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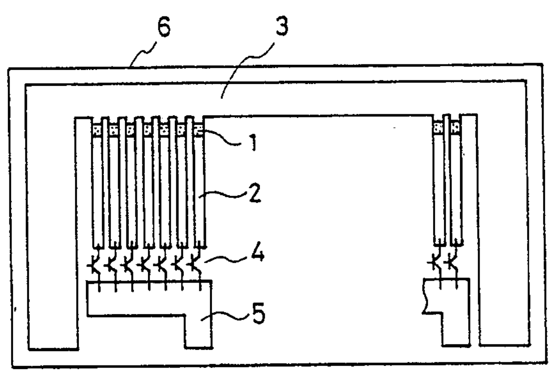
(54) **Method and apparatus for thermally recording data in a recording medium.**

(57) A method and apparatus are applicable to a thermal recording system which records data in a recording medium using a heat generated by applying a power to a resistor. According to the invention the resistor itself or a monitor, which is disposed in the path of electric current applied to the resistor, is made of a material having the metallic/non-metallic phase transition characteristics at predetermined temperature, whereby the resistor or the monitor can have a function to interrupt the electric current at the predetermined temperature so that the peak temperature of the resistor s controlled constantly regardless of the value or period of the applied voltage. Further, it achieves a uniform recording property and a stable continuous tone recording property by controlling the period for holding the peak temperature of the resistor.

FIG. 1



EP 0 423 708 A2

METHOD AND APPARATUS FOR THERMALLY RECORDING DATA IN A RECORDING MEDIUM

BACKGROUND OF THE INVENTION

1. Field of the invention

The present invention relates to a method and an apparatus for thermally recording information in a recording medium and, more particularly, for realizing an excellent recording by controlling the peak temperature of heating resistor as it does not exceed the specific temperature.

2. Description of the Prior Art

Conventional apparatuses for recording information in the recording medium thermally utilize a resistor of a metallic compound such as ruthenium oxide or tantalum nitrido, or a cermet resistor prepared by dispersing an insulator such as silicon oxide into a refractory metal such as tantalum in the heating resistor of the thermal head.

When a proper voltage is applied to the aforementioned heating resistor of the thermal head, an electric current flows through the heating resistor to generate the Joule heat, and this state is maintained for a constant time to give heat-sensitive recording paper a thermal energy necessary for the recording. The energy of the Joule heat generated by the aforementioned heating resistor is determined in dependence upon the resistance of the heating resistor, the applied voltage and the time period for applying the voltage.

The conventional thermal recording apparatus so adjusts the applied voltage or the time period for applying the voltage according to the heat sensitivity of the heat-sensitive papers used, the background temperature around the heating resistor, the temperature of the recording medium itself and the thermal conductivity which the thermal energy generated by the heating resistor is transmitted from the heating resistor to the heat-sensitive paper that it obtains the optimum recording quality and the desired recording density.

On the other hand, the powered transfer recording apparatus comprises an ink donor sheet having a power heating resistor layer which consists of carbon paint and a power supply head. When the power heating resistor layer is powered by the power supply head, the ink donor sheet is heated by the thermal energy generated by the power heating resistor layer so that the ink may be melted or sublimated and transferred to the recording medium. It so adjusts the applied voltage or the voltage applying time period according to the sheet resistance of the powered heating resistor layer, the temperature of the ink donor sheet and the electrode temperature of the power supply head that it makes the thermal energy generated the powered heating resistor layer most suitable so as to obtain the optimum recording quality and the desired recording density.

In the thermal recording method of the prior art, for the following reasons, the adjustment of recording thermal energy according to the voltage and the pulse width to be applied to the heating resistor is seriously troublesome to raise the production cost for the recording apparatus.

The thermal energy to be generated in the heating resistor by applying voltage pulses can be determined in dependence upon the voltage or the pulse width of the applied pulses, as has been described hereinbefore. Despite of this fact, however, the temperature of the heating resistor will fluctuate with the pulse applying histories such as the period of applying the pulse and the number of the pulse applied continuously, the thermal histories of the heating resistor, or the temperature of the supporting substrate of the thermal head or the environments.

The thermal recording mechanism depends directly not upon the level of the thermal energy generated by the heating resistor but upon the temperature of the coloring layer of the heat-sensitive recording paper or the ink layer, i.e., the temperature of the heating resistor. If, therefore, it uniforms the temperature of the heating resistor at the heating time so as to achieve a uniform thermal recording to the heat-sensitive papers or the like, it needs to collect or predict the thermal data of the environment and histories in which the heating resistor is placed at the instant of heating. It has to so adjust and determine the voltage value or the pulse width of the applied voltage based on those data that the temperature of the heating resistor raises to the desired temperature.

The data collecting means, data predicting means and recording condition deciding means exert seriously high loads upon the hardwares such as a variety of temperature sensors for detecting the temperature of the thermal head substrate of the environment, memories for storing the past recorded data so as to grasp the recording histories, simulators such as a thermal equivalent circuit for predicting the thermal states, and the CPU and gate circuits for processing data. Seriously complex softwares are also required for supporting those hardwares. Especially, either a large-sized highly precise thermal recording apparatus having a plurality of heating resistors or an apparatus for recording data with continuous tone of density has to process massive data so that it cannot avoid the increase in the size and price while sacrificing the recording quality. On the other hand, the processing time for collecting and predicting the data and deciding the recording conditions is restricted by the CPU or the like to trouble the high-speed recording.

Moreover, the thermal head is usually formed with a glazed layer as a heat insulating layer for enhancing the thermal efficiency. This glazed layer is formed by a thick film process so that its thickness disperses over ± 20% of the average value of the thickness so that the heat insulating effect by the glazed layer randomly disperses among the individual thermal heads. No matter how accurately the data of the thermal environment of the heating resistor might be grasped and processed to decide the individual recording condition, as has been described herein-before, the highly accurate exothermic temperature control would be blocked by the dispersion of the thermal characteristics of the thermal heads. If a more highly accurate control of the exothermic temperature is to be accomplished, the dispersion of the thermal characteristics of the individual thermal heads also has to be incorporated as the control parameter so that the mass-productivity has to be seriously sacrificed by adjusting the recording apparatus one by one. If it is considered to replace the thermal heads in the recording apparatus because of their troubles or lifetimes, it is almost difficult to adjust the settings of the recording apparatus for the individual characteristics of the thermal heads. The dispersions of the thermal capacity and the thermal resistance also depend upon the periphery of the heating resistor layer in the powered thermal recording, thus raising problems similar to those of the aforementioned case of the thermal head.

SUMMARY OF THE INVENTION

An object of the present invention is to provide an improved method and apparatus for uniformly controlling a temperature of a heating resistor on which the thermal recording mechanism depends.

Another object of the present invention is to provide an improved method and apparatus for recording continuous tone data according to a period of time for holding peak temperature of a heating resistor.

To realize above objects, the present invention gives the thermal head itself a temperature selfcontrol function to prevent the temperature of the heating resistor from exceeding a predetermined level.

More particularly, there is provided a monitor, which performs a temperature change equal or similar to that of the heating resistor in synchronism with both the temperature rise of the heating resistor energized and the temperature drop of the heating resistor due to the interruption of the power-supply to the heating resistor, in the path which the electric current flows to the heating resistor.

