April 26, 1955 G. FRIES 2,707,162

RECORDING OF ELECTRONIC IMAGES

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FIG. 1a.

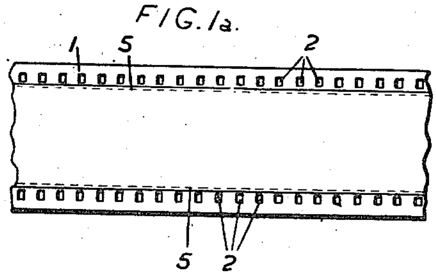


FIG. 1b.

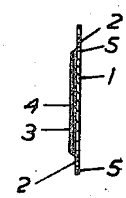


FIG. 3.

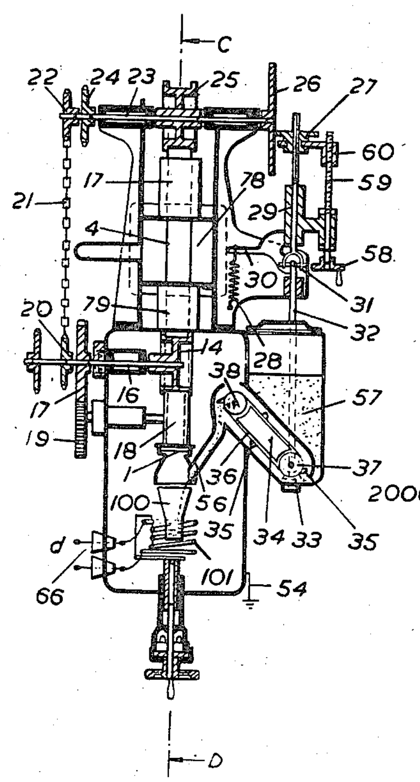
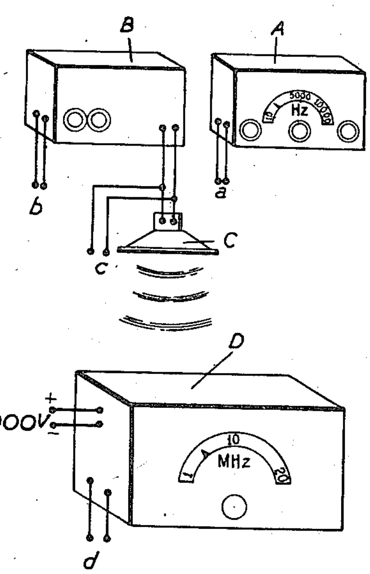


FIG. 4.



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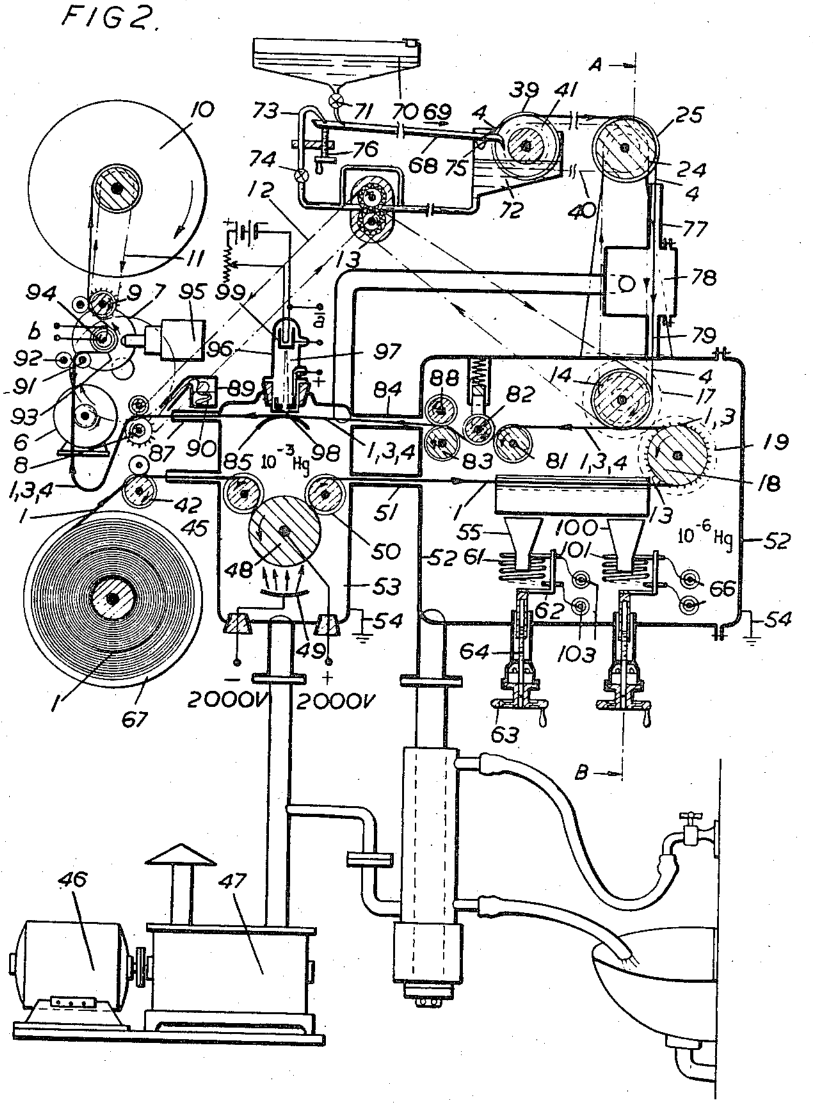
2 Sheets-Sheet 2

