Oct. 5, 1965 R. G. OLDEN 3,210,185

SIMULTANEOUS IDENTICAL ELECTROSTATIC IMAGE RECORDING ON MULTIPLE RECORDING ELEMENTS

Filed March 22, 1961 2 Sheets-Sheet 1

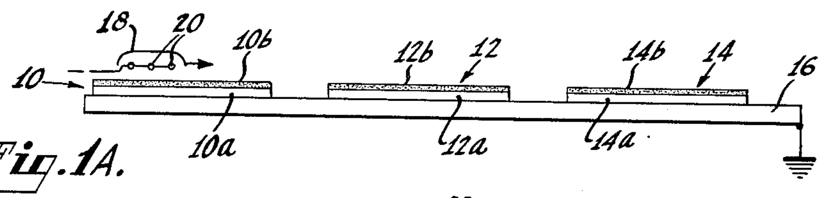


Fig. 1A.

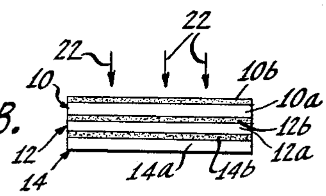
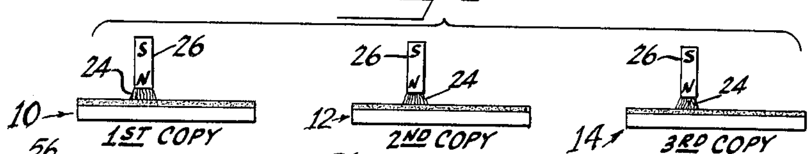


Fig. 1B.

Fig. 1C.



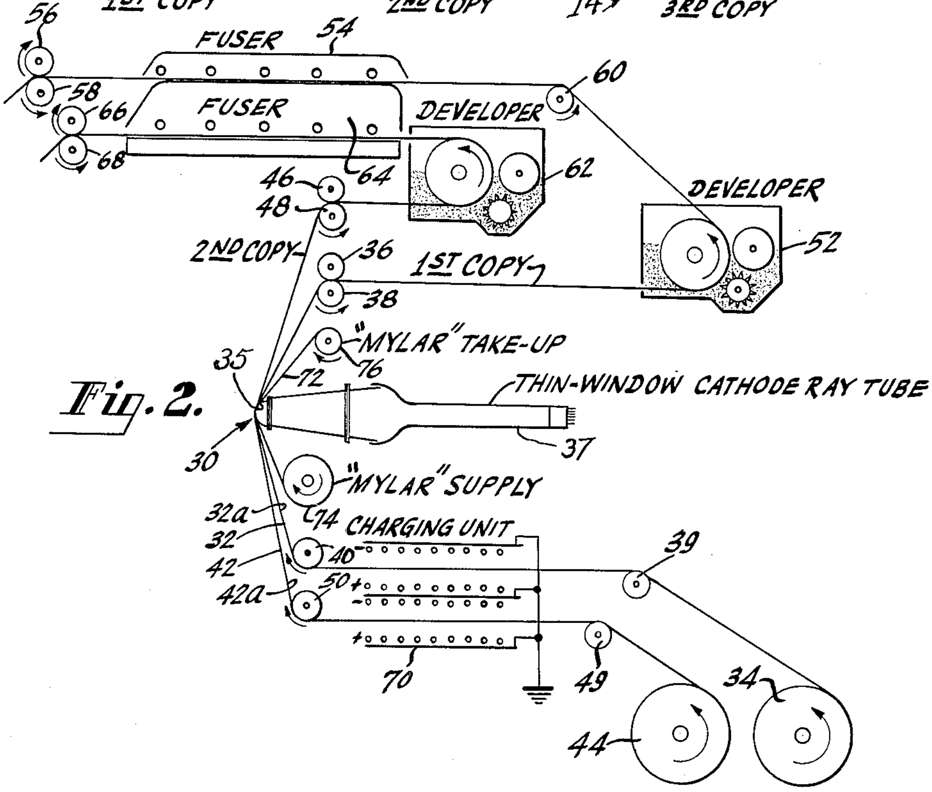


Fig. 2.