It makes the monitor of a material of phase transition having its electric conductivity changed metallic at a lower temperature across a predetermined temperature range and non-metallic at a higher temperature. When the temperature of the heating resistor is raised to reach the predetermined temperature, i.e., the metallic/non-metallic phase transition temperature by applying the voltage to the heating resistor so as to generate the Joule heat, the phase transition material has its resistance increased substantially to that of an insulator or semiconductor to interrupt the current substantially. Therefore, the monitor suppresses to apply the power so as to interrupt the temperature rise of the heating resistor when the temperature of the monitor rises to the predetermined temperature range, and it makes to apply the power again so as to rise the temperature of the heating resistor when lower than the predetermined temperature range. As a result, the temperature of the heating resistor is not raised to exceed the phase transition temperature so that its peak temperature can be uniformly controlled within the phase transition temperature range. By this uniform control of the peak temperature, the thermal recording can be uniformed. Further, by the control of a period of time for holding the peak temperature, it can achive a stable and excellently reproducible recording of contenious tone data.

Further more, the heating resistor itself may be made of the material of phase transition.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a plane view of an embodiment of a thermal head of the present invention;

Figs. 2 and 3 are graphical representations showing the heating temperature characteristics of the thermal head shown in Fig. 1;

Figs. 4, 5, 6 and 11 are diagrammatic renditions of a burn point area of the thermal head of the present invention, showing various embodiments, which Figs. 4(A), 5, 6(A) and 11 are partially plane views of various embodiment and Figs. 4(B) and 6(B) are partially sectional views of the thermal head shown in Figs. 4(A) and 6(A);

Fig. 7 is a plane view of still alternate embodiment of the thermal head of the present invention;

Fig. 8 is a graphical representation showing the heating temperature characteristics of the thermal head shown in Fig. 7;

Fig. 9 is a block diagram of an embodiment of a driving control circuit for carrying out the method of the present invention;

Fig. 10 is a timing chart showing control timing of the driving control circuit shown in Fig. 9;

Fig. 12 is a graphical representation showing the heating temperature characteristics of the thermal head of the present invention;

Fig. 13 is a graphical representation showing the contenious tone heating temperature characteristics of the thermal head of the present invention;

Fig. 14 is a graphical representation showing the temperature dependency of the linear resistance of the material exhibiting the metallic/non-metallic phase transition;

Figs. 15 and 17 are partially sectional views of apparatus for carrying the method of the present invention;

Fig. 16 is a partially perspective illustration of the thermal recording head to be used in the method of the present invention; and

Fig. 18 is a partially perspective illustration of the power heating sheet to be used in the method of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The invention will now be described with reference to the accompanying drawings representing an embodiment thereof.

Fig. 1 is a plan view of an embodiment of a thermal head of the present invention. This thermal head is constructed by forming thin-film heating resistors 1, which are made of a material having metallic characteristics of electric conductivity at a lower temperature across about 300° C and non-metallic characteristics at a higher temperature such as vanadium oxide doped with about 0.1% of Cr to V, over a substrate 6 made of glazed alumina ceramics, by connecting one-side terminals of the heating resistors 1 with individual electrodes 2 and the other-side terminals with a first common electrode 3, and by connecting the individual electrodes 2 with current switching elements 4 such as transistors. Numeral 5 designates a second common electrode connected with the switching elements 4. The thermal head need not be equipped with the switching elements 4 and the second common electrode 5 but may be separately provided as the recording apparatus.

The first common electrode 3 is fed with a plus potential whereas the second common electrode 5 is fed with a minus potential, and voltage pulses are applied to the aforementioned heating resistors 1 by switching the switching elements 4. If the voltage pulses are applied to the heating resistors 1, a suitable power consumption is caused by the applied voltage and the resistances of the heating resistors 1, as in the thermal head in the thermal recording of the prior art, to generate the Joule heat so that the temperature rise of the heating resistors 1 is started.

Fig. 2 is a graphical representation showing the time changes of the surface temperature of the heating resistors 1 according to a pulse applying in the thermal head of Fig. 1. In Fig. 2, letter T_c designates the temperature of the metallic/non-metallic phase transition at the electric conductivity of the heating resistors. Letter t_{on} designates the time to start the applying of pulses. Letter t_P designates the time at which the surface temperature of the heating resistors reaches the above-specified phase transition temperature (T_c). Letter t_{off} designates the time to end the pulse applying. For the period between the time t_p and the time t_{off}, the heating resistors 1 repeat the metallic/non-metallic phase transitions from the higher to lower temperatures and vice versa so that their surface temperature calms down in the vicinity of the aforementioned phase transition temperature T_C. The actual temperature of the heating resistor may be raised to a slightly higher level than the level T_C by either the heat capacity of the structural member in the periphery of the heating resistors themselves or the thermal inertia due to the thermal resistance. The surface temperature of the heating resistors reaches the level T_C of about 300° C for a time period as short as about 0.5 millisecs from the time t_{on} unless a heat absorber such as heat-sensitive papers are brought into contact with the heating resistors, in case the heating resistors 1 have an area of 0.015 mm^2 corresponding to the heating resistor density of 8 dots/mm, in case the heating resistors 1 have a resistance of about 1,000 Ω at the lower temperature, and in case the applied voltage is 20 V. This time period is individually different for the structures of the thermal head because the thermal characteristics such as the thermal resistance or heat capacity of the vicinity of the heating resistors are different in dependence upon the glazing thickness of the glazed substrate 6 of the thermal head or the thickness of the protecting layer coating the surfaces of the heating resistors 1. Since, however, the peak temperature of the heating resistors 1 is determined by the aforementioned phase-transition temperature T_C of the material making the heating resistors, it does not depend upon the aforementioned thermal characteristics of the thermal head or the structure of the thermal head.

Further, the dispersion of the thermal characteristics, which the thermal head has, appears as the temperature rising gradient from the time t_{on} to the time t_p, i.e., at the time t_p.

In the direct heat-sensitive recording system, the color developing mechanism is the chemical reaction of a coloring agent due to the heat and the reaction rate depends upon the temperature. In the thermal transfer recording system, the recording mechanism is the physical phase change such as the melting or sublimation of the ink and is dominated by the temperature of the ink. Therefore, the effect of the dispersion of the thermal characteristics on the recording characteristics is far smaller than those of the prior art in which the peak temperature of the heating resistor fluctuates.

On the other hand, the dispersion of the resistance of the heating resistors may exist in not only the thermal head in the thermal recording of the prior art but also the thermal head in the thermal recording of the present invention in dependence upon the thickness of the resistive films. However, this dispersion appears only as that of the period from the time t_{on} to the time t_p in the thermal head in the present invention so that the peak temperature of the heating resistor is unvaried. If it is intended to strictly reduce the dispersion of the temperature rising gradient, i.e., the dispersion of the time t_p due to the resistance dispersion of the heating resistors, the applied voltage may be adjusted and set to uniform the electric power according to the magnitude of the resistance of the heating resistors in the metallic electric conductivity phase of the heating resistors at the lower temperature.

As has been described hereinbefore, the effect of the thermal characteristic dispersion and resistance dispersion of the thermal head upon the recording characteristics are remarkably small in the case of the thermal head in the present invention. For the larger applied pulse width, i.e., the longer time period from the time t_{on} to the time t_{off} of Fig. 2, as compared with the temperature rising period from the time t_{on} to the time t_p, the changing and dispersing rates of the holding time period (t_{off} - t_p) of the peak temperature, which is the most contributable to the recording characteristics, are reduced the more to improve the recording quality the better.

In the embodiment described above, the temperature for the metallic/non-metallic phase transition of the heating resistors is set at about 300 °C. In the case of a thermal head required for a higher recording speed, however, the heating resistors used have a higher phase transition temperature of 400 to 450 °C so that their resistance may be lowered (or the applied voltage may be raised) to increase the electric power. Then, at a higher temperature rising rate and at a higher peak temperature, the coloring reaction of the heat-sensitive paper is sufficiently effected for a shorter time so that the peak temperature holding time can be retained for a shorter applied pulse width (t_{off} -t_{on}) to ensure the uniform recording operation. In a thermal head of lower speed and power consumption type, on the contrary, the power consumption rate in the heating resistors may be reduced by dropping the applied voltage (or by increasing the resistance of the heating resistors), or the aforementioned phase transition temperature may be dropped to about 250 °C. Alternatively, these two methods may be combined.