FIG 2.



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RECORDING OF ELECTRONIC IMAGES

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Application October 9, 1951, Serial No. 250,472

8 Claims. (Cl. 154—123)

This invention relates to electron-sensitive recording material and has for one of its objects to provide a new kind of normally transparent electron-sensitive recording material, hereinafter referred to as record carrier, mainly in the form of films or plates, which can be used under ordinary atmospheric conditions, and which under the impact of cathode rays or similar electron radiation will become locally coloured or darkened but can be restored to its normal transparent condition by, for example, the application of heat.

It has been known since 1894 that certain ionic crystals, including the alkali-halides change colour upon bombardment with electrons (cathode rays). This phenomenon occurs when these substances are bombarded with electrons in a high vacuum, and is caused by addition of electrons to and redistribution of the electrons of the substance. It is also known that the change of colour of an ionic crystal layer can be uncoloured again by suitable means, e. g., by heating the layer.

The property of such ionic-crystal layers has already been practically used in technical electronics. It has for example been described in "Electronics and Television and Short-Wave World" of February 1940 for application in connection with television tubes, under the title "The Skiatron."

But this and all other known applications have hitherto been hampered by the fact that the image carrier has been located in a highly evacuated chamber.

It is therefore a further object of the present invention to produce a carrier which makes it possible for electron images or other electronic phenomena to be recorded in a persistent form on an ionic-crystal layer of this character when the record carrier equipped with this layer is either inside or outside a high vacuum chamber. Outside the high vacuum chamber it is employed at a point at which, for example, through an electron-permeable window (Lenard window), the electrons can pass out of the vacuum chamber. Other objects are to provide methods and apparatus by which the novel record carrier may be conveniently produced.

In the following description the particular features of the novel image carrier of this invention will first be described and compared with those of a photographic film.

Contrary to the sensitised layer of a photographic film, the image layer of the novel film has no grain. That is to say the power of image resolution is only limited by the wavelength of the corpuscle size of an electron or some other electrically charged particle of nuclear physics which is utilised for image recording, and by the thickness of the active layer. The latter is applied to a suitable transparent carrier such as a film of transparent cellulose material. The ionic crystal layer is preferably applied with a thickness of 10^{-4} mm. or less, so that an image point may still be represented with a size down to 0.1μ and less.

The electron-active image recording layer is vapour-deposited upon the carrier in a high vacuum in known manner, but is then, according to the invention, protected against the influence of the atmosphere (air) by an electron-pervious protective layer (e. g. cellulose, quartz, aluminium oxide, copper). According to the method of production as herein described, after the active layer has been applied in a high vacuum, the protective layer is applied so as to cover and seal it before the carrier is removed from the high vacuum. The thickness of the protective layer should not exceed 0.01 mm.

The active layer is, therefore, after removal from the

vacuum, permanently in the condition as though it were still in the vacuum.

