A NEW SYSTEM FOR HIGH RESOLUTION IMAGESETTING

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Abstract: A totally new and revolutionary imaging system which produces high quality and dry output has been constructed to satisfy the most demanding requirements of imagesetting. A new digital (binary) film has been invented that is exposed by laser energy. The essence of the new digital film is a dry *laser controlled pigment transfer*. Typically, the imaging portion of the film consists of two layers coated consecutively on a polyester base. The first layer is a thin uniform laser-energy sensitive material, on top of which is an imaging layer consisting of carbon particles embedded in a polymeric matrix. Imaging occurs when a laser beam of appropriate energy, higher than the film threshold, is focused at the interface between the energy sensitive layer and the imaging layer. The absorbed laser energy causes a transformation at the interface between the imaging layer and the energy sensitive layer leading to a strong adhesion between the two layers. The exposed dot is revealed, or is *physically developed* by a precise and controlled peeling process. Dots of very sharp edges are revealed. The film is capable of forming very well-defined dots, as small as 5 μm in diameter, when exposed adiabatically to laser energy higher than the threshold value. These dots have visible optical density Dmax in excess of 4.0 and higher than 5.0 Dmax in UV.

Introduction

Silver-halide films have been the most capable medium to satisfy the demands of imagesetting. Over the years researchers have invented alternative imaging systems in an attempt to create a more convenient to use system (Storge et al, 1989; Johnson, 1992). Not withstanding the special features of these new systems, they fell short from satisfying all requirements of imagesetting simultaneously.

The Polaroid Helios™ technology is the first digital platform that has the imaging capabilities of the analog silver-halide technology and yet eliminates the inconveniences of wet chemistry and light-tight requirements (Habbal et al, 1994). This technology was used to create a high resolution 8″x10″ and 14″x17″ hardcopy outputs for the most demanding digital diagnostic medical imaging such as computed tomography (CT), magnetic resonance imaging (MRI),

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digital radio fluoroscopy (DRF), nuclear medicine, and ultrasound (Habbal et al, 1993). The hardcopies produced by this technology faithfully render all of the diagnostic information without degradation due to loss of contrast sensitivity or limitation in modulation transfer function (Habbal et al, 1993; Scarff et al, 1996).

In this paper we present the performance of this technology in imagesetting. This technology is marketed under the name Dry Tech™.

Limitations of Analog Imaging Systems

Silver-halide film is an intelligent medium. It is able to respond to the simple stimulus of light intensity over a wide range, and thus requires very simple hardware. The response of this medium to light exposure is tailored to meet diverse application requirements, and more recently, researchers created excellent films for imagesetting. However, several short comings continue to limit the applications of this system for future use. In particular, chemical processing makes the silver system cumbersome and environmentally challenging. Also, the inherent stochastic and analog nature of the silver system (e.g. size and distribution of the silver-halide grains, composition of grains, multi-quantum threshold, and chemical processing) limit its spatial resolution. In particular, the complex relationship between density and exposure and chemical processing cause variations in the output films. These variations are limited by calibrating the exposing system, and continuously monitoring the chemical processor. Automatic film processors are customarily used to develop the silver film, yet variables such as processing cycle temperature, chemical purity and concentration, chemical replenishment rates, agitation and drying must be controlled. For example fluctuations in developing time and bath temperature can result in fluctuation in the optical density and dot size, both of which have adverse effects in printing-plate generation.

A High Resolution Digital Imaging System

For reasons mentioned above, analog imaging system, utilizing either photon sensor or thermal energy, produce dots (or lines) with inherent limitations. Diffusion and stochastic processes will blur edges and thus limit the resolution of the system. Thus, in the inventing of our new digital system, we concentrated our research in the area of non-equilibrium processes with short exposures such as the transmitted energy process is adiabatic.

In the construction of this new platform, we realized that a complete systems approach must be taken; we created the optimum performance by designing the interactions between the media and hardware. Figure 1 illustrates the different interactions that we paid attention to.

The High Resolution Digital Film

Typically, the imaging portion of the digital film (Dry Tech™) consists of two layers coated consecutively on a polyester base. The first layer is an energy sensitive material, on top of which the imaging layer is coated. This structure is sandwiched between two polyester substrates.