Figs. 4(A) and 4(B) are a partially plane view and a partially sectional view of modified thermal head.

The thermal head disposes a monitor 8 between the heating resistor 7 and the individual electrode 2. The heating resistor 7 is made of ordinary resistive material such as tantalum nitride. The monitor 8 is made of the material having the metallic/non-metallic phase transition used in the heating resistor shown in Fig. 1 and is set to have a lower linear resistance than that of the heating resistor 7. Therefore, when the power is applied between the common electrode 3 and the individual electrode 2, the heat contributable to the recording is generated mainly in the heating resistor 7 and the monitor 8 generates a far lower heat than that at the heating resistor 7. If the material used to make the monitor 8 could form a film having a lower sheet resistance such as several tens mm Ω than that of the heating resistor 7, the individual electrode 2 could also be made of the material of the metallic/non-metallic phase transition without discriminating it from the monitor 8.

When the voltage is applied to the heating resistor 7, the heating resistor 7 is heated by the Joule heat and the temperature of the monitor 8 is rised by the heat generated at the heating resistor 7. If the metallic/non-metallic phase transition temperature of the monitor 8 is 200 °C, the electric current flows till the temperature of the monitor 8 reaches 200 °C. When the temperature of the monitor 8 reaches 200 °C, the current is substantially blocked by the non-metallic electric conductivity of the monitor 8 so as to interrupt the generation of the Joule heat. When the temperature of the monitor 8 is below 200 °C, the current flows again to cause the heat generation of the heating resistor 7. Thus, the temperature of the monitor 8 is held at the temperature of 200 °C while the voltage is being applied. Therefore, the temperature of the heating resistor 7 is substantially constant at a higher temperature than at least that of the monitor 8 so that the surface temperature of the heating resistor 7 cannot exceed the constant level but is controlled. The accuracy of the temperature control of the heating resistor 7 is the higher if the monitor 8 is the closer to the heating resistor 7, and the monitor 8 may be disposed in the burn area of the heating resistor 7.

Fig. 5 shows a burn point area of the modified thermal head of the present invention.

The thermal head disposes monitors 8 made of the material having the metallic/non-metallic phase transition at the two sides of the heating resistor 7 made of ordinary resistive material such as tantalum nitride.

In the case of the embodiment thus far described, the wiring line 8 is disposed in contact with one side of the heating resistor but may be disposed at the two sides, as shown in Fig. 5. In case the electric conductivity of the material of the metallic/non-metallic phase transition used in the monitor 8 is not so small that an electric current will leak even at a higher temperature to raise the temperature of the heating resistor continuously, or in case the monitor 8 is heated by the leakage current at the higher temperature, it is preferable from the stand-point of the temperature control that the monitors 8 are disposed at the two sides of the heating resistor 7, as shown in Fig. 5, to enhance the current blocking ability.

Figs. 6(A) and 6(B) show a burn point area of still modified thermal head of the present invention.

This thermal head disposes electrodes 22 between the heating resistor 7 and the monitors 8 in the thermal head shown in Fig. 5 and the behavior of the monitor 8 by the heating of the heating resistor 7 is not changed.

Especially in case the materials of the heating resistor 7 and the monitor 8 may possibly change their characteristics as a result of chemical reactions at a high temperature, it is more effective because the electrode 22 may be made of a stable metal such as gold in combination with at least the material of the monitor 8 to separate the monitor 8 from the heating resistor 7.

Fig. 3 shows the behaviors of the surface temperature changes of the heating resistor when the aforementioned thermal heads are driven with continuous pulses.

The peak temperature is constant for the time period from the first pulse to the n-th pulse, and the temperature rising time by the first pulse is the longer for the lower initial background temperature of the heating resistors, but the heating curves are substantially identical on and after the second pulse. Thus, the self-control can be made to a constant heating temperature without any driving control. The large length of the heating temperature-rising time by the first pulse raises no especial problem even in the sublimation type continuous tone printer. In case a strict recording density management is necessary, the applied pulse width may be elongated the more for the temperature-rising time only in case the first pulse, i.e., the background temperature is low, to control the peak temperature holding time uniform.

In the recording apparatus for the continuous tone recording, it is ordinary to control the continuous tone according to the width of the applied pulses no matter whether the recording might be of the direct heat-sensitive type or the sublimation transfer type. In the thermal head of the prior art, the continuous tone control is difficult due to the fluctuations of the peak temperature of the heating resistor because the peak temperature will change together with the pulse width.

In the thermal head of the present invention, on the contrary, the peak temperature is self-controlled to a constant level so that the continuous tone can be more finely controlled with the parameter of time only independently of the peak temperature. In the example of the prior art, some relative density control performs sixty four continuous tones, but the absolute density control is restricted to sixteen continuous tones at most. In the thermal head of the present invention, however, the absolute density control can be facilitated to one hundred and twenty eight continuous tones or two hundreds and fifty six continuous tones, as has been apparent from the description thus far made. Fig.15 is a diagram showing the waveforms of the surface temperature of the heating resistor with respect to the pulse width applied to the heating resistor, in case the thermal head of the present invention is utilized in the continuous tone recording. A heating resistor temperature waveform (18-1) by the first gradation pulse (19-1) starts its cooled drop midway of the temperature rise. Even with this gradation pulse setting, the continuous tone accuracy is high if the heating peak by almost pulses to the N-th continuous tone is within the time range controlling the peak temperature flat.

The aforementioned embodiments are embodiments controlling uniformly the temperature generated by the heating resistor of the thermal head to apply the heat on the recording medium such as the heat-sensitive recording paper or the ink donor sheet in the direct heat-sensitive recording system or the thermal transfer recording system.

In the powered thermal recording system which the heat-sensitive recording paper or the ink donor sheet having a heat resistive layer itself is heated by applying the power on the heat resistive layer, too, the heating temperature of the heat resistive layer is uniformed by making the heat resistive layer of the material having the metallic/non-metallic phase transition so that it oan record uniformly. The present invention in the powered thermal recording will be described in the following in connection with the embodiments thereof.

Fig. 15 shows a powered thermal recording device of the present invention.

A head 60 has a pair of electrodes 61, 62. A powered heat-sensitive recording sheet 50 is composed of a base sheet 52 such as a plastic sheet, a coloring recording layer 51 disposed on one surface of the base sheet 52 and a heat resistive layer 53 disposed on another surface of the base sheet 52. The coloring recording layer 51 is compounds of coloring agent and binder. The heat resistive layer 53 is made of the material having the metallic/non-metallic phase transition. The powered heat-sensitive recording sheet 50 is sandwiched between a platen 55 and the head 60 and is carried by rotating the platen 55. When voltage pulses are applied between electrodes 61, 62, the electric current flows from the portion of the heat resistive layer 53 coming in contact with the electrode 61 to the portion of the heat resistive layer 53 coming in contact with the electrode 62 so that the heat is generated in the aforementioned area of the heat resistive layer 53. The heat is transmitted to the coloring recording layer 51 through the base sheet 52 so that the area of the coloring recording layer 51 corresponding to the heated area of the heat resistive layer 53 generates color with the chemical reaction of the coloring agent due to the heat.