For the production of the active layer or the film any known suitable ionic-crystal material may be used, for example alkali halides, that is to say, salts of an alkali metal or of an alkaline earth metal (e. g. N=sodium, K=potassium, Li=lithium, Ca=calcium, Sr=strontium) and a so-called halogen (Cl=chlorine, Br=bromine, I=iodine, F=fluorine). These materials possess a cubic crystal lattice constituted by negative (halogen) and positive (metal) ions.

The method of producing an electron-sensitive record carrier according to this invention consists in applying the electron-sensitive ionic-crystal material to a film or other carrier within a high vacuum chamber, and applying a protective layer over the electron-sensitive material whilst still in the high vacuum, thereby sealing the electron-sensitive material against contact with the air when the film or carrier is subsequently removed from the vacuum. A feature of the invention consists in vapour-depositing the electron-sensitive material upon the film or other carrier within the vacuum chamber.

A further feature of the invention consists in providing a continuous process for making the film, in which the film carrier is fed continuously into and out of the high vacuum chamber, where the electron-sensitive material is applied and protected, through a pre-vacuum chamber in which the degree of vacuum is lower than in the high vacuum chamber. The pre-vacuum chamber is preferably connected to the high vacuum chamber, and to the atmosphere, through narrow passages through which the film is adapted continuously to pass.

Another feature of the invention consists in the method of testing, and/or controlling, the quality of the manufacturing process. To this end the finished film, whilst still moving through the apparatus and before being wound up on a spool, has a sound or tone recorded thereon by means of a cathode ray tube or the like, which sound or tone is optically reproduced immediately after recording. Thus the reproduced tone, and its quality, give an indication that the manufacturing process is operating correctly, and this before the processed film is wound up on its spool. The reproduced signal may be used for automatically controlling the various stages of the process, for example the uniformity of the active layer, and cessation of the signal could, of course, be used for automatically stopping the apparatus.

According to one embodiment, the method of producing an image film consists in introducing the film which is intended to carry the active image layer and its protective layer through a passage acting as a capillary into a pre-vacuum chamber. There its surface is degasified, which may be effectively assisted by electron bombardment. Then the carrier film travels through a second passage into the high vacuum chamber. In the latter upon one of the surfaces of the film the active image layer is vapour-deposited. The protective layer is then applied in the high vacuum chamber. This protective layer may also be vapour-deposited and may comprise cellulose, quartz, aluminium oxide, copper or some other electron-pervious material.

Preferably the protective layer consists of the same film-forming material as the carrier. This protective layer is produced to the required thickness outside the vacuum, and passes through a passage, a pre-vacuum chamber and a second passage into the high vacuum chamber. Here the protective film is guided in such manner that it meets the carrier upon which the image layer has been applied, and is secured over the active image layer.

The method runs continuously and for this reason the finished film passes from the high vacuum chamber and through a passage to a pre-vacuum chamber, and leaves the latter through a further passage.

The invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figs. 1*a* and 1*b* show respectively a front view and a section through a film according to this invention,

Fig. 2 is a general view of the apparatus for manufacturing the film viewed in the sectional plane C—D of Figure 3,

Fig. 3 is a section in the plane A—B of Figure 2, and

Fig. 4 shows auxiliary equipment for the operation of the apparatus in which, according to the applied signs, A represents a sound frequency generator, B and C represent a sound frequency amplifier and a loudspeaker, and D represents a high frequency heating generator.

The designations *a*, *b*, *c* and *d* in Figure 4 indicate connections which lead to the correspondingly marked connections in Figures 2 and 3. The connection *c* of Figure 3 is the point from which a regulating device, if any, may be controlled.

In Figs. 1*a* and 1*b* a film according to the invention is illustrated. **1** is the carrier of transparent cellulose film material. The perforations **2** are stamped out before the application of the layers **3** and **4**. This is desirable in order to prevent the applied layers from being damaged by subsequent perforation.

The active layer **3** upon which some radiation (e. g. electron radiation) acts for the image recording is protected against the atmosphere (air) by the protective layer **4** in such manner that the protective layer **4** extends at both edges beyond the layer **3**, as shown at **5**, to seal with the carrier **1**.

