Laser Diode (LD) Imagings and Photopolymers for LD Imaging

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The laser photopolymers and the laser imaging systems equipped with various laser diodes such as 410nm-Violet laser, 532nm-frequency-doubled laser and high-power-infrared laser are presented. The photopolymer’s performances such as sensitivity, resolution and safety-light character dependent on the wavelength and power of laser light are discussed from the image-formation mechanisms.

Keywords: laser, violet, high power, photopolymer, safety light

1. Introduction
Rapid development of laser diode (LD) changes the laser imaging systems in graphic arts, especially laser-printing-plate systems. 10 years ago, the laser-plate-imaging systems using a 532nm-frequency-doubled YAG laser (FD YAG laser), which is pumped by laser diode, were predominant. 5 years ago, 830nm-high-power infrared lasers were applied to the laser-plate-imaging systems. Recently, much attention is paid to new-systems equipped with 410nm-low-power-Violet lasers as next-generation laser-imaging systems. The development of laser diodes accelerates the replacement of conventional-plate making to laser-plate imaging. The specially designed photopolymers have been developed in respect to spectral sensitivity, resolution and safety-light character dependent on the wavelength and power of the lasers.

The conventional-plate-making systems using a mask and the laser-plate-making system equipped with a FD-YAG laser are depicted in Fig. 1. The...
required sensitivity of the laser plate is ca. 0.1 mJcm\(^2\), which is ca. 10000 times higher than that of the conventional plate. The high-speed photopolymer is a key technology for the laser-printing-plate systems.

2. SPECTRAL SENSITIVITY

Fig. 2 shows the spectral sensitivity of photopolymers and the laser emission wavelength. The power for FD-YAG laser (532 nm) is 50-100 mW, 5 - 30 mW for Violet laser (410 nm) and 1 - 40 W for IR laser (832 nm and 1064 nm). The negative photopolymerizations are used for the FD-YAG laser plate and Violet laser plate systems[1], and the polymer phase-transfer, for positive-IR-laser-plate systems [2].

3. LASER SETTER

The laser plate is generally exposed by scanning of ca. 10 \(\mu\)m laser spot (resolution 1000 - 4000 dpi and 0.5 - 10 min / m\(^2\)). There exist three different exposure systems (laser setters) for laser plates. The outer and inner drum type laser setters (Figs. 3 and 4, respectively) provide high-resolution photopolymer images on the plates, and used for high quality printings for commercial-color printing matters. The flatbed-type-laser setter (Fig. 5) is
suitable for high-speed-plate making such as newspaper printings.

4. NEGATIVE LASER PLATE
4-1. FD-Yag laser plate
The power of FD-YAG laser is rather low (50 - 200 mW). Thus the required sensitivity is 50 - 200 \( \mu \text{Jcm}^{-2} \) at 532 nm. Mitsubishi Chemical Corp. (MCC) is the first maker in Japan supplying FD-YAG laser plates. The plate-making systems using the FD-YAG laser are now mature technologies, affording high-speed-exposure (productivity) and stability in image-formation. The combinations of FD-YAG laser plates and flatbed laser setters are generally applied to newspaper printings due to the high producibility, however the systems have a disadvantage in safety-light character. FD-YAG laser plates need a safety-light condition of orange.

4-2. Violet laser plate
The power of Violet laser is very low (5 - 30 mW). The required sensitivity is 15 - 30 \( \mu \text{Jcm}^{-2} \) at 410 nm. MCC demonstrated platemakings using MCC's-violet-laser plates first in the world at International Graphic Arts Exhibition “Drupa 2000” May 2000. Violet-laser-plate-making system has two advantages. One is ignorable amount of maintenance fee due to cheap violet lasers, and the other is yellow-safety-light character.

As for the sensitivity of violet laser plate, the sensitivity is almost same as an ultimate sensitivity of photopolymer obtained from a permeating rate of oxygen (2.1 x 10^{13} molecules/cm^2 sec ) through 2 \( \mu \) m-thick poly(vinyl alcohol) (PVA) layer as an oxygen-barrier layer (in Fig.6). Bird et al. theoretically estimated the ultimate sensitivity as the light energy (13.2 \( \mu \text{Jcm}^{-2} \)), which provides the condition for photopolymer-image-forming; the radical polymerization is higher than radical trapping by oxygen permeated through PVA layer [3].

