

IMAGE FORMING METHOD

BACKGROUND OF THE INVENTION

Field of the invention

5 The present invention relates to a method of forming an image with high gradation by exposure to light, particularly to laser or LED light.

Related Background Art

10 Image forming methods are known in which light is projected onto a photosensitive material like a silver halide in accordance with image information. In such an image forming method, use of a light source of a narrow wavelength width such as laser and LED enables irradiation of microscopical spot light in a high
15 energy density, and image output with a high speed and high resolution.

 The photosensitive materials composed mainly of silver halide are classified into two types: ones which develop an image by wet treatment of a latent image
20 formed by light exposure, and ones which develop an image by dry heating treatment of a latent image formed by light exposure.

 For formation of images with light irradiation with high gradation by varying light energy on the
25 aforementioned photosensitive material, known methods include: (1) light intensity modulation methods in which light energy intensity is varied, and (2) pulse



width modulation methods in which light irradiation time, namely light source driving pulse width, is varied.

These known methods involves disadvantages below
5 in reproducing images with precise gradation:

(1) The light intensity modulation methods require change of the output intensity of the light source in many levels for each of the image elements. However, reproduction of images with many gradation levels of
10 gradation is not achievable especially at low output levels, for example, by semiconductor laser because of the I-L characteristics (current intensity-light emission characteristics) of the semiconductor laser, and by LED because of difficulty in fine control of
15 light output electric current.

(2) The pulse width modulation methods require extremely narrow pulse width of light irradiation to reproduce the image in many gradation levels. This is limited inherently by response characteristics of the
20 light source.

SUMMARY OF THE INVENTION

The present invention intends to provide a method for forming an image with many gradation levels with
25 high sharpness without the disadvantages of prior arts.

The image forming method by light irradiation of the present invention comprises projecting two or more

kinds of light beams having different wavelengths onto
a photosensitive material by utilizing difference of
sensitivities of the photosensitive material to each of
the light beams to form an image with density
5 gradation.

BRIEF DESCRIPTION OF THE INVENTION

Fig. 1 is a graph showing an example of a spectral
sensitivity distribution of a photosensitive material
10 employed in the present invention.

Fig. 2 is a graph showing dependency of the
optical density on the projected light energy for three
different wavelengths with the photosensitive material
having the spectral sensitivity as shown in Fig. 1.

15 Fig. 3 is a side view of an example of an
apparatus for practicing the image forming method of
the present invention.

Fig. 4 is a plan view of an example of an image
exposure means as shown in Fig. 3.

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DESCRIPTION OF THE PREFERRED EMBODIMENTS

The image forming method of the present invention
forms images with gradation of optical density by
projecting two or more kinds of light beams having
25 different wavelengths on a photosensitive material.
The image forming method of the present invention
utilizes the dependence of photosensitivity of a

photosensitive material on the wavelength of the projected light.

More specifically, when three kinds of light beams of wavelengths of λ_a , λ_b , and λ_c are projected onto
5 separate areas on a photosensitive material having spectral sensitivity as shown in Fig. 1, the light beam of λ_a gives the highest optical density; the light beam of λ_b give a lower one; and the light beam of λ_c gives the lowest one. The image forming method of the
10 present invention forms an image in many gradation levels by utilizing the above differences in optical density. Accordingly, in the present invention, each one spot of the photosensitive material is required to be irradiated with only one of the plural kinds of
15 light beams.

An image forming method of the present invention is explained for a dry silver salt type photosensitive material by reference to Fig. 3.

The dry silver salt type photosensitive material
20 contains an organic silver salt, a reducing agent, and a silver halide in a photosensitive layer as described later in detail. When the dry silver salt type photosensitive material is exposed to image forming light, silver nuclei are formed from silver salt to
25 give a latent image. On heating the photosensitive material having the latent image, the organic silver salt is reduced to silver, under catalytic action of

the formed silver nuclei, by oxidation-reduction reaction of the organic silver salt with the reducing agent to form an image.