Referring to the apparatus shown in Figs. 2–4 for manufacturing the film, on the supply spool **67** (Fig. 2) there is wound the perforated carrier film **1**. Motor **6** drives the two toothed film feed rollers **8** and **9** through gear wheel **7**; from the toothed roller **9** the film take-up spool **10** is driven by a belt **11**. Furthermore, the driving connection, e. g. by means of chain **12**, for the gear pump **13**, is derived from toothed roller **8** and is passed on from **13** to the roller **14** by which the protective film **4** is applied to film **1**. The gear wheel **17** mounted on the shaft **16** (Fig. 3) of roller **14** further drives a toothed drum **18** through gear wheel **19**. Similarly, shaft **23** is driven from a sprocket wheel **20** on shaft **16** through chain **21**, and sprocket wheel **22**. Fixed on the shaft **23** are the sprocket wheel **24**, the drum **25** and the friction disc **26** (Fig. 3). Friction disc **26** transmits its movement to friction wheel **27**. This friction wheel **27** is urged against the friction disc **26** by the spring **28** acting on the pivoted lever **30** which carries the bearing **29** for the wheel **27**. The fulcrum point of the lever **30** is disposed at the height of the universal joint **31** which transmits the rotation of the friction wheel **27** through a shaft **32** and bevel gear drive **33** to the conveyor mechanism **34**. The scoops **35** of the latter revolved with their conveyor band **36** over the rollers **37** and **38**. Finally there is the drive of the pick-up drum **39** (Fig. 2) from the sprocket wheel **24** by means of chain **40** to sprocket wheel **41**.

Now when the motor **6** is started all the previously described rotatory elements of the apparatus start moving in the directions of movement indicated by the arrows thereon. That is to say, when the film **1** has been threaded from the supply spool **67** up to the take-up spool **10** through the device of Figure 2, it will be withdrawn from the spool **67** by the toothed drum **18**. In its movement, the film **1** runs over the guide roller **42**, through the first passage **43**, and over the guide roller **44** into the pre-vacuum chamber **45**. From this chamber **45** the air has been evacuated by the pre-vacuum pump **47** driven by motor **46** down to a pressure of approximately 10^{-3} mm. of mercury.

After being deflected over roller **44**, film **1** is fed over the roller **48** which is high-voltage insulated against the housing **53**. Applied to this roller is the positive pole of a D. C. voltage of approximately 2,000 volts. The negative pole is connected to the electrode **49** facing the roller **48**. Due to the chosen vacuum in the chamber **45**, a glow-discharge forms between the electrode **49** and the roller **48** in the direction towards the roller **48**. Thereby the film **1**, which is fed over the roller **48**, is bombarded with electrons on its surface facing the electrode **49**, and in this manner is freed from last traces of gas and impurities. During its further travel, the film **1** passes over the guide roller **50** and through the passage **51** into the high vaccum chamber **52**, in which a vacuum of 10^{-6} mm. Hg is maintained. Any electric charge still adhering to the surface of the film **1** is removed during its passage over the roller **50** since the latter is conductively connected with the metal housing **53** of the chamber **45**,

the later in its turn being "earthed," like all other metal housing parts of the apparatus, at **54**.

Before the film reaches the toothed drum **18**, the active image layer **3** is vapour-deposited thereon from evaporation vessel **55** (this vessel **55** being preferably made of tantalum or molybdenum). The material to be vapour-deposited (ionic crystals) is fed into the vessel **55** in powder form by means of the dredger mechanism **34** via the chute **56**. The conveyor mechanism **34** itself scoops the material from the supply reservoir **57**, Fig. 3.

By means of the hand wheel **58**, screw spindle **59** and spindle nut **60** the rate of supply of the conveyor mechanism **34** can be accurately regulated by displacing the friction wheel **27** upon the friction disc **26**, thus accurately measuring the quantity of the material fed to the vessel **55** from the reservoir **57**. This measuring may also be made automatically adjustable.

The evaporation of the material from vessel **55** is effected by heating the latter by eddy currents produced in the metal by a winding **61**, arranged around the bottom of vessel **55**, which is energized from a high frequency generator *d*, Figure 4, with an alternating electric current, preferably having a frequency between 1 and 20 megacycles per second.