Double Amplifying Photoinitiator (DAP)
Fig. 7. Ultimate sensitivity of Photopolymer

SD: sensitizer dye  S*: Dye radical  SD*: photoexcited sensitizer dye
RR: radical generator  R*: radical from RR  M: acrylate monomer
M*: acrylate monomer radicals

Fig. 8. Positive laser plate
technology, to increase the sensitivity of photopolymer close to the ultimate sensitivity, MCC developed new photoinitiator systems (DAP). We consider the mechanism of the photoinitiator as a scheme in Fig. 7. Sensitizer dyes (SD) sensitively decompose Radical generators (RR), emitting radicals (R.). The radicals (R.) additionally react to acrylate monomers (M), forming acrylate-monomer radicals and polymer radicals (M.). The radicals (M.) undergo induced decomposition of SD and RR, emitting more active radicals S. and R.. In the photoinitiator system, the photopolymer is doubly accelerated by the photochemical dye-sensitization (sensitization 1) and the induced decomposition of RR and SR (sensitization 2), affording the near ultimate sensitivity.

5. POSITIVE IR LASER PLATE

The power of IR laser is significantly high. Thus the required sensitivity is 100 – 200 mJcm⁻² at 832 and 1064 nm. MCC demonstrated platemakings using MCC’s-IR-laser plates first in Japanese companies 1997. IR-laser-plate-making system has advantages of the good reproducibility of photopolymer image, and the white-safety-light character. The plate is constructed by an aluminum-printing substrate and a 2 µm photopolymer layer on the substrate containing binder polymers and dyes as an IR light absorbent. The photopolymer images are formed by the photothermal conversion and subsequent-polymer-phase transfer.

Photopolymer nano-structure controlled (PNSC) technology [2], Fig. 9 shows the temperature distribution in the photopolymer layer of 2 µm thickness at the exposure of 10 µm beam spot from 832 nm IR laser (7.6 W) (Fig. 8). Since the thermal conductivity of aluminum substrate is ca. three orders of magnitude higher than photopolymer, the temperature of photopolymer at near surface (facing air) and near substrate can be simulated as ca. 1000 and 500 °C, respectively. Considering the distribution of temperature in the photopolymer layer at laser exposure, we established the technology of controlling a hydrogen-bonding matrix in the photopolymer layer against the thickness (Z coordination in Fig. 8.) from surface to the substrate by applying a particular-physical treatment to afford much higher density of matrix at near surface than that at near substrate (Fig. 10). The high-density matrix is insoluble against an alkaline developer. The spot exposure from IR laser deceases the density of matrix, and increases solubility of the photopolymer layer. The degree of the matrix density is directly observed from a dynamic DSC (DDSC) as a response change of signal at a frequency as depicted in Fig. 11 [2].

In the image reproducibility of IR laser plate, Fig. 12 schematically exhibits the distribution of light.
intensity in IR laser spot and the comparison of the spot image of IR positive-laser plate to that of light, so then higher reproducibility of image is achieved compared to negative laser plates.

Fig. 11. Dynamic DSC at 0.002 Hz and 5°C/mm

negative laser plates. There exists a discreet threshold of light intensity in the image-formation by IR laser. Since the image-formation by IR laser is governed by not photochemical but photophysical reactions such as the photo-thermal conversion and the phase transfer of polymer binders, the IR laser plate has only sensitivity at high-intensity-light exposure such as laser spots, and no sensitivity against week-intensity light such as room lights. Moreover the image-formation of IR laser plate is not influenced by a halation reflected on the substrate and a background laser.

6. IMAGE SAMPLES

Fig. 13 exhibits a photograph of sharp positive image (200 lpi 50% screen) of IR laser plate at scanning exposure of 2400 dpi. Fig. 14 shows other application examples, which are copper-etching patterns formed using the FD-YAG-laser photopolymers resists. The technologies of laser photopolymers are attractive for not only graphic-arts application but also other applications such as holography image and memory, 3-D manufacturing and microelectronics.
Fig. 14. Copper-etching patterns formed using FD-YAG laser photopolymer resist

References