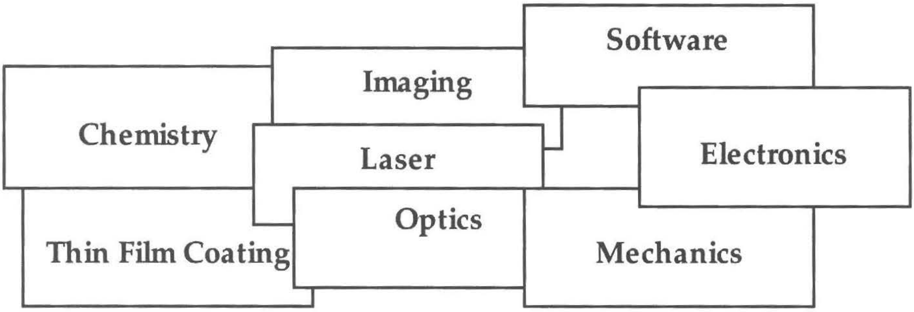


Figure 1: System design elements.

Other layers are added to the film structure for practical reasons (Etzel, 1988, Chang, 1992, and Kelly 1994). We use a 4 mil polyester substrate, identical to the one used in conventional imagesetting film, on top of the imaging layer. Figure 2 shows schematically the imaging portion of the film structure.

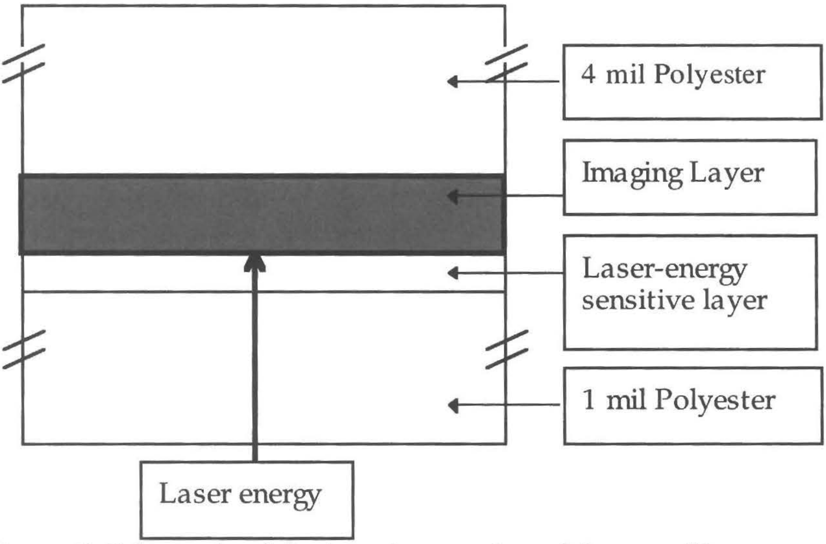


Figure 2: Schematic of the imaging portion of the new film.

The energy sensitive layer is a thin (0.5 μm) uniform and transparent polymeric layer that has a weak adhesion to the imaging layer. The imaging layer consists of carbon particles embedded in a suitable polymeric matrix. The carbon particles have a size distribution in the range 50 Å to 100 Å.

Proper milling processes and careful addition of the polymers are necessary to ensure a uniform dispersion. This dispersion is then coated using a precision slot coating technique and then dried creating a defect free layer of uniform thickness of about 1μm, and visible optical density, of 4.0 .

Imaging Mechanism

The silver-halide grains have several quantum thresholds; imaging occurs when a number of photons of energy higher than the quantum thresholds strike the silver-halide grain.

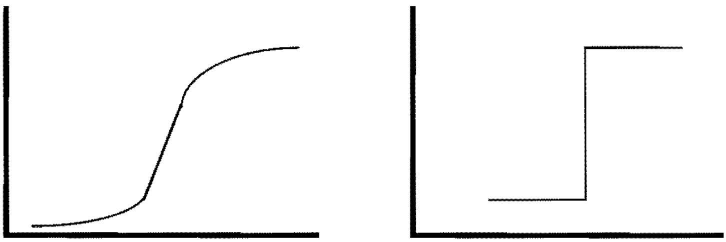
The Dry Tech™ film is a binary film and has a single energy threshold. Imaging occurs when a laser beam, of energy that exceed the film threshold energy, S_T, is focused at the weak-bond interface between the imaging layer and the energy sensitive layer. The laser beam is focused through the thin polyester substrate. No exposure occurs if the energy is less than the threshold, S_T of about 35 mJ/cm^2

During the exposure, the laser energy is absorbed by the carbon black and causes an increase in the adhesion between the two layers, only at the site where the laser energy is absorbed. An increase in adhesion force by two orders of magnitude is typically found after exposure.

The exposure of the Dry Tech™ media is irreversible and non-linear in time and temperature. The laser energy, E, is deposited in a short time order of 30 - 300 nano-second generate to create dots of excellent (hard) edge quality.