The winding **61** is mounted on a holder **62** which is adapted to be moved up and down by means of hand wheel **63**, screw spindle **64** and spindle nut **65**. In this manner the vessel **55** is immersed to a greater or less depth into the high frequency alternating field of the winding **61**, and in this manner the temperature of the vessel **55** can be controlled and thereby the rate of evaporation of the material placed therein. This process may also be automatically controlled in a manner to be described hereinafter in order to enable the manufacture of the image film to take place automatically.

There is further provided a second evaporation vessel **100** of the same construction as described with respect to vessel **55**. This second vessel is intended for use when the protective layer is to be vapour deposited, instead of the protective layer being applied in the form of a film as is described below. As in the case of vessel **55**, a material supply reservoir such as **57** and a conveyor mechanism **34** with chute **56** are associated with the evaporation vessel **100**.

The heating current is supplied to the windings **61** for vessel **55** and **101** for vessel **100** by means of the conductors **103** and **66** which are led through the wall of the chamber **52** in an insulated and vacuum-proof manner from the high frequency generator D (Fig. 4).

From toothed roller **18** the film **1** now provided with the active layer **3** is then drawn further by means of the toothed drum **8**. During this movement, the protective layer **4** is applied over the layer **3** while the film passes under the roller **14**. This protective film is produced from zapon varnish (a cellulose varnish well known in Europe and defined in the 1948 edition of "Schweizer Lexikon," a Swiss encyclopedia in the German language published in Zurich by Encyclios Verlag, as a water-clear solution of nitro-cellulose or acetyl cellulose in various solvents (butyl acetate, amyl acetate and amyl alcohol) and additions, for the production of protective colorless glossy coatings on wood, paper, metal, etc. Particularly suitable is Z116 of the Agfa Film Factory) which is fed from the reservoir **70** through the conduit provided with regulating cock **71** on to a layer of water which runs on the channel **68** in the direction of the arrow **69**. The flow of water is maintained by the gear pump **13**, the latter supplying the water from the collecting reservoir **72** in a continuous circulation through the conduit **73** with regulating cock **74**. The rate of flow of the water is adapted to be regulated by the channel **68** being rotatably mounted at **75** and adapted to be moved to a more or less steeply inclined position by means of a screwed spindle **76**. The channel **68** is of sufficient length to allow the zapon varnish flowing upon the water surface to spread thereon and become partly dried before reaching the end of the channel. During this procedure the zapon varnish layer which flows on the water may be prevented from sticking to the sides of the channel **68** by means of a small supersonic generator (not shown). The zapon varnish film **4** which is partly dried is picked up at the end of the channel **68** by the pick-up drum **39** and continues drying on its way to the guide roller **25**. After passing over this roller it moves through the passage **77** into the pre-vacuum chamber **78** and through the passage **79** to the roller **14** beneath which it is placed on top of the layer **3** on the carrier **1** coming from the toothed roller **18**.

The film **1** with the layer **3** and the protective layer **4** is then drawn by the toothed drum **8** over the rollers **81**, **82** and **83** through the passage **84** into the pre-vacuum chamber **45** and over the slightly curved track **85**. Over this track **85** the film runs in close contact since the roller **82**, biased by the spring **86**, keeps the film taut between the toothed drums **8** and **18**. The track **85** may also be replaced by a roller with a flywheel.

In order to prevent air from reaching the layer **3** at the edges **5** of the coating layer when the film enters the atmosphere through the passage **87**, there is provided in the high vacuum chamber an electrically heated roller **88** above the roller **83**, which has the purpose to weld together the edges of the coating layer **4** and the film **1**. In principle this may also be effected by high frequency heating by causing the two side edges of the film to pass through an electrostatic high frequency field within the high vacuum chamber **52** after passing the roller **14**.

For safety's sake, after the film leaves the passage **87**, the two edges of the protective layer are lightly painted with acetone or some other film solvent which is supplied from the reservoir **89** through two wicks **90** to the film edges.

After leaving the toothed roller **8** the further feed movement of the complete film is effected by the toothed roller **9**. The film during this movement is conducted over the guide roller **91**, with which the pressure roller **92** is associated, and the constant speed drum **93** in which is placed the photocell **94** which is adapted to be illuminated by the light source **95**.