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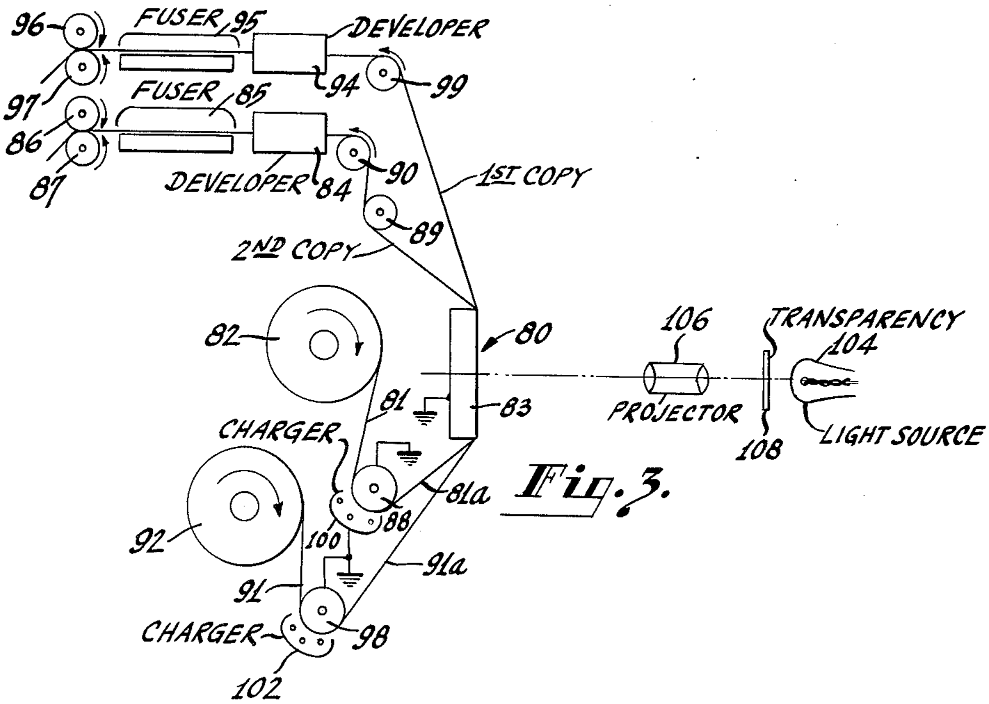

Fig. 3.

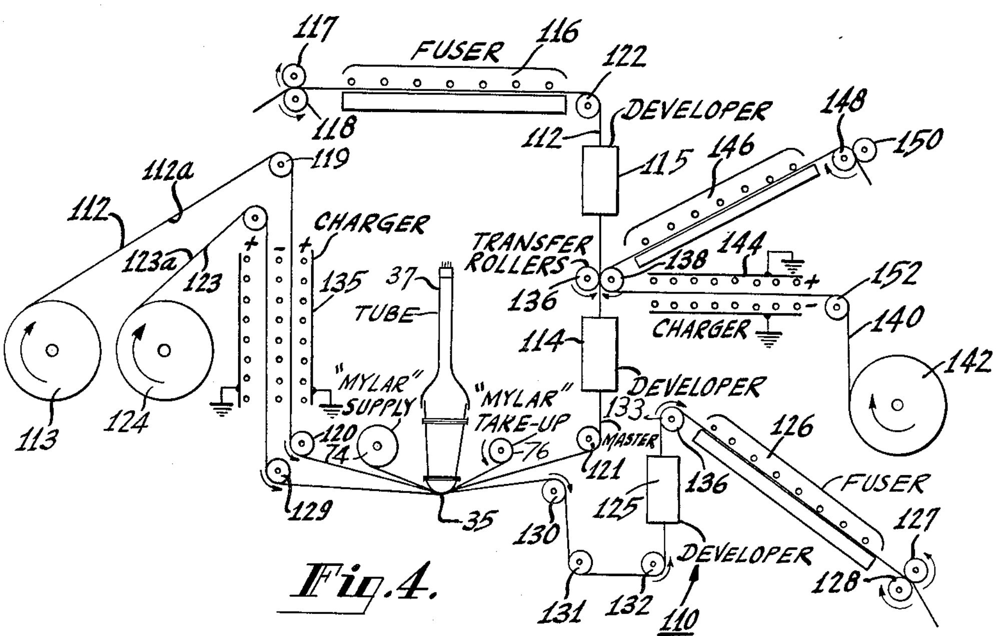

Fig. 4.

