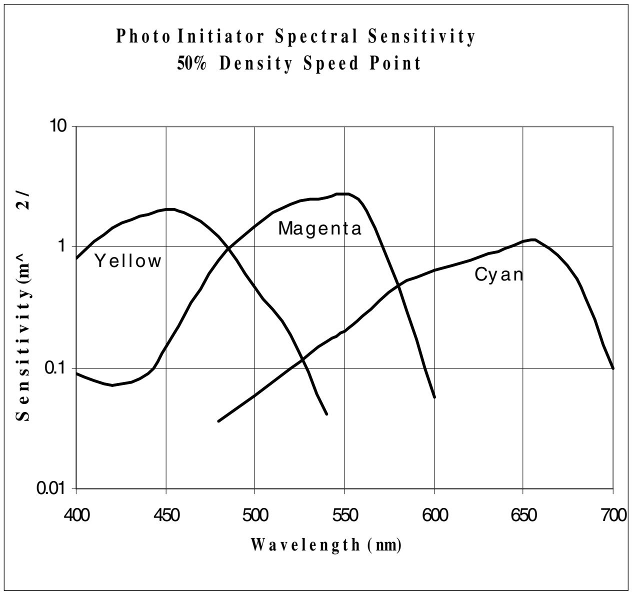

Figure 2. Cycolor Media Spectral Sensitivity

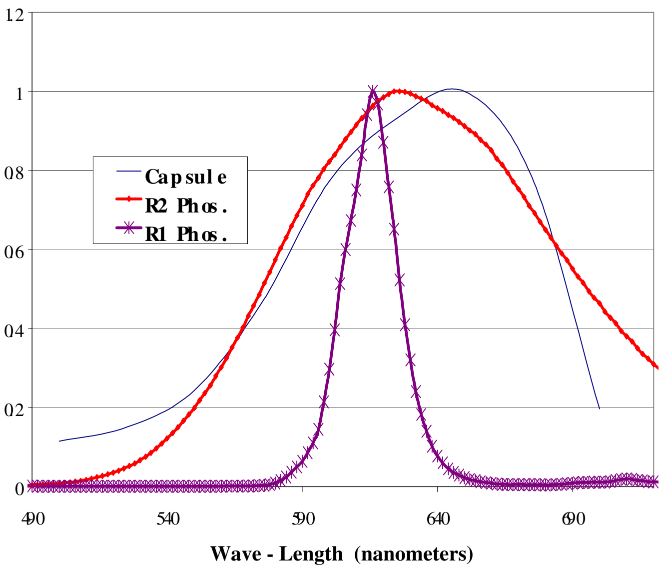

Figure 3. Normalized Spectra for the Red System

As can be seen in Fig. 4 the cross-talk effects from the R-1 phosphor are very low. There is no exposure of the green-sensitive and blue-sensitive capsules even when the red-sensitive system is taken all the way to D-min.

With the R-2 phosphor on the other hand, because of the wide band spectral output of its emissions, there is significant exposure in the green–sensitive capsule system. Fig 5 shows how much the green system can be affected by just exposure to the red light from phosphor R-2. The density of the green system starts to fall off well before the red system has reached D-min. With such a system it will be impossible to get a single color green D-max that is satisfactory.