After leaving the toothed drum the completed film is wound on the spool **10** driven by belt **11**.

The testing of the complete film is effected by arranging above the track **85**, a cathode ray tube **96** of which the cathode ray beam **97**, which leaves the tube through a Lenard window **98**, is used to produce a sound record upon the film as it passes the Lenard window. The cathode ray beam **97** is modulated with a sound frequency from the generator A, Fig. 4, which is impressed upon the cathode ray gun to modulate its beam energy.

The recorded sound is subsequently reproduced where the film moves around the drum **93** between the light source **95** and the photocell **94**, the output from the photocell **94** being fed to the amplifier B, Fig. 4, which reproduces the sound by means of the loudspeaker C. In addition or alternatively, the amplifier output may be used for automatically controlling the film making process.

This method of checking and controlling a film-manufacturing process by sound is novel per se and is to be separately protected. At present it is only applicable to films according to the invention.

The process and film-making apparatus according to the invention can also be used for producing short lengths or elements of film. Each element may correspond, for example, to the size of a single picture to be recorded. This may be achieved by also transversely welding the protective layer to the carrier film in narrow bands between the individual elements. The complete film may then be severed transversely along lines lying within these transverse bands so that, in the individual elements, the protective layer will be sealed to the carrier film all around its edges. The transverse welding may be effected by a roller having spaced ribs, corresponding to the spacing of successive bands to be welded, the ribs serving as welding electrodes similar to the roller **88**. The welding may be effected by heating the ribs or by employing the ribs as high frequency electrodes.

By means of the process according to the invention the active layer of ionic crystals on the film is, until coloured by electron bombardment, completely transparent. This transparency is restored on erasing the electron-image. If exposed to the atmosphere the active layer becomes semi-transparent or whitish-opaque. This normal transparency of the active layer of the film according to this invention is an important characteristic since all active layers, as hitherto produced, have been semi-transparent or of whitish opacity when enclosed within the vacuum chamber, and before being electron bombarded. This characteristic transparency of the active layer produced by this invention appears to be due to the fact that the active layer is vapour-deposited in a vacuum and is at all times thereafter protected against coming into contact with air.

Recent researches have shown that it is possible to produce a glass film which is sensitive to irradiation. It seems at present that this glass film is not sensitive to electron bombardment, but is sensitive to ultra-violet light and X-rays. Relatively long exposure times are necessary. The recorded image requires development, for example by heating before it becomes visible. The image is then permanent. Such a sensitive glass film does not have to be in a vacuum and is therefore particularly suitable for the printing of permanent copies from the images recorded on electron-sensitive film. Since the glass film is non-granular, it has a high power of image resolution and produces a grainless image.

The glass film may be rendered less breakable by coating one or both surfaces thereof with a thin film of cellulose acetate or other suitable resilient film-forming material.

Such a glass film may also be used as a protective layer for the active layer of an electron-sensitive film as above described. In this case the image may be instantaneously recorded as a negative on the active layer. By illuminating the glass layer with ultra-violet light passing through the negative image; a positive image may be recorded on the glass layer. Upon the application of heat to develop the positive image in the glass the electron image is simultaneously erased and a film with a positive image thereon results.

The glass layer may be vapour-deposited over the active layer. Vapour-deposition of the glass may also be employed when the glass merely forms a layer on a film carrier and not as a protective layer for an ionic crystal layer.

A further feature of the invention consists in a method of recording sound by means of the novel film above described. Since the active layer is grainless and the sound recording is effected by electron beam, the tone quality and power attainable with this method of recording is at least equal to, e. g. that of the high-frequency magnetic sound recording process, and most possibly far superior to it.

This is due to the fact that it is possible to form an electronic image gap for sound recording which is much more sharply defined and narrower than can be obtained with a light gap or a magnetic gap.

The method of this invention also enables the dynamics of sound recording to exceed the limits possible with magnetic sound recording, which method has hitherto been considered the best method of sound recording. This is because:

1. A cathode ray is inertialess and can be recorded with great intensity.
2. The carrier layer of the new film is grainless whereby background noise is reduced. Background noise can be further reduced by utilising ultra-violet light for sound reproduction, thereby also enabling the reproducing gap to be made narrower.