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1

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SIMULTANEOUS IDENTICAL ELECTROSTATIC IMAGE RECORDING ON MULTIPLE RECORDING ELEMENTS

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1 Claim. (Cl. 96—1)

This invention relates generally to electrostatic printing, and more particularly to novel methods of and apparatus for exposing a plurality of electrophotographic recording elements simultaneously. The novel methods and apparatus of the present invention are particularly useful for making duplicate copies of an image by electrophotographic means.

Previously, duplicate electrostatic prints have been made by exposing a plurality of uniformly charged, electrophotographic recording elements to the same light image successively and developing each recording element separately. Data read-out time in electronic computers, for example, is at a premium. Therefore, successive read-out for making duplicate copies of computer data is not desirable. Heretofore, if duplicate electrostatic prints were desired in a period of time less than that required to produce these prints successively in one automatic processing machine, duplicate machines had to be employed. Since machines for automatically producing electrostatic prints are expensive, the use of duplicate apparatus to speed production may be prohibitive in many instances.

Accordingly, it is an object of the present invention to provide improved methods of and means for producing electrostatic prints faster and more economically than is possible by prior art methods and apparatus.

Another object of the present invention is to provide improved methods and automatic apparatus for making a plurality of electrostatic prints in substantially the same amount of time required to process a single electrostatic print.

Still another object of the present invention is to provide improved apparatus for making a plurality of electrostatic prints by employing novel means to expose a plurality of uniformly charged electrophotographic recording elements simultaneously.

A further object of the present invention is to provide improved means for making simultaneously a plurality of electrostatic prints, including a master print useful in making reproductions by another reproductive process.

In accordance with the present invention, the improved method for producing a plurality of electrostatic prints comprises: applying an electrostatic charge to each of a plurality of electrophotographic recording elements, arranging the recording elements one behind the other and in contact with each other, exposing all of the charged recording elements simultaneously with an image of electromagnetic radiation of sufficient intensity to penetrate the recording elements and to produce a latent electrostatic image on each recording element, and developing each latent electrostatic image. The recording elements comprise a backing sheet of translucent material, such as paper, on which a relatively thin photoconductive layer has been deposited.

Briefly, a preferred embodiment of the improved apparatus of the present invention comprises automatic means for processing a plurality of recording elements simultaneously. In each of the embodiments of the apparatus described herein, a plurality of recording elements are exposed simultaneously. In one embodiment of the present invention, all of the recording elements are oriented similarly so that the backing sheet of one recording element is in contact with the photoconductive

2

layer of an adjacent recording element during the exposure step in the process. In another embodiment of the present invention, two recording elements are arranged so that their photoconductive layers contact each other during the exposure step, thereby providing for a mirror-image master print that may be used in other reproductive processes.

Other novel features of the present invention, both as to its organization and methods of operation, as well as additional objects and advantages thereof, will be described in greater detail by reference to the accompanying drawings, in which similar reference characters designate similar parts throughout, and in which:

FIGS. 1A, 1B and 1C show three electrophotographic recording elements undergoing successive steps of charging, exposing, and developing, respectively, in the process of electrostatic printing, in accordance with the present invention;

FIG. 2 is a schematic diagram of one embodiment of improved apparatus, employing a thin-window cathode ray tube, for exposing a plurality of electrophotographic recording elements simultaneously in the process of making duplicate electrostatic prints, in accordance with the present invention;

FIG. 3 is a schematic diagram of another embodiment of improved apparatus, employing light means, for exposing a plurality of electrophotographic recording elements simultaneously, in accordance with the present invention; and

FIG. 4 is a schematic diagram of still another embodiment of improved apparatus, employing a thin-window cathode ray tube, for exposing a plurality of electrophotographic recording elements simultaneously in a manner to produce one master copy for use in another reproductive process, in accordance with the present invention.

Referring now to FIGS. 1A, 1B and 1C, there are shown three electrophotographic recording elements **10**, **12** and **14** in some of the steps of the process of electrophotographic printing, in accordance with the present invention. The recording elements **10**, **12** and **14** comprise backing sheets **10***a*, **12***a* and **14***a* having photoconductive layers **10***b*, **12***b* and **14***b* on their upper surfaces, respectively. The backing sheets **10***a*, **12***b* and **14***a* may comprise any suitable translucent material, such as paper and the like, and the photoconductive layers **10***b*, **12***b* and **14***b* may comprise photoconductive zinc oxide embedded in a resin binder. The photoconductive layers **10***b*, **12***b* and **14***b* may also contain different amounts of dyes mixed in the binder for the purpose of rendering each successive layer more sensitive to electromagnetic radiation, for the purpose hereinafter appearing.

