

[54] **METHOD AND APPARATUS FOR DEVELOPING HEAT PROCESSABLE PHOTOGRAPHIC FILM**

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[22] Filed: Aug. 3, 1972

[21] Appl. No.: 277,665

[52] U.S. Cl. 96/48 HD, 96/66 T

[51] Int. Cl. G03c 5/24, G03c 5/30

[58] Field of Search 96/48 HD, 66 T, 114.1, 96/48 R, 119 R

[56] **References Cited**

UNITED STATES PATENTS

3,458,314	7/1969	Linowitski et al.	96/49
3,573,046	3/1971	Fotland et al.	96/48 R
3,679,418	7/1972	Stroszynski	96/33
3,785,821	1/1974	Notley	96/48 HD

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[57]

ABSTRACT

After exposure to light, heat is applied to the emulsion side of a heat processable film at a sufficient rate to maintain the emulsion side at a high temperature where the emulsion is processed at a rapid rate. Heat is removed from the base side of the film at a sufficient rate to maintain the interior of the emulsion at a low temperature where the emulsion is processed at a slow or negligible rate. The heat is applied only long enough to process the surface of the emulsion side to completion. If the base material has a softening temperature lower than the temperature where the emulsion is readily processable, heat removal is at a sufficient rate to maintain the base at a temperature below its softening temperature.