Fig. 17 shows a powered thermal transfer recording device of the present invention. An ink donor sheet is composed of a base sheet 54 made of metal having lower conductivity than that of the heat resistive layer 53, the heat resistive layer 53 disposed on one surface of the base sheet 54 and an ink layer 66 disposed on another surface of the base sheet 54. The ink layer 66 is made of the thermal melting ink. The ink donor sheet and a recording paper 67 are sandwiched between a platen 55 and a head having an electrode 61 and is carried by rotating the platen 55. Further, an electrode 65 is disposed in contact with the heat resistive layer 53. When voltage pulses are applied between electrodes 61, 65, the electric current flows from the electrode 61 to the electrode 65 through the heat resistive layer 53 and the base sheet 54. The electric current flows mainly in the depth direction in the heat resistive layer 53 because the base sheet 54 has lower conductivity than that of the heat resistive layer 53. Therefore, the portion of the heat resistive layer 53 being in contact with the electrode 61 generates the heat. The heat is transmitted to the ink layer 66 through the base sheet 54 so that the portion of the ink layer 66 corresponding to the electrode 61 is melted by the heat and the melted ink is transferred to the recording paper 67.

In the devices shown in Figs. 15 and 17, the peak temperature of the heat resistive layer 53 is always constant independently of the applied voltage, the power apply time, the sheet resistance of the heat resistive layer 53, the temperature of the head, and the temperature of the platen 55 and the environment because the heat resistive layer 53 is made of the material having the metallic/non-metallic phase transition.

Fig. 16 shows a modified head for applying the power in the powered thermal recording system. A head is composed of a supporting substrate 63, the electrodes 61 disposed on the supporting substrate 63 and for applying the power, and portions 64 disposed at the each pointed end of the electrodes 61. Each portion 64 is made of the material having the metallic/non-metallic phase transition, has a function to interrupt the electric current base on its temperature and is contact with the powered recording medium having the heat resistive layer. When the applied voltage pulse is applied to the heat resistive layer of the powered recording medium by the head, the heat resistive layer generates the heat. The temperature of the portion 64 rises accompanying the temperature rise of the heat resistive layer. If the temperature of the portion 64 reaches the phase transition temperature of the material having the metallic/non-metallic phase transition, the portion 64 changes to non-metallic phase and interrupts the electric current. As a result, the head can control the peak temperature of the heat resistive layer to a constant level. In this case, the heat resistive layer can be made of conventional material such as tantalum nitride.

Here, the aforementioned material having the metallic/non-metallic phase transition is exemplified by a compound of vanadium oxide. This vanadium oxide will change the metallic/non-metallic electric conductivity, if doped with a minute amount of Cr, in a region at a higher temperature than the room temperature. The doped vanadium oxide has a non-metallic electric conductivity at a higher temperature and a metallic electric conductivity at a lower temperature. Both vanadium and its oxide are refractory materials and can be used to make the heating resistors. The heating resistor film can be formed by the thin-film process such as the sputtering or by the thick-film process of spreading either a paste, which is prepared by powdering the material and mixing it with a binder, or an organic metal. In either case, the filmed vanadium oxide component is required to have at least a polycrystalline structure. The sputtering process is exemplified either by sputtering an alloy target of metallic vanadium and chromium or a metallic vanadium target having buried chromium with a mixture gas of argon and oxygen, or by high-frequency sputtering a target, which is sintered of vanadium oxide powder and chromium oxide power, with argon gases or a mixture gas of argon and minute oxygen. In either sputtering method, the temperature to be filmed is desirably at several hundreds °C or higher so as to crystalize surely.

In the case of doping of a proper amount of Cr, the electric conductivity will change by 2 to 3 orders at the aforementioned phase transition temperature. If, therefore, the material is used to make the heating resistor of the thermal head and the heating resistive layer of the heat-sensitive papers, the power to be consumed around the aforementioned phase transition temperature in the state of constant voltage application change by 2 to 3 orders and it follows from this that it takes hold of heating state and non-heating state substantially from the thermal recording standpoint. The phase transition temperature can be changed according to the ratio of the doping Cr so that the peak temperature of the heating resistors can be set. Further, the phase transition temperature shifts to lower temperature side as the ratio of the doping Cr increases. The vanadium oxide having no dopant of Cr has its resistance changing at a small rate and gently for the temperature. Since, however, the resistance rises by one order form the lower to higher temperatures across about 400°C, the undoped vanadium oxide can also be used in the thermal head of the present invention.

Fig. 14 is a diagram showing the temperature changes of the linear resistance of the heating resistor exhibiting the metallic/non-metallic phase transition. The linear resistance itself presents a reference because it is changed with the film thickness and the line width. However, the vanadium oxide doped with about 0.5% of Cr has its resistance changed by 3 orders at about 150 °C, as indicated by a linear resistance characteristic curve 31. The temperature range for causing the resistance change with the dope of Cr is so changed with the increase of the dopant Cr that it is gradually shifted to the lower temperature side. If the doping ratio of Cr to V of the vanadium oxide exceeds several percentages, the change of increasing the resistance from the lower to higher temperatures disappears so that the object of the present invention cannot be achieved. Since the doping ratio of Cr changes the temperature characteristics of the resistance change, as has been described hereinbefore, the change of the linear resistance may be made gentle to have a certain temperature width, as indicated by a curve 32 in Fig. 14, by the inhomogeneity of Cr doped in the vanadium oxide even if the doping ratio of Cr to V of the vanadium oxide is 0.5%. With this gentle change, the object of the present invention can be achieved. When a heating resistor having a side of several mm below 1 , for example, is to be energized and heated, its resistance change appears gentle, as indicated by the curve 32 of Fig. 14, in case the above-specified material is used to make the heating resistor of the thermal head, because the temperature rise is not spatially uniform in the heating resistor. In this case, too, the temperature rise and the energization stop are caused in a micro manner so that the heating resistor can realize the temperature rise or not without any problem.

Further, the material having the metallic/non-metallic phase transition characteristic is a mixed crystal, represented by $Ba_x Pb_{1-x} TiO_3$, composed of barium titanate and lead titanate. In this case, it has the phase transition temperature of about 300°C and the electric conductivity changes by 2 to 3 orders at the phase transition temperature when x is equal to 0.55.

Next, another driving method of the thermal head or the power supply head in the thermal recording method of the present invention will be described in connection with the embodiment thereof.

Fig. 7 is a top plan view showing the thermal head in which the switching element of the aforementioned thermal head of Fig. 1 is made of a thyristor. The thyristors 10, which are connected at 1 : 1 with the individual heating resistors 1 having the metallic/non-metallic phase transition characteristics are turned on by inputting a turn-on signal to their gates 11 at an arbitrary timing according to the recorded data. The first common electrode 3 is fed with a plus potential , and the second common electrode 5 is fed with a minus potential. When the thyristors 10 are turned on, the heating resistors 1 are substantially fed with the difference between the plus and minus potential so that they start to pass the electric currents. Upon this energization, the heating resistors 1 generate the Joule heat so that their temperature rises are started. when the temperature of the heating resistors 1 reach the metallic/non-metallic phase transition temperature of the material making the heating resistors, the value of the current flowing through the heating resistors drops by 2 to 3 orders if the heating resistors are made of vanadium oxide doped with Cr, for example. If elements having suitable turn-off characteristics are selected as the thyristors 10, these thyristors 10 are turned off by interrupting the current through the heating resistors 1. Once the thyristors 10 are turned off, the heating resistors 1 cannot be energized again so long as the turn-on signal is not inputted to the gate 11, so that the heating resistors 1 interrupt their heat generations. In other words, the heating resistors 1 automatically interrupt their heat generations, when they are energized to have their temperature reaching the aforementioned phase transition level, and are cooled down to stand-by for the subsequent input of the thyristor turn-on signal.