Referring now to FIG. 1A, the recording elements **10**, **12** and **14** are shown in the process of receiving a uniform electrostatic charge. The recording elements **10**, **12** and **14** are placed on a sheet **16** of electrically conducting material so that their respective backing sheets **10***a*, **12***a* and **14***a* are in contact with the sheet **16**. The sheet **16** is grounded. A corona discharge device, that is, a charging unit **18** is connected to a source (not shown) of relatively high unidirectional voltage (about 6,000 volts) for producing a corona discharge from wires **20** of the charging unit. The charging unit **18** is moved over the photoconductive layers **10***b*, **12***b* and **14***b* of recording elements so as to deposit a uniform negative electrostatic charge on the photoconductive layers.

In the next step, the uniformly charged recording elements **10**, **12** and **14** are arranged one behind the other, front to back, so that the backing sheet of one recording element is in contact with the photoconductive layer of an adjacent recording element, as shown in FIG. 1B. When so arranged, the recording elements **10**, **12** and **14** are exposed simultaneously by an image of electromagnetic radiation directed onto one recording element, the recording element **10**, for example, with an intensity sufficient to penetrate this and other translucent recording elements and to permit a latent electrostatic image to be formed on each of the photoconductive layers **10*b***, **12*b*** and **14*b*** of the recording elements. The image of electromagnetic radiation is directed preferably perpendicularly to the photoconductive layers, as illustrated by the arrows **22** in FIG. 1B. The image of electromagnetic radiation may be formed with visible light, infra red radiation, and X-rays, for example. The recording element that is farthest from the source of electromangetic radiation need not be transparent because its photoconductive layer can be exposed through the translucent elements in front of it. If, for example, the photoconductive layers **10*b***, **12*b*** and **14*b*** were sensitized with fluoroescein, rose bengal and methylene blue, respectively, each of the stacked recording elements **10**, **12** and **14** would be sensitive to electromagnetic radiations in a different spectral range. Thus, differently sensitized recording elements may be exposed simultaneously by a color image, including light in all the spectral ranges, to produce separation prints useful in some color printing methods.

After the simultaneous exposure of the recording elements **10**, **12** and **14**, they are separated from each other and developed separately, as shown in FIG. 1C. To this end, each of the recording elements **10**, **12** and **14** is brushed with a developing mixture **24** of tribo-electrically charged particles, comprising, for example, a powdered dye material mixed with iron filings. The developing mixture **24** is applied to the latent images by means of a magnet **26**, as described, for example, in U.S. Patent 2,874,063 to H. G. Greig.

Referring now to FIG. 2, there is shown schematically apparatus **30** for making two electrostatic prints simultaneously. One web of a continuous recording element **32**, stored on a roll **34**, is pulled past the window **35** of a thin-window cathode ray tube **37** by means of a pair of drive rollers **36** and **38**, and guide rollers **39** and **40**. The drive rollers **36** and **38** are driven by any suitable means (not shown). Another web of a continuous recording element **42**, stored on a roll **44**, is pulled over the recording element **32** at the site where the recording element **32** comes in contact with the window **35**, by means of a pair of drive rollers **46** and **48**, and guide rollers **49** and **50**. The recording element **42** is directly behind, and in contact with, the recording element **32** at the window **35**, the exposure station. The drive rollers **46** and **48** are driven by any suitable means (not shown). The recording elements **32** and **42** are similar to the recording elements **10**, **12** and **14**, previously described, and they have photoconductive layers **32*a*** and **42*a***, respectively, on the sides that face the window **35** of the tube **37**.

The recording element **32** is pulled past a developer trough **52** and a fuser **54** by means of a pair of drive rollers **56** and **58** and a guide roller **60**. The developer trough **52**, as well as other developer apparatus described herein, may comprise the apparatus described by A. Stavrakis et al. in U.S. Patent No. 2,910,964. The recording element **42** is pulled past a developer trough **62** and a fuser **64** by means of a pair of drive rollers **66** and **68**. A charging unit **70**, with voltage applied to its elements as indicated, is disposed about the webs of the recording elements **32** and **42** to charge the photoconductive layers **32*a*** and **42*a*** negatively, in a manner well known in the art. The charging unit **70** is located between the guide rollers **39** and **40** and between the guide rollers **49** and **50**.