9 Claims, 4 Drawing Figures

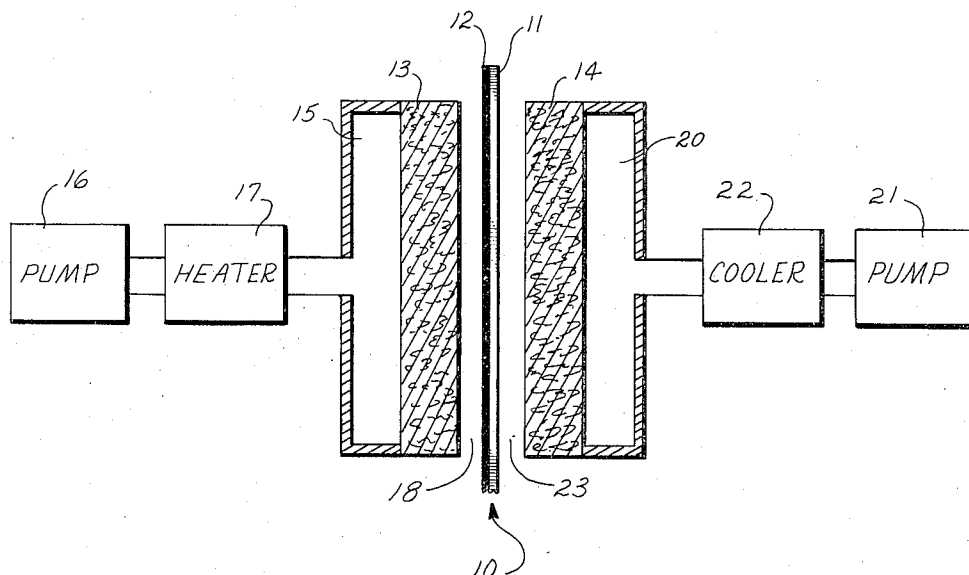


FIG. 1

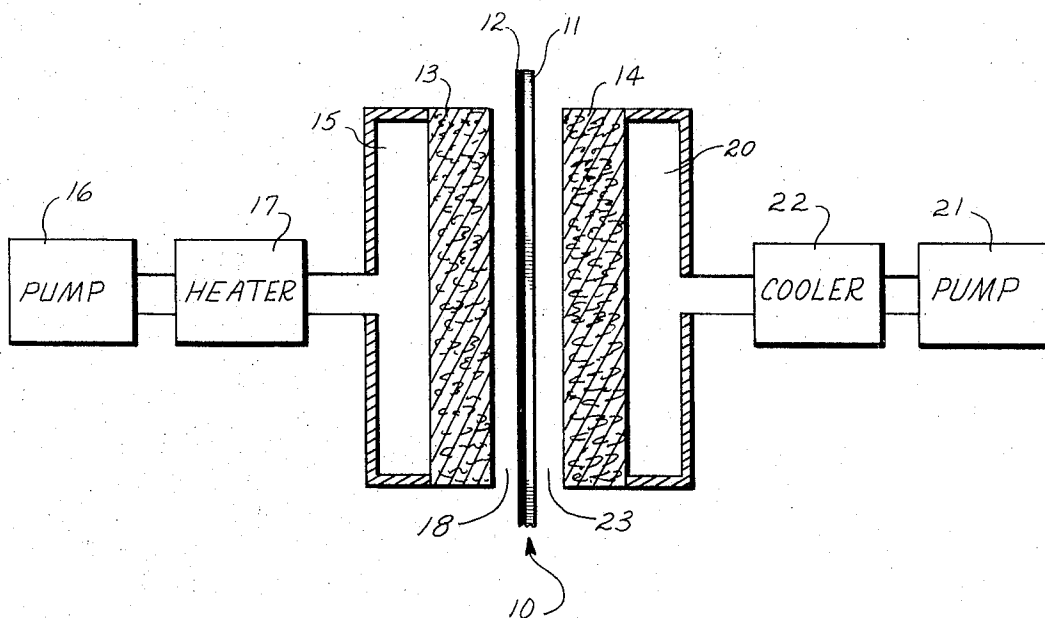


FIG. 2

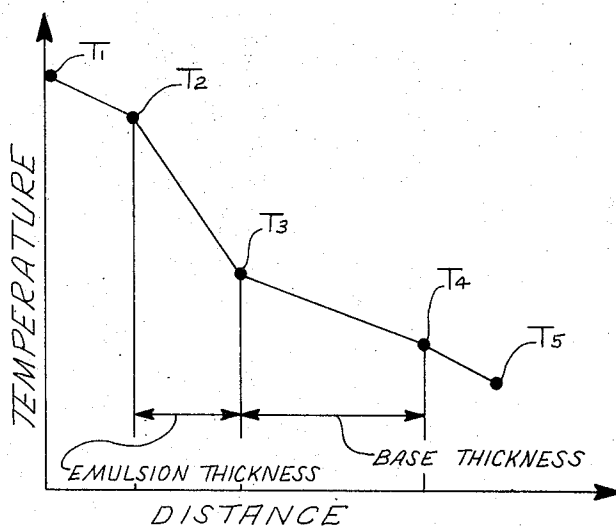


FIG. 3A

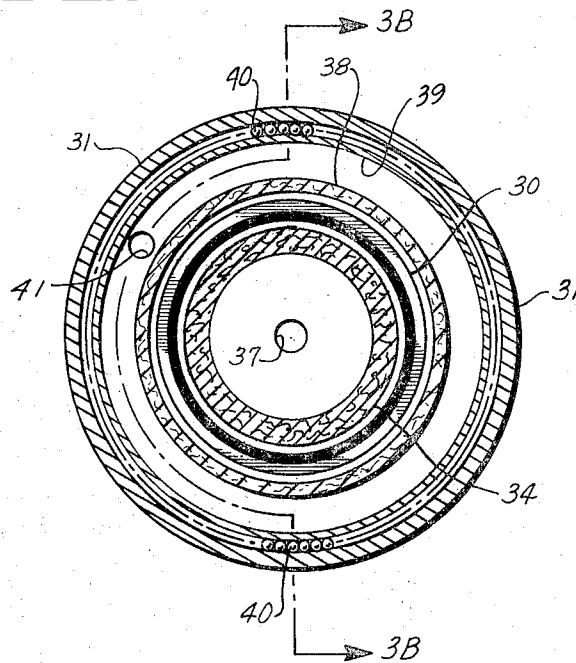
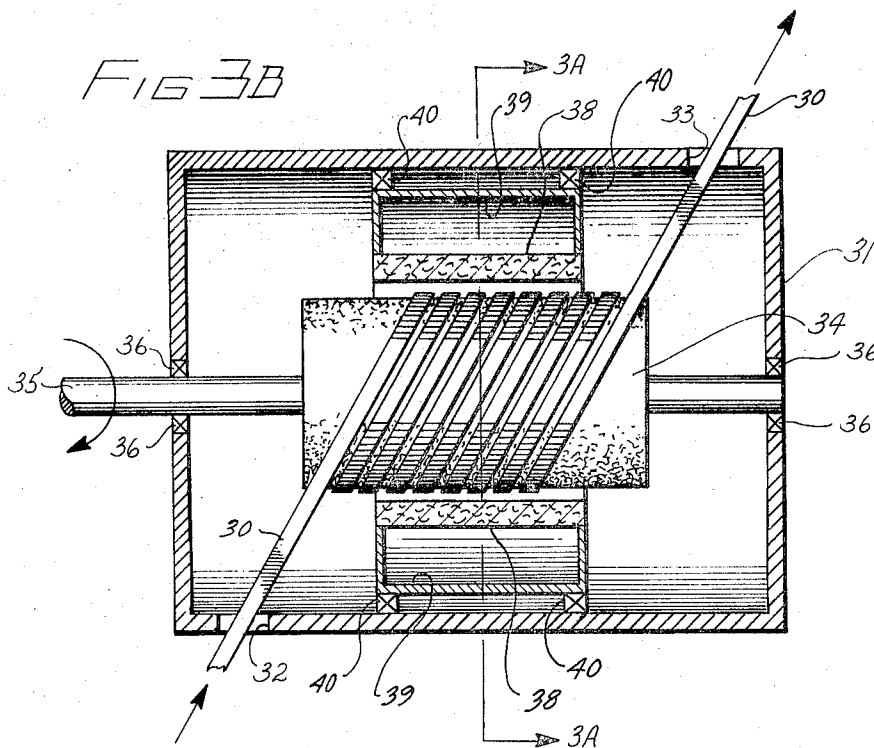


FIG. 3B



METHOD AND APPARATUS FOR DEVELOPING HEAT PROCESSABLE PHOTOGRAPHIC FILM

BACKGROUND OF THE INVENTION

This invention relates to the development of heat processable photosensitive materials and, more particularly, to a developing method and apparatus that improves image resolution and reduces image distortion.

Heat processable photosensitive films are well known. See, for example, the following U.S. Pat. Nos. 3,257,205, issued June 21, 1966; 3,438,776, issued Apr. 15, 1969; and 3,468,664, issued Sept. 23, 1969. The rate at which development of the film proceeds is temperature dependent, being more rapid at higher temperature. For many applications, heat processable film is an attractive alternative to the more conventional film developed by chemicals, because the developing process is substantially simpler.

One conventional technique for developing heat processable film, which is referenced in U.S. Pat. No. 3,468,664, is to place the base side of the film in contact with a heated surface such as a drum, with the emulsion side of the film exposed to the atmosphere. The temperature gradient developed across the film in this technique is such that the temperature of the base side of the film is higher than the temperature of the emulsion side of the film. Another technique for developing heat processable film is to place the base side of the film in contact with the unheated surface of a film support member and to subject the emulsion side of the film to a so-called hot air knife, i.e., a wide stream of hot air. Due to the large thermal resistance that the support member normally has, the entire thickness of the film is essentially at the same temperature, i.e., there is no appreciable temperature gradient.

One problem associated with heat processable film is the softening of the base material during the application of heat. Many of the materials conventionally used for film bases have a softening temperature that is lower than the temperature at which many heat processable photosensitive materials can be readily developed. When the base material softens and deforms, the image on the emulsion becomes distorted.

Another problem associated with heat processable film is the impairment of image resolution by the development of the full depth of the emulsion layer. Due to the tendency of the light to spread as it moves through the emulsion layer during exposure, the light activated portions of the emulsion layer expand in area, moving inwardly from the surface of the emulsion layer.

SUMMARY OF THE INVENTION

According to one aspect of the invention, a decreasing temperature gradient is established between first and second surfaces of a heat processable photosensitive material after exposure of the first surface to light to develop the material near the first surface without developing the material near the second surface. As a result, the image resolution is improved because image spreading is curtailed. The temperature gradient is established by coupling a heat source to the first surface through a thermal resistance in the same order of magnitude as the thermal resistance of the material, and coupling the second surface of the material to a heat receiver through a thermal resistance in the same order of magnitude as the thermal resistance of the material.