Fig. 8 is a diagram showing the time changes of the surface temperature of the heating resistors in case the heating resistors 1 of the thermal head shown in Fig. 7 are continuously driven by the aforementioned thyristors 10. Numeral 13 indicates the surface temperature of the heating resistors, and numeral 14 indicates the gate input signal of the thyristors 10, i.e., the timing signal for starting the heating. Letters Tc designate the aforementioned phase transition temperature. No matter what timing gate input pulses 14 might be inputted, as is apparent from Fig. 8, the surface temperature of the heating resistors would not exceed the level Tc, but the temperature rising and dropping curve in the vicinity of the peak temperature, which belongs to the most important temperature for the thermal recording, is identical for either heat generation.

In the foregoing description of the temperature rising and dropping curve, it has been clarified that the curve is not influenced by the heating history of a specific one of the heating resistors. However, the rising and dropping curves of the peak temperature of the specific heating resistor 1 are not influenced to realize the uniform heat generation at all times even for the simultaneous heat generations, the histories of the past heat generations of the heating resistors adjacent to or around the specific heating resistor or the temperature of the substrate 6 of the thermal head. Moreover, even if the applied power dispersion accompanying the dispersion of the resistances of the heating resistors and the thermal characteristic dispersion accompanying the dispersion of the glazed layer thickness exists between either the individual heating resistors or the individual thermal heads, the peak temperature to be determined by the aforementioned phase transition temperature and the heating waveforms in the vicinity of the peak temperature are uniformed.

In the case of the thermal head having the combination of the aforementioned material for the metallic/non-metallic phase transition and the thyristor, the peak temperature of the heating resistor is always constant. As a result, under the identical thermal driving conditions, the recording density will be different in case the coloring sensitivity is different due to the difference of the kinds of the heat-sensitive paper. As shown in Fig. 12, the surface temperature of the heating resistors changes with the voltage applied to the heating resistors, as indicated by temperature rising curves (15, 16 and 17). In case the heat-sensitive paper of standard sensitivity is used, for example, the aforementioned applied voltages are so set as to follow the rising curve 16 of the heating resistor surface temperature. In the case of the heat-sensitive paper of low sensitivity, the applied voltage is set by lowering the applied voltage to elongate the temperature maintaining time of the vicinity of the peak temperature, as indicated by the curve 17. In the case of the heat-sensitive paper of high sensitivity, on the contrary, the applied voltage is raised to reach the peak temperature instantly, as indicated by the curve 15. Thermal head can correspond to the difference in the recording sensitivity characteristics of the heat-sensitive paper by solely changing the applied voltage.

Another effective method for coping with the sensitivity difference is also exemplified by a preheat of the heat-sensitive paper or the ink donor sheet immediately before heating of the heating resistor. In the case of low heat-sensitive paper, for example, no change in the voltage applied to the heating resistor can be sufficient if the aforementioned preheating temperature is set at a high level.

The thyristor can be utilized in switching the power applied to the head 60 in the powered thermal recording device shown in Fig. 15. In this case, a circuitous current path is left so that an extremely current reduction cannot be desired, even if a minute portion corresponding to one picture element turns inconductive, because the heat resistive layer 53 is widely planar. It is, therefore, necessary to provide a circuit having a large turn-off current. Further, it can reduce the circuitous current, can ensure the current blocking property of the heat resistive layer 53 and can achieve the fine recording property by which the heat resistive layer 53 is divided into a plurality of islands 53a having a similar size to the recording picture element, as shown in perspective view in Fig. 18.

Fig. 9 is shows one embodiment of the heating drive control circuit, and Fig. 10 is a driving timing chart of the thermal head using the drive control circuit. In Fig. 9, reference numeral 35 designates serial-in parallel-out shift registers having a serial input terminal 31 and a shift clock terminal 32, and numeral 36 designates an AND gate which is fed with the parallel outputs of the shift registers 55 and the heating timing signal coming from an input terminal 33 and which has an output terminal 34. This output terminal 34 of the AND gate 36 is connected with the gate 11 of a thyristor 10, which in turn is connected with the heating resistor, so that it can turn on the thyristor 10 selectively. In Fig. 10, numeral 41 designates video data of one recording line, and numeral 42 designates a shift clock. If the video data 41 are arrayed in the aforementioned shift registers 35, a heating timing signal 43 is inputted in the form of pulses of several microsecs so that the input signal 44 of the gate 11 of the thyristor 10 is outputted in the form of pulses of several microsecs from the aforementioned output terminal 34 in accordance with the content of the video data 41. When the input signal 44 is outputted, the drive control circuit shown in Fig. 9 can be released from the heating operation and shifted to a series of the aforementioned preparations for the next line.

The drive control circuit of the conventional thermal head is enabled to perform the high-speed processing by having a latch circuit so that the recording video data may be written in parallel with the heating operations of the heating resistors. However, in the present invention, the high-speed parallel processing can be accomplished without the latch circuit by combining the heating resistors of the metallic/non-metallic transition and the thyristors. As a result, it is possible not only to reduce the size and drop the cost of the drive control circuit but also to reduce the size of the thermal head packaging the drive control circuit.

In all the embodiments excepting the aforementioned powered recording one, the peak temperature of the heating resistors is unvaried no matter whether the recording medium such as the heat-sensitive papers acting as an endothermic source might contact with the heating resistors or not. As a result, the thermal head of the present invention is freed from the deterioration or breakage of the heating resistors due to an abnormal rise of the peak temperature, which might otherwise be caused in the state of no paper feed of the heating resistors of the thermal head of the prior art. Moreover, a high reliability is exhibited even in the event of malfunction or runaway of the drive control circuit of CPU due to noises.

This effect is commonly applied to the powered thermal recording by enhancing the reliability and safety of the apparatus with neither the abnormal heat generation or firing of the powered heat-sensitive recording paper due to the runabout of the circuit nor the breakage of the parts such as the platen.

Fig. 11 is a top plan view showing an essential portion of the thermal head, in which the heating simulator 23 made of the material of the metallic/non-metallic phase transition is arranged in series with the individual electrode 2 at a position apart from the heating resistor 7 made similar to that of Fig. 4. The aforementioned heating simulator 23 is given a linear resistance lower than that of the heating resistor 7 and higher than the individual electrode 2. If the heating resistor 7 is energized to generate the heat, the heating simulator 23 starts a gentle heat generation. If the temperature of the metallic/non-metallic phase transition of the heating simulator 23 is set at about 120°C, for example, the heating simulator 23 is heated by the Joule heat to about 120°C simultaneously with the temperature rise of the heating resistor 7 so that it is transferred to the non-metallic phase. As a result, the current flowing through the individual electrode 2 connected in series with the heating simulator 23 and the heating resistor 8 can be blocked like the aforementioned individual embodiments to realize the heating control of the heating resistor 7. The heating and cooling behaviors of the heating simulator 23 are substantially similar to those of the aforementioned heating resistor 7 but are highly different in the peak temperature. The heating simulator 23 is not directly influenced by the temperature changes due to the voltage pulse applied to the heating resistor 7 because it is positioned apart from the heating resistor 7. The heating simulator 23 is most seriously influenced by the background temperature resulting from the flow heat storage or rise of the thermal head substrate due to the heat storage around the exothermic simulator itself, the environmental temperature or the heat generation of the heating resistor. As a result, the heat generation by the heating resistor cannot be completely controlled, but a sensitive reaction is exhibited for the fluctuations of the apparent coloring sensitivity due to the temperature fluctuations of the heat-sensitive papers accompanying the fluctuations of the environmental temperature and the inside temperature of the recording apparatus. As to the influences of the heating resistors around or adjacent to a heating resistor being noted, the peripheral heating simulator thermally interfere with one another to effect the heating simulations of the grouped heating resistors, if the heating simulators 23 are aligned with one another like the positional relationship of the heating resistors 7, as shown in Fig. 11. Since, moreover the heating simulator is not heated to a high temperature but has a small thermal impact, it is advantageous in the heat-resisting reliability for the material of the metallic/non-metallic phase transition. If a protecting layer over the heating resistor is likewise formed over the heating simulator, the reliabilities are improved against the oxidation or thermal degradation of the heating simulator and against the impact of the crystalline structural change accompanying the aforementioned phase transfer.