In Fig. 3, a dry silver salt type photosensitive material 6 is housed in a magazine 16. With the progress of the recording, the photosensitive material 6 is pulled out from the magazine 16 successively. The pulled-out photosensitive material 6 is delivered along the peripheral face of a delivery drum 17. The photosensitive material 6, during the delivery, is exposed to image forming light from an image light projection means 1 in accordance with an image data.

In this embodiment, the image light projection means 1 projects light beams of wavelengths of λ_a , λ_b , and λ_c by semiconductor lasers 31, 32, 33 as shown in Fig. 4. The semiconductor lasers 31, 32, 33 are driven under control by a data processing part 40 in accordance with the optical density of the image to be recorded. More specifically, the image data inputted to the data processing part 40 is divided into data for the respective semiconductor lasers. The divided data are transmitted respectively through a modulator 41 to each of driving circuits 42, 43, 44 to irradiate light beams from the semiconductor lasers 31, 32, 33 at the wavelength corresponding to the optical density of the image data.

In the present invention, fine gradation will be

achieved by combining the wavelength change method with the aforementioned light intensity modulation method which varies the intensity of irradiation light, or the aforementioned pulse width modulation method which
5 varies the time of light irradiation.

The light beams from the semiconductor lasers 31, 32, 33 are projected to a dry silver salt type photosensitive material through condenser lenses 45, 46, 47, a half mirror 11, a polarization beam splitter
10 3, a polygon mirror 4, and an f- θ lens 5. The projected light beam is allowed to scan the dry silver salt photosensitive material by means of the polygon mirror 4. The semiconductor lasers are not limited to three in number, but may be two, or four or more.

15 The dry silver salt photosensitive material 6 after image light exposure is delivered from the delivery roller 7 along a peripheral face of a delivery drum 8. The dry silver salt type photosensitive material 6 is heated for image development by planar
20 heater 10 on the peripheral face of the delivery drum 8. The peripheral face of the delivery drum 8 is covered with a protecting material such as nonwoven fabric, so that the photosensitive material 6 is heated uniformly without scratching.

25 After the heat development, the dry silver salt type photosensitive material 6 is cut in a desired size by means of a cutter 9.

The light source for the image light projection means 1 may be a gas laser, or an LED instead of the semiconductor laser. The projected light is preferably monochromatic light. In the present invention, the monochromatic light signifies light of a narrow spectrum width having a half-width of intensity distribution ranging from 0.02 nm to 20 nm. (The half-width herein means spectrum width at half intensity of the peak.)

10 In an embodiment of the image forming method of the present invention, an image is formed by employing two light beams of different wavelengths preferably in combination with light intensity modulation or pulse width modulation. The wavelengths of the two light beams are selected such that the sensitivity of the photosensitive material to the one light beam is lower than that of the other light beam by a factor of from 1/2 to 1/1000, preferably from 1/5 to 1/1000 (e.g., as shown in the graph in Fig. 1). If the above sensitivity ratio is higher than 1/2 or lower than 1/1000, the advantage of use of the two light beams of different wavelengths is not obtained satisfactorily, and many levels of gradation is not reproduced precisely.

25 The heating temperature with the planar heater 10 is preferably in the range of from 60°C to 200°C, more preferably from 70°C to 150°C. The heating time is

preferably in the range of from 1 second to 3 minutes,
more preferably from 3 seconds to 60 seconds. The
heating may be conducted with a heating roll or by a
high temperature atmosphere in place of the planar
5 heater 10.

The delivery rate of the photosensitive material
is preferably in the range of from 10 to 300 mm/sec,
more preferably from 40 to 200 mm/sec.

The dry silver salt type photosensitive material
10 employed in the present invention comprises a
photosensitive layer provided on a base material, the
photosensitive layer containing at least an organic
silver salt, a reducing agent, and a silver halide.

The organic silver salt includes silver salts of
15 organic acids, silver salts of acetylene derivatives,
silver salts of organic compounds having an imino group
or a mercapto group, and the like. In particular,
those are preferred which do not change (e.g., in
color) at room temperature and under room light. The
20 silver salt of organic is preferably silver behenate.