Thus, the temperature at the first and second surfaces, respectively, can be controlled to provide the desired gradient by selecting the temperatures of the heat source and receiver, respectively.

According to another aspect of the invention, after exposure to light a temperature gradient is established across a film that comprises a layer of heat processable photosensitive material attached to a layer of base material having a softening temperature below the temperature at which the photosensitive material is readily heat processable. The surface of the photosensitive layer is maintained at a temperature where development of the photosensitive material readily occurs, while the temperature of the base layer is maintained below its softening temperature. Thus, image distortion due to deformation of the base layer during heat processing is prevented.

In the preferred embodiment of the invention, the heat source is hot gas under pressure brought into contact with the surface of the photosensitive layer of the film, and the heat receiver is cool gas under pressure brought into contact with the surface of the base layer of the film. The heat source and/or heat receiver is coupled to the film through a piece of microporous material to form between the film and the microporous material a gas cushion that can also function to support the film. Most advantageously, the microporous material is moved relative to the film at a sufficiently high velocity to create turbulence within the gas cushion, thereby improving heat transfer.

BRIEF DESCRIPTION OF THE DRAWINGS

The features of specific embodiments of the best mode contemplated of carrying out the invention are illustrated in the drawings, in which:

FIG. 1 is a schematic, partially block diagram of one embodiment of film developing apparatus incorporating the principles of the invention;

FIG. 2 is a graph illustrating the temperature relationships established by the apparatus of FIG. 1; and

FIGS. 3A and 3B are a side sectional view and a front partially sectional view, respectively, of another embodiment of heat developing apparatus incorporating the principles of the invention.

DETAILED DESCRIPTION OF THE SPECIFIC EMBODIMENTS

In FIG. 1, a film 10 comprises a layer of base material 11 and a layer of a heat processable photosensitive emulsion 12 attached to layer 11. The surface of layer 12 has previously been selectively exposed to a source of light so portions of layer 12 are light activated in accordance with an image. A flat platen 13 of microporous material is disposed adjacent to layer 12, and a flat platen 14 of microporous material is disposed adjacent to layer 11. The microporous material could comprise cast Tamastone, oilite, filter porcelain, or a porous sintered metal. As a result, there are formed through platens 13 and 14 a very large number of multidirectional passages. A rectangular housing 15, which is open at one end, is attached to the back of platen 13. Atmospheric air is supplied to the interior of housing 15 by a pump 16 via a heater 17, which serves as a heat source. The hot air under pressure within housing 15 escapes through the microporous passages of platen 13 into a space 18 between platen 13 and layer 12. As a result, heat is supplied, i.e., conductively coupled to the

surface of layer 12. A housing 20, which is open at one end, is attached to the back of platen 14. Atmospheric air is supplied to the interior of housing 20 by a pump 21 via a cooler 22, which serves as a heat reservoir. The cool air under pressure within housing 20 escapes through the microporous passages of platen 14 into a space 23 between platen 14 and layer 11. As a result, heat is removed, i.e., conductively coupled from the surface of layer 11. Depending upon the required rate of heat removal from the surface of layer 11, air at ambient temperature could be supplied to housing 20 and cooler 22 could be eliminated in some cases. Film 10 is transported through the space between platens 13 and 14, either continuously or in discrete steps. In addition to the heat transfer function performed by the air supplied by platens 13 and 14, this air could also be used to support film 10, as described in Long U.S. Pat. No. 3,245,334. In some cases, it will be desirable to provide separate means for supporting film 10, in order to increase the separation between film 10 and platens 13 and 14.