We have studied the thermal diffusion at the interface using a three-dimensional finite element modeling and obtained temperature profiles as a function of time and position. These computer simulations take into account thermal diffusion and the thermodynamic properties of the layers, but assume an equilibrium process. A temperature rise at the interface in the range of 700 ^{o}C to 1000 ^{o}C is found. The use of equilibrium values in the model may give an upper estimate for the temperature.

The exposure curve for the silver-halide and the Helios technologies are very different, figure 3. For silver, the curve is very non-linear and has a slope, or finite gamma.



Silver-halide - Analog Film   Dry Tech - Digital Film

Figure 3: Exposure curves of the silver-halide and the Dry Tech™ digital film.

Thus silver dots will always have soft edges, figure 4. For the new digital film the gamma is almost infinite; dots have very hard edges.

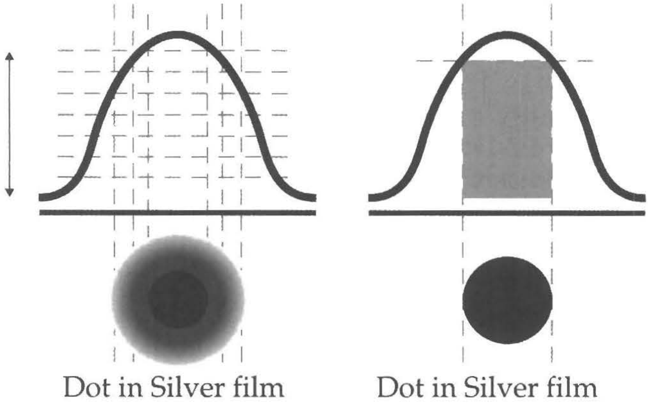
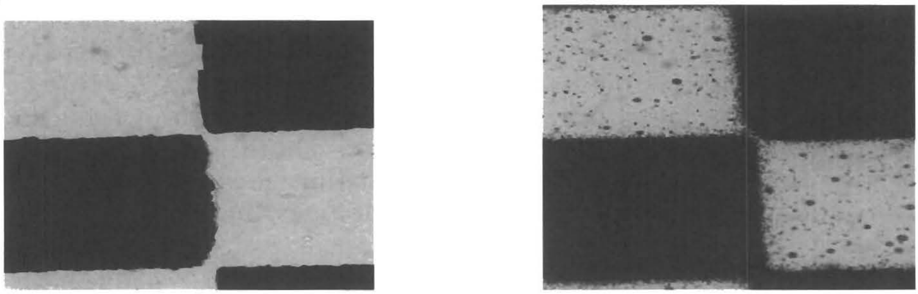


Figure 4: Dot formation in silver-halide and Dry Tech™ films.

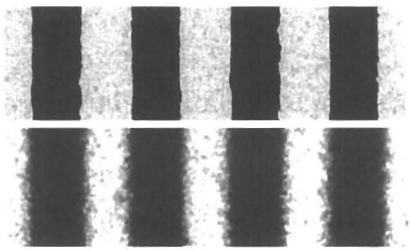
In figures 5 and 6, we show examples of the image quality of the new digital film.



(A) (B)

Figure 5: (A) Photo of a 50% tint at 80 lines/cm image on Dry Tech™ film.
(B) Photo of the same as in (A), on a silver-halide film.

In figure 6, the effect of soft edges in the silver film results in an uncertainty in the width of the black and white bars and will be printed on the plate. In the new film such an uncertainty does not exist.



(A)

(B)

Figure 6: (A) Perfect 20μm line modulation on the Dry Tech™ film.
(B) Soft edges on a silver film create artifacts.

The density of a dot on a silver-halide film is determined, among other factors, by the intensity of the exposing light. In the Dry Tech™ film, the thickness of the imaging layer, and thus its optical density, is determined during manufacturing. The employed precision coating technique insures a high level of quality and consistency and generates films of visible optical densities of 4.0 Dmax and above 5.0 Dmax in the UV, and Dmin is less than 0.04. Since the film is exposed by UV light to print a plate, the high UV absorbing carbon black, the lack of silver granularity, and the extremely high film gamma are more effective than silver in blocking the UV light. Thus an extremely hard dot and excellent dynamic range are created. Furthermore, since the Dry Tech™ film is a binary film, it has a very linear response. Silver films have a complex non-linear response function which reflects several stochastic characteristics of the film. This non-linear response must be linearized using look-up tables.