The reducing agent includes phenols, hydrazines,
naphthols, and pyrazolidones.

The phenols are exemplified by aminophenol,
2,6-dichloroaminophenol,
25 4,4'-dihydroxy-3,3'-di-t-butyl-5,5'-dimethylbiphenyl,
2,2'-dihydroxy-3,3',5,5'-tetrakis-t-butylbiphenyl,
2,2'-dihydroxy-3,3'-dichlorobiphenol,

- 2,2'-methylenebis(6-t-butyl-4-methylphenol),
2,2'-propylenebis(6-t-butyl-4-ethylphenol),
4,4'-butylidenebis(2-t-butyl-6-methylphenol),
4,4'-thiobis(2-t-butyl-6-ethylphenol),
5 2,6-dichloro-4-benzenesulfonamidophenol, etc..

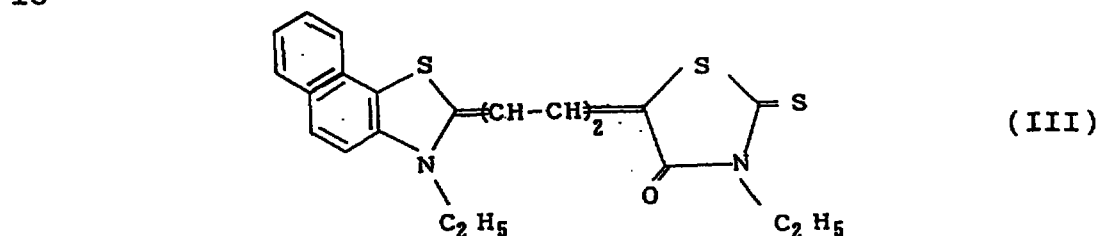
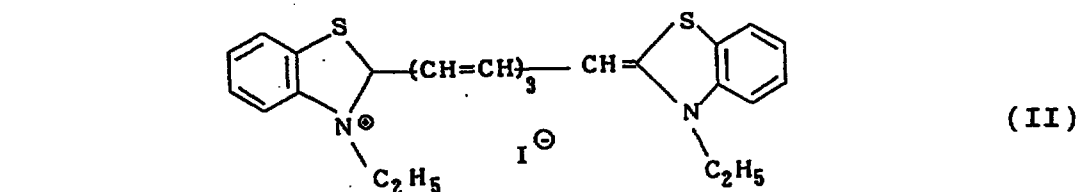
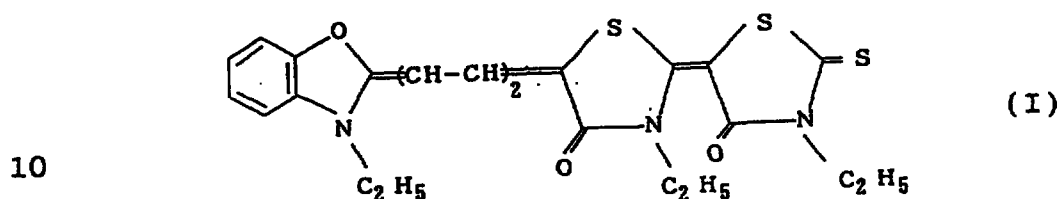
The hydrazines are exemplified by
 β -acetylphenylhydrazine, β -acetyltolylhydrazine, etc..

- The naphthols are exemplified by
4-methoxynaphthol, 4-chloronaphthol,
10 4,4'-methylenebis(2-methylnaphthol),
4-(2,6-dimethyl-4-hydroxybenzyl)-2-methylnaphthol,
4-(2-t-butyl-6-ethyl-4-hydroxybenzyl)-2-methylnaphthol,
etc..

- The pyrazolidones are exemplified by 1-phenyl-3-
15 pyrazolidone, etc..