The hot air under pressure within housing 15 comprises a heat source, and the cool air under pressure within housing 20 comprises a heat receiver. Platen 13, space 18, and the hot air comprise a thermal coupling between the heat source and the emulsion side of film 10. Platen 14, space 23, and the cool air comprise a thermal coupling between the base side of film 10 and the heat receiver. In the graph of FIG. 2, the abscissa represents the distance between the heat source and the heat receiver, and the ordinate represents the temperature. The temperature of the heat source is T_1 , the temperature of the surface of layer 12 is T_2 , the temperature of the interface between layers 11 and 12 is T_3 , the temperature of the surface of layer 11 is T_4 , and the temperature of the heat receiver is T_5 . On the abscissa, the distance between temperatures T_2 and T_3 represents the thickness of layer 12, and the distance between temperatures T_3 and T_4 represents the thickness of layer 11. These distances are not to scale relative to the distance between temperatures T_1 and T_2 , and the distance between temperatures T_4 and T_5 . Temperatures T_2 and T_4 are controlled to produce across layer 12 a sufficiently large temperature gradient that the emulsion is processed at a high rate on the surface of layer 12 and is processed at a low or negligible rate in the interior of layer 12 and at the interface of layers 11 and 12. As a result, the image resolution is improved because the interior of layer 12 where the light activated portions expand in area remains undeveloped. Further, assuming that the softening temperature of layer 11 is lower than the temperature at which layer 12 is readily processible, temperatures T_2 and T_4 are further controlled so temperature T_3 is below this softening temperature. As a result, image distortion due to deformation of layer 11 is obviated. The thermal resistances of the couplings between the heat source and film 10 and film 10 and the heat receiver are in the order of magnitude of the thermal resistance of film 10. In other words, the temperature drop between the heat source and film 10 and/or the temperature drop between film 10 and the heat receiver are not so large as to account for too much of the difference between temperatures T_1 and T_5 to provide a sufficient temperature gradient across film 10 to carry out the described functions. In contrast, if the thermal resistances of the couplings between the heat source and film 10 and film 10

and the heat receiver were much larger than the thermal resistance of film 10, film 10 would essentially be at the same steady state temperature throughout its thickness, or the temperature gradient across film 10 would at least not be sufficient to carry out the described functions.

As soon as the surface of layer 12 is processed to completion, the heat source is removed. This minimizes the extent to which the interior of layer 12 becomes developed. In other words, the transport speed of film 10 is selected so the exposure time of layer 12 meets these conditions.

In FIGS. 3A and 3B, a length of film 30 is guided by means, not shown, in a path to enter a stationary cylindrical housing 31 through an opening 32 and to leave housing 31 through an opening 33. A hollow drum 34 made of microporous material is mounted on a shaft 35 journaled by bearings 36 for rotation relative to housing 31. Film 30 extends within housing 31 in a helical path adjacent to the surface of drum 34. Hot air under pressure is supplied through an inlet 37 to the interior of drum 34. Inlet 37 is connected to a pump and heater not shown in FIGS. 3A and 3B. The hot air within drum 34 escapes through the passages in the microporous material into the space between film 30 and the surface of drum 34 to support film 30 in spaced relationship from drum 34. Drum 34 is rotated by means not shown at a sufficiently high velocity to create turbulent flow of the air in the space between film 30 and the surface of drum 34 so as to improve the heat transfer to the layer of photographic emulsion, which faces toward the surface of drum 34. A ring 38 made of microporous material is adjacent to the layer of base material of film 30. An annular housing 39, which is open along its inner periphery, is attached to ring 38. Housing 39 is supported by bearings 40 for rotation relative to housing 31. Cool air under pressure is supplied through an inlet 41 to the space enclosed by housing 39 and ring 38. Inlet 41 is connected to a pump, not shown in FIGS. 3A and 3B. The pump for inlet 41 and the pump and heater for inlet 37 could either be mounted for rotation with their respective inlets, in which case electrical power for the pumps and heater would be coupled through rotating electrical connections, or could be mounted to remain stationary, in which case the air would be coupled to their respective inlets through rotary fluid couplings. The layer of base material of film 30 is cooled by the air escaping through the passages in the microporous material of ring 38. Ring 38 and housing 39 are rotated by means not shown at a sufficiently high velocity to create turbulent flow of the air in the space between film 30 and the surface of ring 38 so as to improve the heat transfer from the layer of the base material. The length of film 30 in the helical path adjacent to drum 34 and the transport speed of film 30 are selected so each segment of film 30 is exposed to the hot gas only long enough to process the surface of the layer of the photographic emulsion to completion without appreciably processing the interior of the layer.