Incidentally, in all the embodiments thus far described, the characteristics of the material used in the heating resistor, the heat resistive layer, the leading end of the power supply electrode, the wiring line and the heating simulator need not have the electric conductivity changed discontinuously at the predetermined temperature but may have the conductivity changed continuously within a temperature range having a predetermined width. In order to ensure the exhibition of the effects of the present invention, the electric conductivity is at least 1 order or desirably 2 orders or more. This necessary change means the practically minimum changing ratios of both the resistance, which is invited by the power consumption (or energy) to enable the heating temperature rise to reach a level necessary for the recording, and the resistance which the power consumption (or energy) becomes lower than the level for maintaining the temperature of at least the heating resistor or the heat resistive layer at the temperature level relating the recording under the condition of a constant applied voltage. In short, in order to extract the actions of the point of the present invention, it is important to make use of the material which has its electric conductivity changed at the aforementioned minimum ratio in dependence upon the temperature.

According to the present invention, as has been described hereinbefore, the following excellent effects can be exhibited:

(1) The peak temperature of the heating resistor can be uniformly controlled for all the temperature environments in which the heating resistor of the thermal head or the heat resistive layer of the powered heat-sensitive recording sheet is placed;

(2) The dispersion of the recording characteristics can be suppressed for the thermal characteristic dispersion such as the glazed layer of the thermal head;

(3) The recording characteristic dispersion can also be suppressed for the dispersion of the sheet resistance of the heat resistive layer;

(4) The highly precise density gradation control is facilitated;

(5) The heating drive control circuit can be simply constructed to reduce the sizes of the circuit, the thermal head and the power supply head substrate;

(6) The recording can be speeded up with ease;

(7) The temperature data collection circuit or the recording density correction circuit such as the temperature detections of the recording apparatus need not be used so that the apparatus can be provided with a small size and at a reasonable cost; and

(8) A high reliability and safety can be obtained against the runaway of the heating resistor.

Claims

1. An apparatus for thermally recording data in recording medium using a heat generated by applying an electric power to heating means, the apparatus comprising:
said heating means made of a material giving a metallic/non-metallic phase transition at a specific temperature and for generating said heat due to said applied electric power;
first electrode disposed in contact with one side of said heating means;
second electrode disposed in contact with other side of said heating means; and
an electric power source for applying said electric power to said heating means via a pair of said first and second electrodes; whereby said heating means reduces an electric current flowed in itself when a temperature of said heating means rises to said specific temperature.

2. An apparatus for thermally recording data in recording medium using a heat generated by applying an electric power to heating means, the apparatus comprising:
said heating means for generating said heat due to said applied electric power;
first electrode disposed in contact with one side of said heating means;
second electrode disposed in contact with other side of said heating means;
an electric power source for applying said electric power to said heating means via a pair of said first and second electrodes; and
monitor means disposed in the path, in which said electric power is applied to said heating means, made of a material giving a metallic/non-metallic phase transition at a specific temperature and for monitoring a temperature of said heating means; whereby said monitor means reduces an electric current flowed in itself when said monitored temperature of said heating means rises to said specific temperature.

3. An apparatus as claimed in claim 1, further comprising switching means disposed in the path, in which said electric power is applied to said heating means, and for cutting off said electric current flowed in said heating means corresponding to said electric current reduced by said heating means.

4. An apparatus as claimed in claim 2, further comprising switching means disposed in said path and for cutting off said electric current flowed in said monitor means corresponding to said electric current reduced by said monitor means.

5. A method for recording continuous tone data in an apparatus having a heating resistor which is made of a material giving a metallic/non-metallic phase transition at a specific temperature, generates a heat due to an applied electric power and maintains a peak temperature of said heating resistor at a same temperature as said specific temperature during said electric power application, comprising the steps of:
determining a period holding said peak temperature due to the tone of said continuous tone data, and
applying a voltage pulse having a pulse width based on said period to said heating resistor.

6. A method for recording continuous tone data in an apparatus having a heating resistor for generating a heat due to an applied electric power and a monitor which is made of a material giving a metallic/non-metallic phase transition at a specific temperature, is disposed in the path applying said electric power to said heating resistor, performs a temperature change similar to that of said heating resistor and maintains a peak temperature of said heating resistor at a same temperature as said specific temperature during said electric power application, comprising the steps of:
determining a period holding said temperature due to the tone of said continuous tone date, and applying a voltage pulse having a pulse width based on said period to said heating resistor.