- The silver halides includes silver chloride,
silver bromide, silver iodide, silver iodobromide,
silver chlorobromide, silver iodochlorobromide, etc..
The silver salt may be doped with an Ir compound. The
20 silver halides are effective which are fine
particulate. Especially, those of a cubic crystal
shape in a size of from 0.01 μm to 0.2 μm are
effective. Fine silver halide can be prepared by
halogenating an organic silver salt by use of a silver
25 halide-forming component such as ammonium bromide,
lithium bromide, sodium chloride, and N-
bromosuccinimide, or the like method.

The silver halide may be preliminarily treated for sensitization such as sulfur sensitization, noble metal sensitization, and reduction sensitization. For the spectral sensitization, various sensitizing dyes are employed. The sensitizing dyes include cyanine dyes, and merocyanine dyes. Specific examples thereof are shown below.



25 The photosensitive layer is formed by mixing the above components with a binder. The binder is preferably a hydrophobic or hydrophilic polymer which is transparent or translucent. A hydrophobic one is more suitable for the binder. The binder is exemplified by polyvinylbutyral, cellulose acetate butyrate, polymethyl methacrylate, polyesters, and polyvinyl chloride, and copolymers thereof.

The base material is exemplified by polyethylene resins, polypropylene resins, polyethylene terephthalate resins, polycarbonate resins, paper, synthetic paper, photographic baryta paper, art paper,
5 etc.

The blending ratios of the above components in the photosensitive layer are as below.

The reducing agent is contained in an amount preferably ranging from 0.05 to 3 moles, more
10 preferably from 0.2 to 1.3 moles per mole of the organic silver salt.

The organic silver salt is contained in an amount preferably ranging from 0.3 to 30 g/m², more preferably from 0.7 to 15 g/m², still more preferably from 1.2 to
15 8 g/m².

The silver halide is contained in an amount preferably ranging from 0.001 to 2 moles, more preferably from 0.05 to 1 mole per mole of the organic silver salt.

20 A color tone-adjusting agent, if it is used, is contained in an amount ranging preferably from 0.01 to 5 moles, more preferably from 0.05 to 2 moles, still more preferably from 0.08 to 1 mole per mole of the organic silver salt.

25 The binder is contained in an amount ranging preferably from 0 to 10 parts, more preferably from 0.5 to 5 parts by weight for one part by weight of the

organic silver salt.

The photosensitive layer has a thickness of preferably from 0.5 to 30 μm , more preferably from 2 to 17 μm .

5 Further, in order to improve color tone of an image and its stability after forming an image, the photosensitive layer may contain an organic acid, an antifoggant, a color protecting agent, an antistatic agent, a UV absorbing agent, an irradiation-preventing
10 agent, a fluorescent whitener, a filter dye, or the like.

 On the photosensitive layer, a protecting layer may be provided, if necessary. The protecting layer is constituted mainly of a binder. The binder includes
15 water-soluble resins such as polyvinyl alcohol, casein, gelatin, and ethylene-maleic anhydride copolymers. The protecting layer may contain additionally colloidal silica, irradiation preventing dye, or the like. The protecting layer has a thickness of preferably from 0.1
20 to 7 μm , more preferably from 0.5 to 5 μm .

 The sensitivity of the photosensitive material depends on the photosensitive elements therein: namely, the silver halide, or the silver halide and the sensitizing dye for sensitizing spectrally the silver
25 halide. The image forming method of the present invention is based on the difference of the sensitivity of the photosensitive elements to different wavelengths

of light.

The present invention is described more specifically by reference to Examples. The units "parts" is based on weight in the description below.