The thin-window cathode ray tube **37** comprises means to write on a phosphor screen with an electron beam in accordance with the principles well known in the television art, as described, for example, in RCA Review, September 1957, vol. XVIII, No. 3, at pages 343 to 350. The electronic circuitry for operating the tube **37** is not shown because it forms no part of the instant invention. The cathode ray tube **37** is formed with a relatively thin window **35** which is elongated in one direction (perpendicular to the direction of travel of the recording elements). It will be understood that when the phosphor screen (not shown) on the window **35** is caused to luminesce by an electron beam impinging on it, the image of the light from the phosphor screen will expose the recording elements **32** and **42**. In order to prevent excessive wear of the window **35** due to friction, a web **72** of transparent plastic material, such as a clear, tough plastic material sold under the trademark "Mylar," is caused to move between the window **35** and the recording element **32**. To this end, the web **72**, stored on a roll **74**, is pulled over the window **35** by a take-up roller **76**, by any suitable means known in the art. In practice, the web **72** is pulled over the window **35** at a relatively much slower rate than the recording elements **32** and **42**.

The operation of the apparatus **30**, in accordance with the present invention, will now be described. The photoconductive layers **32*a*** and **42*a*** of the recording elements **32** and **42** are charged negatively by the charging unit **70** and moved into contact with each other and with the web **72** over the window **35** of the tube **37**. When in contact with each other, the recording elements **32** and **42** are exposed simultaneously by light from the fluorescent window **35**. The light is of sufficient intensity to expose the photoconductive layers **32*a*** and **42*a*** of both of the recording elements **32** and **42**. After exposure, the recording elements **32** and **42** move through the developer troughs **52** and **62** where they are developed. From the developer troughs **52** and **62**, the recording elements **32** and **42** pass through the fusers **54** and **64** where the developer mixture is fused onto the recording elements, and the electrostatic print is finished.

Referring now to FIG. 3, there is shown apparatus **80** for exposing a plurality of recording elements simultaneously to visible light in the process of electrostatic printing according to the present invention. A recording element **81**, wound on a roll **82**, is pulled past a grounded platen **83**, a developer trough **84**, and a fuser **85** by means of drive rollers **86** and **87**, and guide rollers **88**, **89** and **90**. The drive rollers **86** and **87** are driven by any suitable means, such as an electric motor (not shown). A continuous recording element **91**, stored on a roll **92**, is pulled over the recording element **81** at the site of the platen **93**, through a developer trough **94**, and a fuser **95** by means of drive rollers **96** and **97** and guide rollers **98** and **99**. The drive rollers **96** and **97** are driven by any suitable means (not shown). A pair of corona discharge units **100**, **102** are disposed to charge the photoconductive layer **81*a*** and **91*a*** of the recording elements **81** and **91**, respectively, with a uniform negative charge. The photoconductive layers **81*a*** and **91*a*** are separated from each other by the backing sheet of the recording element **91**, and the backing sheet of the recording element **81** is in contact with the grounded platen **83**.

Means are provided to expose the recording elements **81** and **91** simultaneously. To this end, electromagnetic radiation, such as light from a light source **104**, is directed onto the platen **83**, the exposure station, by means of an optical projector **106**. A transparency **108**, such as a photographic negative, for example, disposed between the light source **104** and the projector **106**, produces a light image on the photoconductive surface **91*a*** of recording element **91**. In accordance with the present invention, the light image is of sufficient intensity to penetrate the translucent recording element **91** and to expose the photoconductive layer **81*a*** of the recording element **81**. After the simultaneous exposure of the recording elements **81** and **91**, the recording elements are developed and fused in the manner described for the apparatus **30** of FIG. 2.