FIG. 1

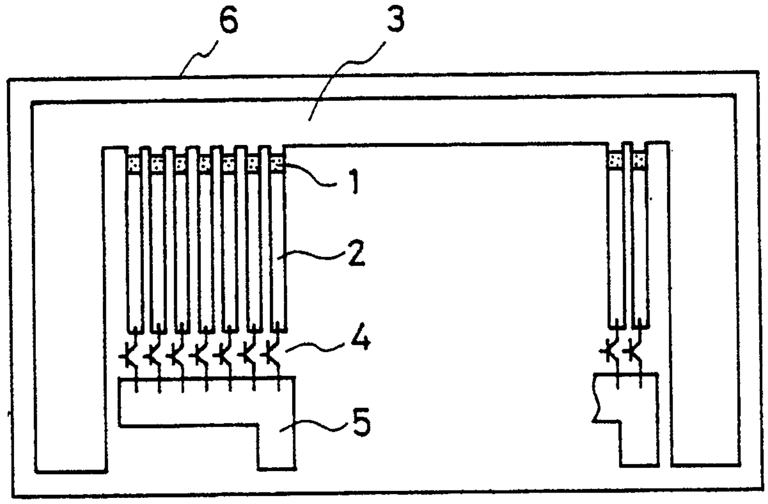


FIG. 2

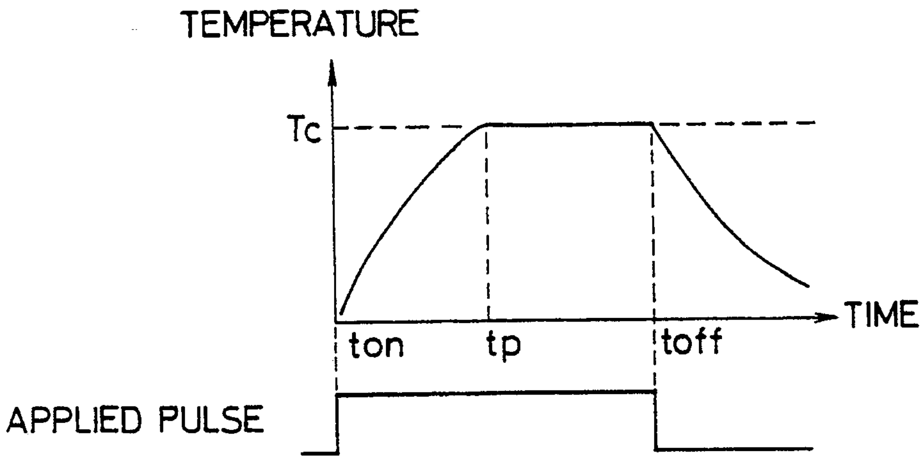


FIG. 3

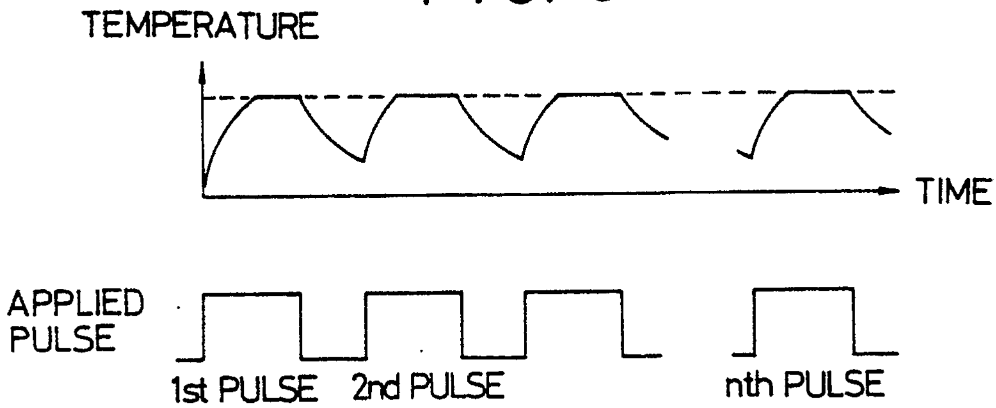


FIG. 4 (A)

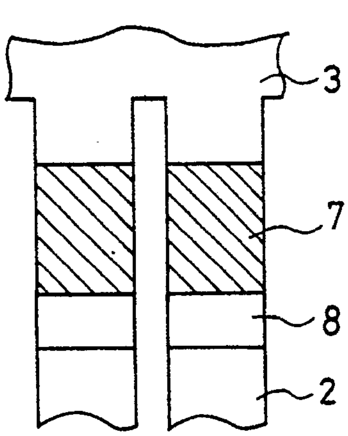


FIG. 4 (B)

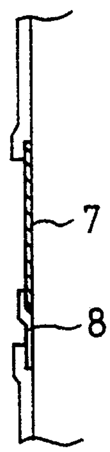


FIG. 5

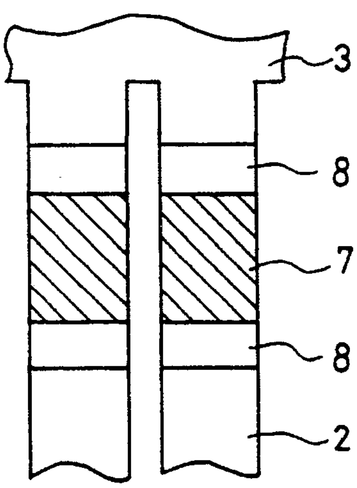


FIG. 6 (A)

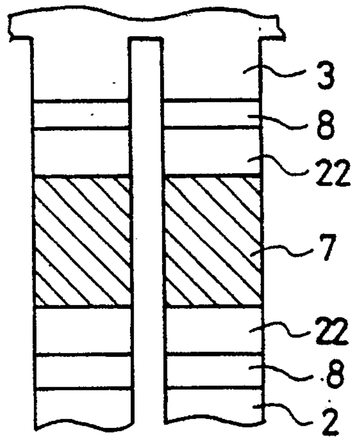


FIG. 6 (B)