5 Example 1

 A dry silver salt type photosensitive material was prepared by applying a photosensitive layer of 10 μ m thick on a polyethylene terephthalate base material of 10 μ m thick by coating, and applying further thereon a
10 polyvinyl alcohol protecting layer of 2 μ m thick. The photosensitive layer had the composition below:

	Polyvinylbutyral	2.5 parts
	Silver bromide (average particle size:60 nm)	0.15 part
	Silver behenate	2.5 parts
15	2,2'-methylenebis(4-methyl-6-t-butylphenol)	1.0 part
	Phthalazinone	0.33 part
	Sensitizing dye of above Formula (I)	0.002 part
	Behenic acid	1.6 parts

 The above dry silver salt type photosensitive
20 material was set on an apparatus as shown in Fig. 3, and an image was formed with 256 gradation levels by employing combinedly a light intensity modulation method to obtain a gray scale pattern. The delivery rate of the dry silver salt type photosensitive
25 material was 50 mm/sec.

 Two semiconductor lasers were employed as the light source: a semiconductor laser of an oscillation

wavelength of 680 nm (TOLD-9140, manufactured by Toshiba Corporation), and another semiconductor laser of an oscillation wavelength of 780 nm (TOLD-121L, manufactured by Toshiba Corporation). The diameters of
5 the laser beams were 20 μm (in the main scanning direction) and 40 μm (in the secondary scanning direction), respectively. The pixel clock was 6 MHz, and the pixel density was 1200 dpi.

The dry silver salt photosensitive material
10 employed in this example had a sensitivity at the wavelength of 780 nm which was lower than that at wavelength of 680 nm by a factor of 1/15. The graph of Fig. 1 shows the spectral sensitivity of this dry silver salt type photosensitive material.

15 The 256 gradation levels were numbered from No. 0 to No. 255 sequentially from the highest level to the lowest level of the optical density. In this Example, the image exposure was conducted with the semiconductor laser of oscillation wavelength of 680 nm for the data
20 of from No. 0 to No. 237, and with the semiconductor laser of oscillation wavelength of 780 nm for the data of from No. 238 to No. 255. After the image exposure, the dry silver salt type photosensitive material was heated at 120°C for 10 seconds for image development.

25 The obtained gray scale of 256 gradation levels was evaluated by measuring the optical densities. The

optical density was measured by means of a Reflectodensitometer DM-800 (manufactured by Dainippon Screen K.K.) for the image portions corresponding to the data of the gradation levels of No. 16, No. 144, and No. 240, respectively for 25 measuring spots. The average values and the standard deviation values (σ) of the measured data were calculated. The results are shown in Table 1.

Comparative Example 1

A gray scale pattern of 256 gradation levels was formed in the same manner as in Example 1 except that the semiconductor laser of the oscillation wavelength of 680 nm only was employed as the light source. The results are shown in Table 1.

Table 1

	Data No.	Average O.D.	Standard deviation (σ)
Example 1	16	3.0896	0.0118
	144	1.4412	0.0103
	240	0.2096	0.0087
Comparative Example 1	16	3.0900	0.0130
	144	1.4384	0.0129
	240	0.2064	0.0196

Example 2

A gray scale pattern of 256 gradation levels was formed on the same dry silver salt type photosensitive material in the same manner as in Example 1 except that

a semiconductor laser of the oscillation wavelength of 720 nm (RLD-72MA, manufactured by Rohm Co.) was employed in addition to the semiconductor lasers employed in Example 1 as the light sources.

5 The delivery rate of the photosensitive material, the laser beam diameter, the pixel clock, and the pixel density were controlled to be the same as in Example 1.

 The dry silver salt type photosensitive material employed had a sensitivity at the wavelength of 720 nm
10 of 1/2 times that at wavelength of 680 nm.

 In this Example, the image exposure was conducted with the semiconductor laser of oscillation wavelength of 680 nm for the data of higher optical density of from No. 0 to No. 127, with the semiconductor laser of
15 oscillation wavelength of 720 nm for the data of from No. 128 to No. 237, and with the semiconductor laser of oscillation wavelength of 780 nm for the data of from No. 238 to No. 255 according to a pulse width modulation method. After the image exposure, the dry
20 silver salt type photosensitive material was heated for image development in the same manner as in Example 1.

 The obtained gray scale of 256 gradation levels was evaluated by measuring the optical densities. The optical density was measured for the image portions
25 corresponding to the data of the gradation levels of No. 16, No. 144, and No. 240, respectively for 25

measuring spots. The average values and the standard deviation values (σ) of the measured data were calculated. The results are shown in Table 2.