The Development Process

In the silver-halide film, multi-steps of wet chemical processing are required to transform the latent image to a visible one. Only in Polaroid instant films this transformation is achieved in one step. In our new film, no chemical processing is required. The exposed dot is revealed, by *physically* separating the two polyester substrates, figure 7. This causes the carbon black layer to fracture and result in a black dot (or a line) on the thin polyester layer of very sharp edges. On the 4 mil polyester film, a clear dot (or line) is generated. The final image is generated, as in the conventional silver film, in the form of half tones, line art, or text.

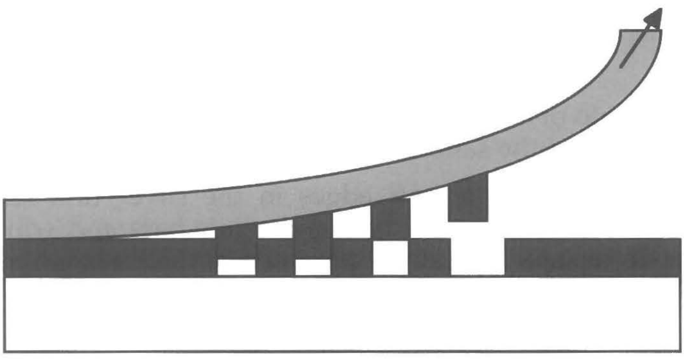


Figure 7: Illustration of peeling the imaged dots.

The quality of the image depends on the quality and consistency of each dot. The peeling initiation and termination are critical in determining the quality of a dot. Appropriate constraints must be applied, so the two cracks meet without creating artifacts (Schuh and Silveira 1992, MacCollum, 1995, and Choi et al, 1996).

The crack propagation path depends on many parameters such as relative adhesion properties between the interface layer, the imaging layer, and the interface of the imaging layer with the 4 mil polyester base, the stress field near the crack tip, material properties, thickness of the structure, and the size of the imaged area. Depending on these parameters, a crack may (1) stay on the same interface or kink and propagate inside the image layer, Fig. 8 -a, (2) jump to the other interface by kinking through the image layer and then kinking back to the interface, Fig. 8 -b, (3) jump to the other interface by delaminating a small area on the other interface and then directly kinking to connect the two cracks, Fig. 8 -c, or (4) jump to the other interface by delaminating an extensive area on the other interface which can cause a blending failure of the image layer when the two cracks are connected, Fig. 8 -D. This mode (#4) happens when both interface adhesions are relatively weak compared to the carbon black material failure strength.

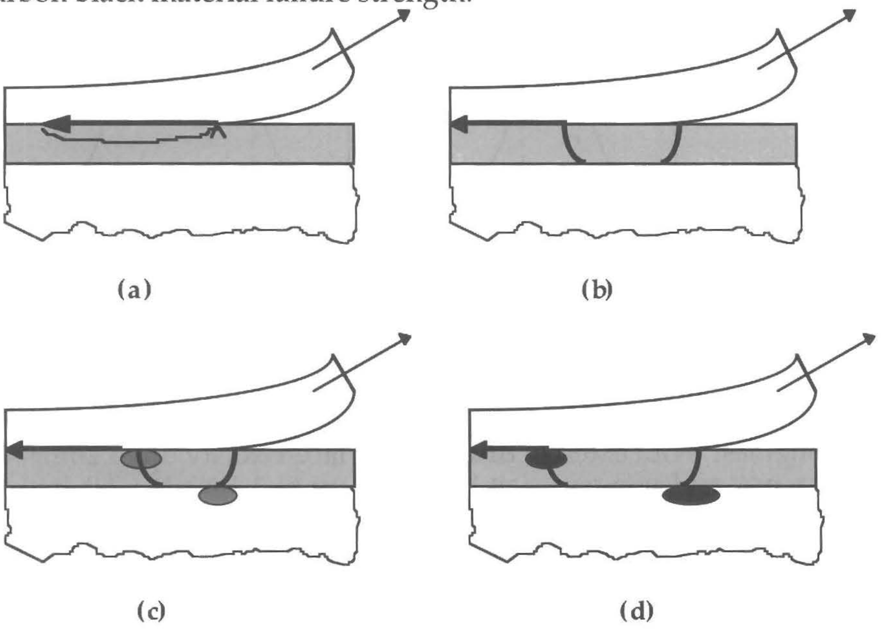


Figure 8: Different dot formation mechanisms

It is very plausible that crack propagation is facilitated by the generation of micro-cracks as the dot volume, upon laser exposure, is subjected to severe thermal stresses as it heats in a very short time to very high temperature.

We have modeled the crack propagation and did experiments which validated our models, (Choi et al, 1996).