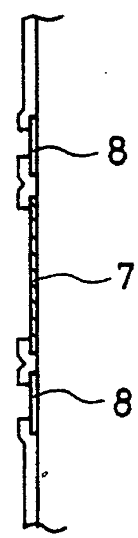


FIG. 7

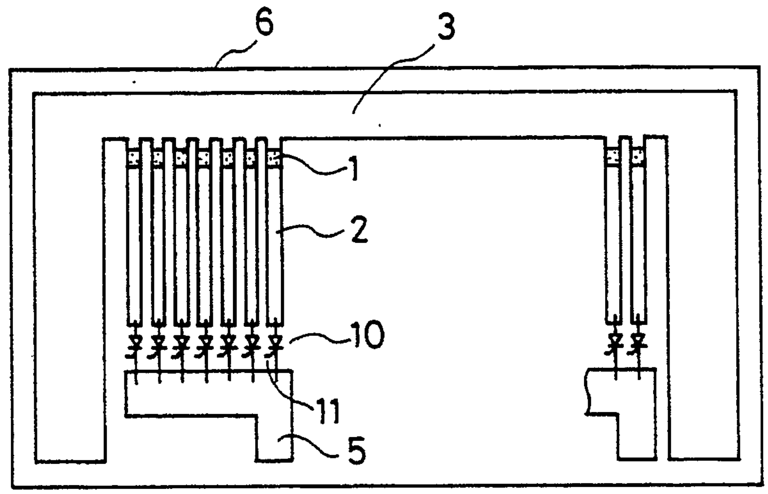


FIG. 8

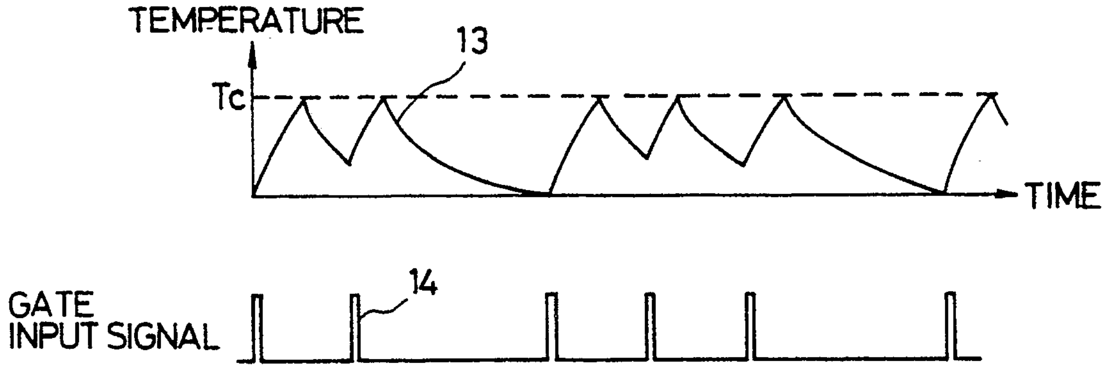


FIG. 9

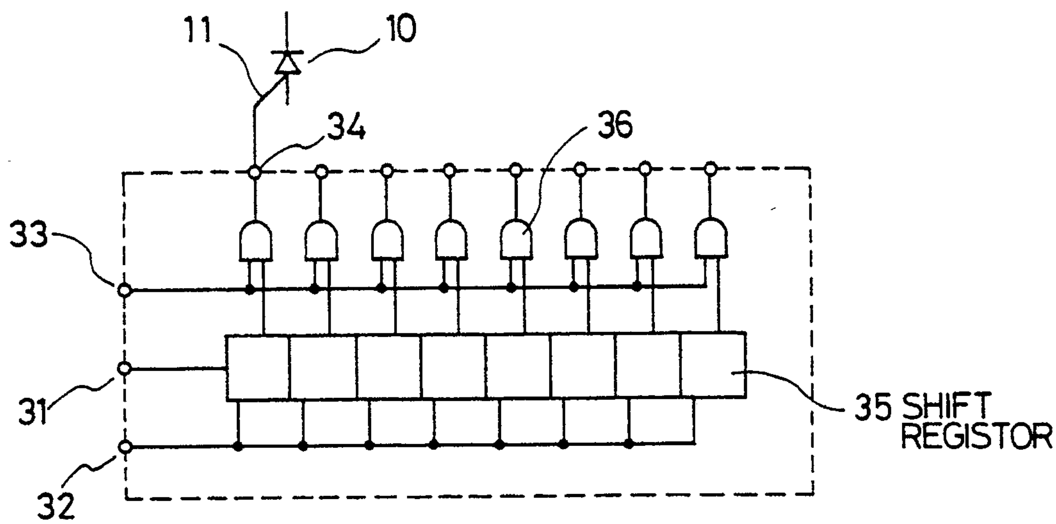


FIG. 10

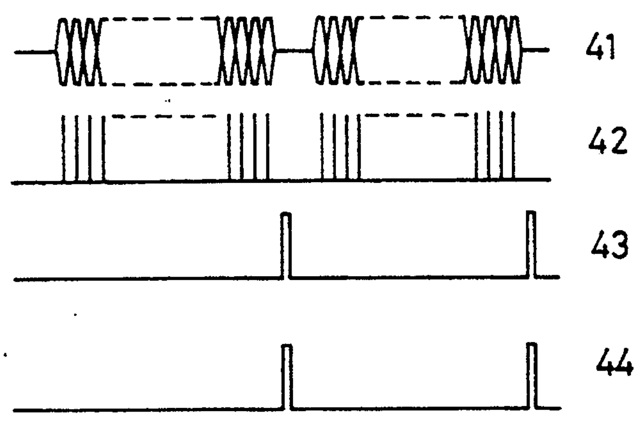


FIG. 11

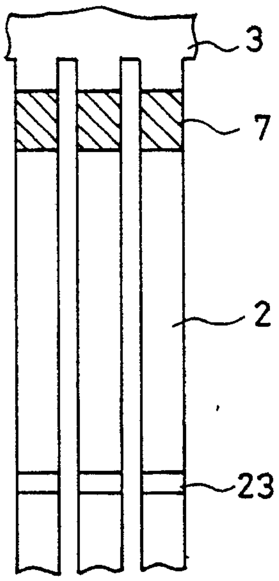


FIG. 13

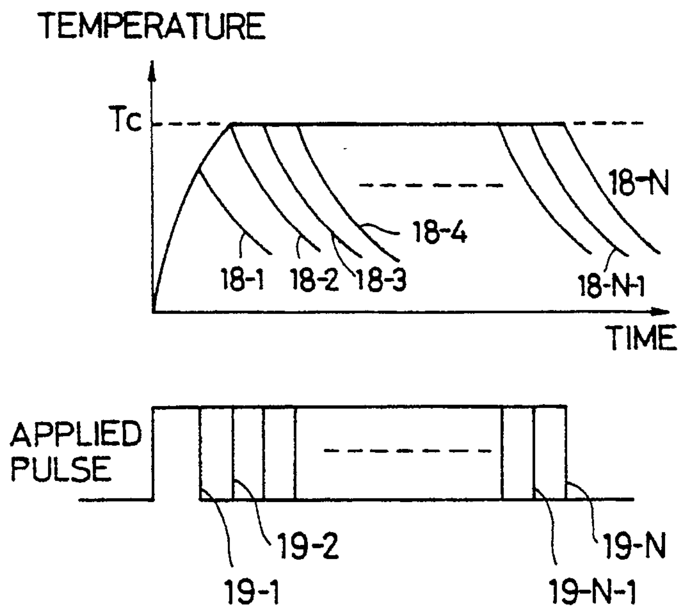


FIG. 12

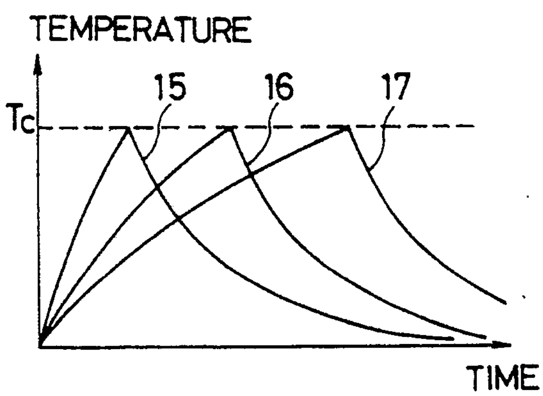


FIG. 14

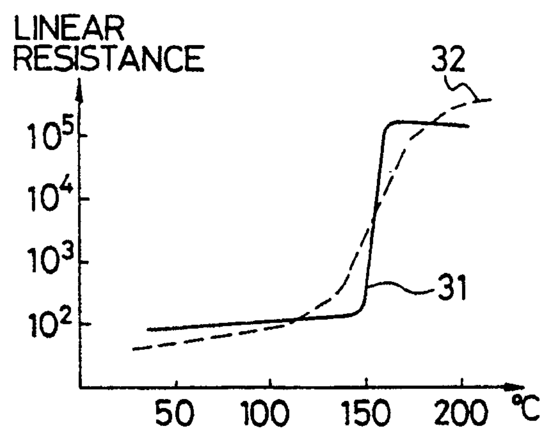


FIG. 15

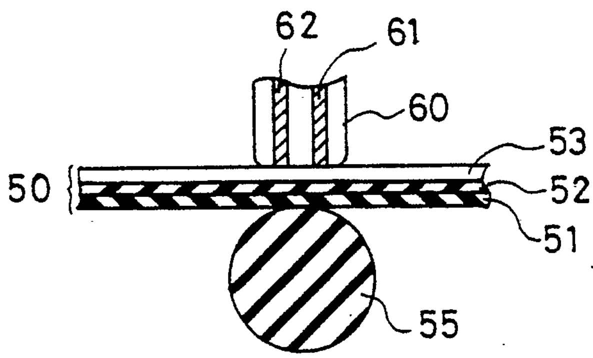


FIG. 17

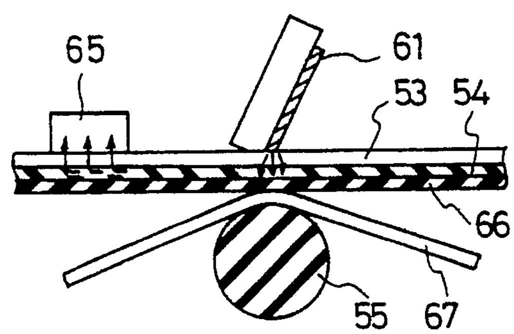
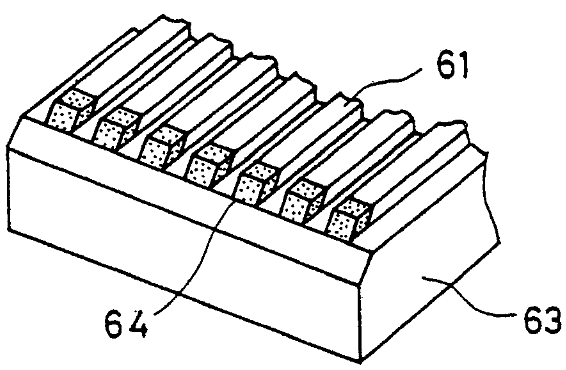


FIG. 16



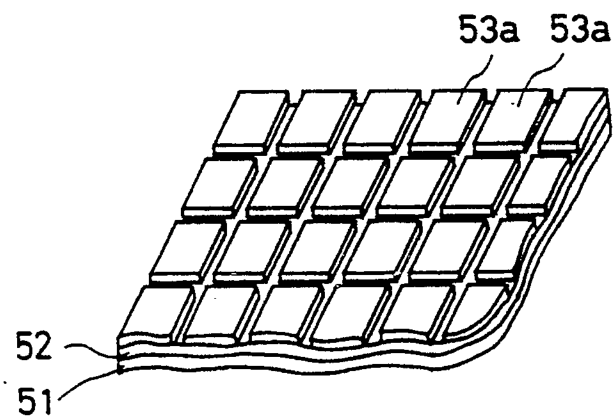


FIG. 18