Referring now to FIG. 4, there is shown apparatus **110** for exposing two recording elements simultaneously in a manner to produce a normal electrostatic print and a master print from which other prints may be made. A recording element **112**, stored on a roll **113**, is pulled across the window **35** of the thin-window cathode ray tube **37** and then successively through a first developer trough **114**, a second developer trough **115**, and a fuser **116** by means of suitably driven drive rollers **117** and **118**, and guide rollers **119**, **120**, **121** and **122**. A recording element **123**, stored on a roll **124**, is pulled over the recording element **112** at the window **35** of the tube **37**, and then successively through a developer trough **125**, and a fuser **126** by means of suitably driven drive rollers **127** and **128**, and guide rollers **129**, **130**, **131**, **132** and **133**. A corona discharge unit **135** is disposed about the recording elements **112** and **123** in a manner to charge adjacent photoconductive layers **112***a* and **123***a*, respectively, with a negative charge. It will be noted that in the embodiment of the apparatus shown in FIG. 4, the photoconductive layers **112***a* and **123***a* of the recording elements **112** and **123**, respectively, are adjacent to each other, face to face.

In operation, the uniformly charged recording elements **112** and **123** are exposed simultaneously by means of writing on the phosphor screen (not shown) on the window **35**, as explained heretofore for the apparatus **30** of FIG. 2. After exposure, the recording elements are separated. The recording element **123** is developed in the developer trough **125**, and the developed image is fused in the fuser **126**.

Since the recording element **112** was exposed with radiant energy that first had to penetrate the backing sheet of the recording element **112**, the latent image produced on the photoconductive layer **112***a* of the recording element **112** is a mirror image of the true image. This mirror image is developed in the developer tank **114**. By means of a pair of opposed pressure rollers **136** and **138**, a uniformly, negatively charged web of uncoated paper **140** can be pressed against the developed image on the photoconductive layer **112***a* of the recording element **112** to cause the unfused developed image on the recording element **112** to be transferred to the paper **140**.

The web of paper **140**, stored on a roll **142**, is pulled past a charging unit **144**, between the rollers **136** and **138**, and through a fuser **146** by means of suitably driven drive rollers **148** and **150**, and a guide roller **152**. Thus, the unfused powdered image transferred to the charged paper **140** can be fused in the fuser **146**. After the transfer process, the recording element **112** may be developed once more in the developer tank **115** and fused in the fuser **116**. The developed image appearing upon the recording element **112** is a mirror image of the images appearing on the recording element **123** and on the paper **140**. Because the image on the recording element **112** is a mirror image, the developed recording element **112** can be used in other recording processes, such as by transfer to a multilith master for the multilith process of reproduction.

From the foregoing description, it will be apparent that

there has been provided improved means for making duplicate electrostatic prints. By means of the methods and apparatus shown and described, a plurality of recording elements, superimposed on each other at an exposure station, are exposed simultaneously with electromagnetic radiation of sufficient intensity to penetrate all of the recording elements. While the apparatus has been illustrated in schematic form, variations in the apparatus coming within the spirit of this invention will, no doubt, readily suggest themselves to those skilled in the art. For example, a greater number of recording elements may be exposed simultaneously than the number described and illustrated. Hence, it is desired that the foregoing description shall be considered merely as illustrative and not in a limiting sense.

What is claimed is:

In a method of electrostatic printing of two electrographic recording elements simultaneously, in the absence of any interlayers between said elements, to obtain an identical print of a light image on each of said elements, each of said elements comprising a backing sheet having a substantially similar photoconductive layer of zinc oxide fixed thereon, and at least one of said elements being light-transmitting, said method comprising the steps of electrostatically charging each of said layers of said elements with a charge of the same polarity with respect to a common reference potential, arranging said charged elements one behind the other with at least a portion of a major surface of one of said elements in direct physical contact with a portion of a major surface of the other of said elements, and directing said light image towards said elements from the side thereof facing said light-transmitting element, said light image being of sufficient intensity to expose, at said portions in physical contact with each other, both said layer on said light-transmitting element and said layer on the other of said two elements, whereby to produce a duplicate electrostatic image of said light image on each of said layers of each of said elements, each of said layers being exposed to substantially the same spectral range of light of said light image.

References Cited by the Examiner

UNITED STATES PATENTS

2,647,049	7/53	Land	96—3
2,844,734	7/58	Hartmann.	
2,909,971	10/59	Barber	95—1.7
2,946,682	7/60	Lauriello	96—1
2,947,625	8/60	Bertelsen	96—1
2,962,374	11/60	Dessauer.	
2,962,375	11/60	Schaffert.	
2,963,365	12/60	Grieg	96—1
2,968,553	1/61	Gundlach	96—1
2,984,163	5/61	Giaimo	95—1.7
3,062,110	11/62	Shepardson et al.	95—1.7

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