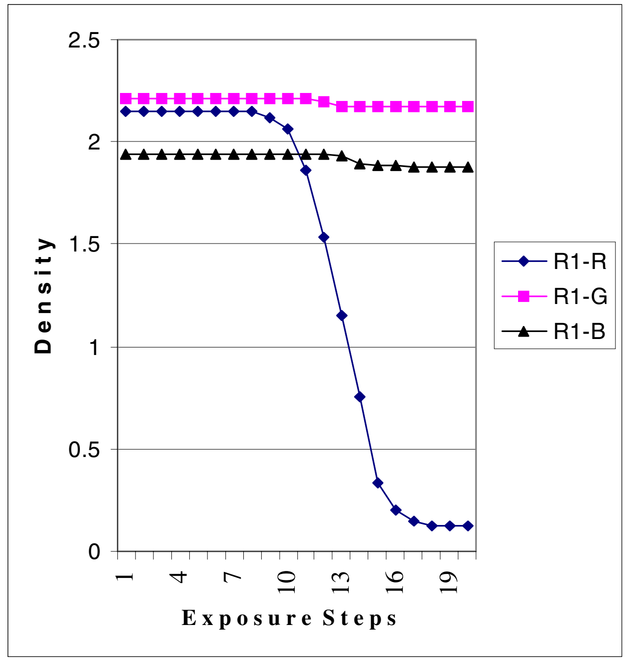

Figure 4. Red Phosphor R-1: No Cross-talk

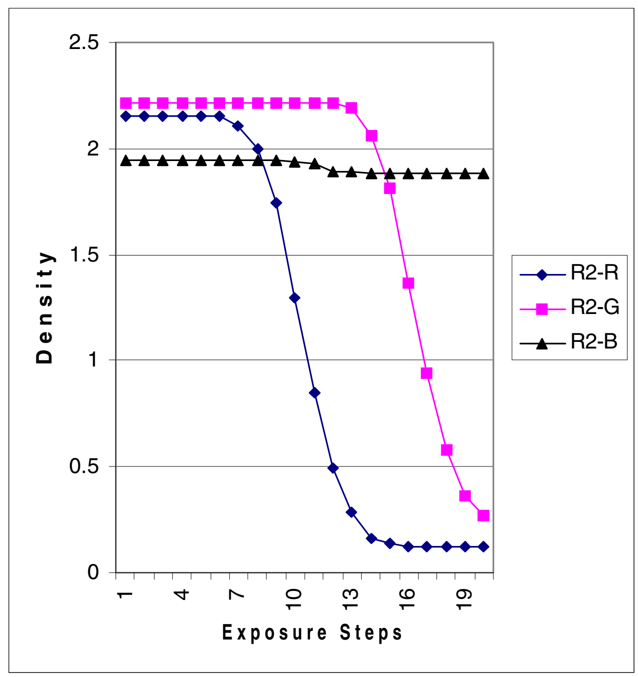

Figure 5. Red Phosphor R-2: Significant cross-talk effect on the Green system (R2-G)

The sensitivity advantage obtained from the greater amount of absorbable light emanating from the R-2 system would have been desirable from looking strictly at its light output. This advantage is evident in comparing (in Figs. 4 and 5) the exposure step at which each of the red phosphors takes the red-sensitive capsule system to D-min.

The introduction of "filters" to block off the red light effects in the green system has been reasonably successful. However, in the end, the phosphor R-1 was chosen anyway for use in the printer. It was decided that a filter was much more important for use in the blue side of the green-sensitive system, and the prospect of loading up the green-sensitive capsules with yet more of these extraneous chemicals was not a palatable solution.

Similar procedures were employed in the selection of the green and blue phosphors.

The linear head will have 3 lines each of the red, green and blue phosphors to provide enough light to take each of the capsule systems to D-min. Each of the phosphor lines is activated by drivers forming an active matrix array to modulate the intensity of the light generated by each color for the image-wise exposure of the Cycolor media resulting in a full color picture being printed in less than 20 seconds.

References

1. F. W. Sanders, G. F. Hillenbrandt, J. S. Arney, R. F. Wright, US Patent # 4,399,209.
2. F. W. Sanders, G. F. Hillenbrandt, J. S. Arney, R. F. Wright, US Patent # 4,440,846.
3. P.C.Adair, "Handbook of Imaging Materials" ed. A. S. Diamond; Marcel Dekker, Inc. 1991, pp. 563-583.
4. P. Gottschalk, R.B.Schuster, US Patent #4,772,530.
5. P. Gottschalk, R.B.Schuster, US Patent #4,772,541.
6. S. Chatterjee, P. Gottschalk, P. Davis and R.B.Schuster, *J. Amer. Chem. Soc*. **110,** 2326.
7. J. C. Camillus, US Patent # 5,783,353.
8. J. C. Camillus, US Patent # 5,916,727.
9. J. Stevens, W. E. Naugler, Jr., US Patent # 5,831,397.
10. J. Stevens, W. E. Naugler, Jr., US Patent # 5,949,395.
11. C. M. Brown, R. G. Capek, US Patent # 6,172,457.

Biography

Joseph Camillus received his B. Sc. (Tech) degree in Chemical Engineering from the University of Madras, Madras, India in 1964 and a Ph. D. also in Chemical Engineering from the University of Pittsburgh in 1970.

He worked at the Polaroid Corporation, Cambridge, Massachusetts, from 1969 to 1988. His assignments were in Research and in Manufacturing and included Manufacturing Technical Support as well as Process and Product Development. In 1988 he joined the then Mead Imaging division (in Miamisburg, Ohio) of the Mead Corporation which later became Cycolor Inc. He is currently Senior Vice President for Research and Development at Cycolor. He is a member of IS&T and of the American Institute of Chemical Engineers.