The described embodiments of the invention are only considered to be preferred and illustrative of the inventive concept; the scope of the invention is not to be restricted to such embodiments. Various and numerous other arrangements may be devised by one skilled in the art without departing from the spirit and scope of this invention. Although it is convenient to couple the

heat source and receiver to the film by gas under pressure, other means of thermal coupling could be employed. In the embodiment of FIGS. 3A and 3B, the hot air could be introduced through inlet 41, and the cold air could be introduced through inlet 37. In this case, the base layer of the film would face drum 34 and the emulsion layer of the film would face away from drum 34.

What is claimed is:

1. A method for developing a heat processable photosensitive material the rate of processing of which is directly related to the temperature of the material, the photosensitive material having first and second approximately parallel surfaces, selected portions of the first surface having been exposed to light, the method comprising the steps of:

supplying heat to the first surface of the material at a sufficient rate to maintain the first surface at a high temperature where the material is processed at a rapid rate;

removing heat from the second surface of the material at a sufficient rate to maintain the second surface of the material at a lower temperature than the first surface said lower temperature being such that the second surface of the material is processed at a lower rate than the first surface or a negligible rate; and

terminating the supply of heat to the first surface after the first surface is processed to completion but before the second surface is processed to completion.

2. The method of claim 1, in which the heat supplying step comprises the step of forming a hot gas cushion in contact with the first surface, and the heat removing step comprises the step of forming a cool gas cushion in contact with the second surface.

3. The method of claim 2, additionally comprising the step of establishing turbulence in the gas cushions.

4. The method of claim 1, comprising the additional step of passing the photosensitive material between a pair of closely spaced parallel pieces of microporous material, the heat supplying step comprising the step of forcing a hot gas through one of the pieces of microporous material into the space between said one piece of microporous material and the first surface of the photosensitive material, and the heat removing step comprises the step of forcing a cool gas through the other piece of microporous material into the space between said other piece of microporous material and the second surface of the photosensitive material.

5. A method of developing a film comprising a first

layer of support material and a second layer of heat processable photosensitive material deposited on the first layer after the photosensitive material has been activated by light traveling transverse to the surface of the second layer, the method comprising the step of:

coupling heat through the film from the surface of the second layer to the surface of the first layer such that a sufficient temperature gradient is established across the film to process the surface of the second layer to completion without appreciably processing the interior of the second layer.

6. The method of claim 5, in which the softening temperature of the support material is below the temperature at which the photosensitive material is readily heat processable and the step of coupling the heat through the film establishes a sufficient temperature gradient so the to heat of the first layer is below said softening temperature while the surface of the second layer is being heat processed to completion.

7. A method of developing a film comprising a first thin layer of base material and a second thin layer of heat processable photosensitive emulsion attached to the base material after the photosensitive emulsion has been activated by light, the emulsion being developed upon exposure to heat at a temperature T_1 for a time period P and the base material having a softening temperature of T_2 where T_2 is lower than T_1 , the method comprising the steps of:

conductively coupling a heat source to the second layer to maintain the emulsion at temperature T_1 for the time period P ; and

simultaneously conductively coupling a heat reservoir to the first layer to maintain the base material below temperature T_2 .

8. The method of claim 5, in which the heat source coupling step comprises forming a hot gas cushion in contact with the second layer and the heat reservoir coupling step comprises forming a cool gas cushion in contact with the first layer.

9. The method of claim 8, additionally comprising the step of passing the film between a pair of closely spaced parallel pieces of microporous material, the step of forming a hot gas cushion comprising forcing a hot gas through one of the pieces of microporous material into the space between said one piece of microporous material and the second layer, and the step of forming a cool gas cushion comprising forcing a cool gas through the other piece of microporous material into the space between said other piece of microporous material and the first layer.

* * * * *

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 3,850,635
DATED : November 26, 1974
INVENTOR(S) : Minard A. Leavitt

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Col. 5, line 27, after "or" should be inserted --at--.

Col. 6, line 17, "to heat" should be changed to --temperature--.

Signed and sealed this 17th day of June 1975.

(SEAL)

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents
and Trademarks

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