For imagesetting applications, we have extensively studied the peeling characteristics of our film. We constructed a device that automatically create a proper peeling control, and generate excellent performance for all screen structures; flat tint, half tone and different stochastic screens.

New Film Exposing Methods

Exposure for the new film occurs only if the laser energy on the film exceeded a single threshold value, S_T. Therefore the shape of the beam above the energy threshold does not affect the dot quality, figure 9, and we can use different exposing devices of gaussian and flat top beams, with different scanning techniques. Also, the film response is independent of the wave length of the energy.

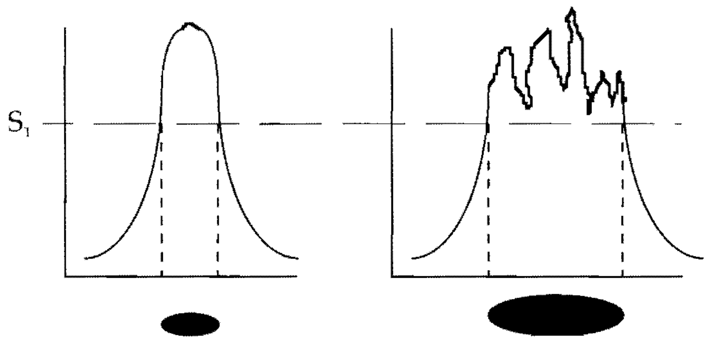


Figure 9: Dots are created using gaussian and non-gaussian beams, the size of which is determined by the film threshold, S_T.

We mounted the film on different types of drums and used different print engines. With external drums of surface velocity up to 20m/sec, we used an array of non-gaussian beams of up to 1.1 watt (750 mw at the film) emitted from solid state (GaAsAl) diodes of wavelength of 820 - 860 nm (Clark and Londono, 1992, and 1994, and Ferla and Habbal 1994) and we also experimented with gaussian beams using a 6 x 6 array of 100 mw solid state diodes constructed by CREO Company (Vancouver, British Columbia). This print engine creates 36 individually controlled spots. These systems created excellent dots and images.

We also used single beam high power lasers scanned using rotating mirrors with the media mounted on the internal side of a fixed drum. We used solid state YAG of 1064 nm wavelength and YLF of 1053 nm wave length, and recently we used Polaroid fiber laser (Po et al, 1993) which emits at 1125 nm. In all cases excellent outputs were generated. We expect that imaging devices capable of delivering 35 mJ/cm^2, or higher, at wavelengths in the range 800 - 1200 nm, to successfully image this media.

The hardware system we utilized for commercial use was designed and manufactured by Linotype-Hell Company. A laser beam of 4.0 watts at the film plane is focused from the laser and scanned with a metal coated mirror spinning at about 16,000 rpm, Fig. 9. The beam is externally modulated and generates dots sizes of 7.5 µm at 3386 dpi and 10µm at 2540 dpi are generated. With Linotype-Hell RIPs, we generated excellent images using Linotype-Hell HQS, IS and Diamond™ Screening algorithms. We also imaged with Polaroid stochastic screens.

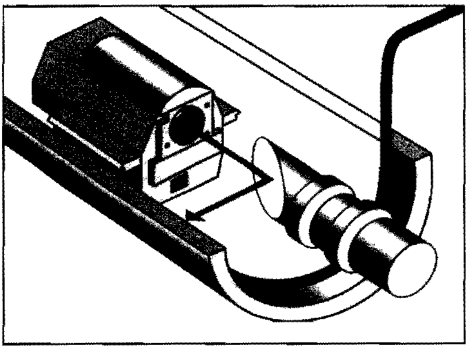


Figure 9: Linotype-Hell laser scanning system.

Film Durability

After the peeling step, the image layer containing the carbon black needs to be protected against scratching by sharp objects. This is done by transferring a very thin durable layer of about 2 µm on top of the image layer.

The durable layer is made of crosslinked polymers of suitable solvent resistance and durability. The durable material is transferred at 80 °C by placing the imaged film and the durable material, which is carried on a separate polyester substrate, in the nip of two rollers. A pressure of about 100 $lb/inch^2$ is applied, and the transfer occurs at a linear velocity of about 1 inch/second.

Conclusion

We presented a new imaging film that is laser imaged, requires no chemicals for development, has high image fidelity, and excellent consistency. The dots of this film are very hard, and have UV optical density in excess of 5.0 Dmax. This film can be used with conventional and stochastic screens, and its appearance is no different from the silver film - visible density is 4.0 Dmax.

Acknowledgment

We would like to acknowledge the years of effort of the men and women of the Polaroid R&D team in creating this new technology and turning it into commercial products. We also would like to acknowledge

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