Comparative Example 2

5 A gray scale pattern of 256 gradation levels was formed in the same manner as in Example 2 except that the semiconductor laser of the oscillation wavelength of 680 nm only was employed as the light source. The results are shown in Table 2. In this Comparative
10 Example, in the low optical density portion corresponding to the data of from No. 249 to No. 255, gradation was not achieved.

Table 2

15		Data No.	Average O.D.	Standard deviation (σ)
	Example 2	16	3.0930	0.0078
		144	1.4255	0.0068
		240	0.2105	0.0080
	Comparative	16	3.0915	0.0096
	Example 2	144	1.4405	0.0112
20		240	0.2110	0.0158

Example 3

A dry silver salt type photosensitive material was prepared in the same manner as in Example 1 except that
25 0.004 parts of the sensitizing dye of the aforementioned Formula (II) was used in place of the sensitizing dye of Example 1.

The above dry silver salt type photosensitive material was set on an apparatus as shown in Fig. 3, and an image was formed with 256 gradation levels by employing combinedly a pulse modulation method to
5 obtain a gray scale pattern. The delivery rate of the dry silver salt type photosensitive material was 150 mm/sec.

In this Example, three semiconductor lasers were employed as the light sources: a first semiconductor
10 laser of oscillation wavelength of 780 nm (SDL-4030, manufactured by Sanyo K.K.), a second semiconductor laser of oscillation wavelength of 830 nm (SDL-4032, manufactured by Sanyo K.K.), and a third semiconductor laser of oscillation wavelength of 870 nm (SDL-5033,
15 manufactured by Sanyo K.K.). The pixel density was 400 dpi, which was lower than that in Examples 1 and 2. The lower pixel density enabled reduction of image exposure time. The laser beam was ellipsoidal, having the major diameter of 100 μm and the minor diameter of
20 60 μm . The pixel clock was 6 MHz.

The dry silver salt type photosensitive material employed had sensitivities at the wavelengths of 830 nm and 870 nm, respectively, of 4/9 times and 1/11 times that at wavelength of 780 nm.

25 In this Example, the image exposure was conducted with the semiconductor laser of oscillation wavelength

of 780 nm for the data of higher optical density of
from No. 0 to No. 141, with the semiconductor laser of
oscillation wavelength of 830 nm for the data of from
No. 142 to No. 231, and with the semiconductor laser of
5 oscillation wavelength of 870 nm for the data of from
No. 232 to No. 255. After the image exposure, the dry
silver salt type photosensitive material was heated at
120°C for 10 seconds for image development.

Consequently, a sharp image of 256 gradation
10 levels was obtained without image roughness.

Comparative Example 3

A gray scale pattern of 256 gradation levels was
formed in the same manner as in Example 3 except that
the semiconductor laser of the oscillation wavelength
15 of 780 nm only was employed as the light source. As
the result, roughness of the image was observed in the
low optical density portion of the image.



WHAT IS CLAIMED IS:

1. An image forming method for forming an image by irradiation of light, comprising projecting two or more kinds of light beams having different wavelengths onto a photosensitive material by utilizing difference of sensitivities of the photosensitive material to each of the light beams to form an image with density gradation.
2. The image forming method according to claim 1, wherein the photosensitive material is heated after projection of the light beams.
3. The image forming method according to claim 1, wherein the light beams are monochromatic.
4. The image forming method according to claim 1, wherein two kinds of light beams of different wavelengths are employed, the sensitivity of the photosensitive material to the one light beam being not higher than $1/2$ times, but not lower than $1/1000$ times that to the other light beam.
5. The image forming method according to claim 4, wherein the sensitivity of the photosensitive material to the one light beam is not higher than $1/5$ times, but not lower than $1/1000$ times that to the



other light beam.

6. The image forming method according to claim
1, wherein three kinds of light beams of different
5 wavelengths are employed.