At the same time the novel method of sound recording still possesses the other advantages of the magnetic recording, that is to say the sound record may be reproduced acoustically immediately after recording and can also be erased so that the film can be used repeatedly.

The same is also true for picture recording. The novel film material is also suitable for use in the art of reproduction printing, and more particularly for the manufacture of electron optically-selected colour extracts for the purpose of producing printing plates for multicolour printing. This may be effected by projecting the colour picture on to the photo-cathode of an image converted tube through colour filters, the resulting electron images being recorded on the film and selectively used for producing the printing plates for the different colours.

Further the film can be used for the electronic recording of electrically controlled matric images in phototype setting machines, and also for other purposes in which an electron optical image can be produced by a radiation transformer, this image being then utilised for influencing the film electronically and being fixed there. Examples of this are: the electron super microscope, the field electron microscope, image transformers for infra-red rays and X-rays.

Finally, it is also possible to use the film as an intermediate member for large screen television projection, it being considered herein that colour images and stereoscopic (three dimensional) images may also be reproduced with the novel film. For this purpose the film may be bombarded with cathode rays modulated in accordance with the television picture, the corresponding picture recorded simultaneously on the film being subsequently projected by a light source on to a large screen. The film may, if desired, run in a continuous loop, the recorded picture being erased, by submitting the film to heat or an electrostatic field, before it is again fed past the cathode ray device where another picture is recorded for projection.

I claim:

1. Method of producing a transparent electron-sensitive record carrier, which comprises forming on a sheet of transparent material a transparent ionic-crystal layer by vapour-depositing ionic-crystal material of the type which changes color under electron bombardment on said sheet in a high vacuum, applying over said ionic-crystal layer while still in the high vacuum and still transparent, an air-impervious but electron-pervious protective layer of transparent material, and sealing said layer to said sheet so as to form jointly with said sheet an air-tight enclosure preventing the access of air to said ionic-crystal layer when the record carrier is subsequently removed from the vacuum.

2. Method of producing a transparent electron-sensitive record carrier incorporating a layer of ionic crystals of the type which change color under electron bombardment which consists in applying a layer of said crystals to a sheet of transparent material within a high vacuum, and applying a protective layer of transparent material over said layer of crystals whilst still in the high vacuum in such manner as to hermetically seal said crystals against contact with the air when said record carrier is subsequently removed from the vacuum.

3. Method as claimed in claim 2, in which the protective layer is vapour-deposited over the ionic crystal layer.

4. Method of producing a transparent electron-sensitive film material, which comprises feeding a strip of film of transparent material into and out of a high vacuum zone, vapour depositing on to said film while the said film moves through said zone a layer of ionic crystal material of the type which changes color under electron bombardment, applying over said ionic crystal layer while it is still in said high vacuum zone an air-impervious but cathode-ray pervious protective layer of transparent material so as to enclose said ionic-crystal layer in an airtight manner between said film and said protective layer, recording a modulated signal on the ionic-crystal layer of the composite film by feeding the composite film continuously past a modulated electron beam, reproducing the recorded signals, and controlling the rate at which the ionic crystal material is being vapour deposited on to the film in accordance with the amplitude of the reproduced signals, so as to maintain the amplitude of said reproduced signals substantially constant.

5. Method of producing a transparent electron-sensitive film material, which comprises feeding a first strip of film of transparent material continuously through a high vacuum chamber, vapour-depositing on to one surface of said first film while the film is being fed through said chamber a layer of ionic crystal material of the type which changes color under electron bombardment, feeding a second strip of film of transparent material toward the said first film whilst the latter is still in the chamber and applying said second film over those parts of the said surface of the first film on which the ionic crystal layer has been deposited, and while the said films are still in the vacuum chamber sealing the two films together in an air-tight manner along zones extending substantially parallel to the edges of the films so as to produce a laminated film with the ionic-crystal layer sealed between the two films, and feeding the composite film out of the high vacuum chamber and into the atmosphere.

6. A transparent electron-sensitive record carrier comprising a sheet of transparent material which is impervious to air, a microscopically thin grainless layer of ionic-crystal material of the type which changes color under electron bombardment applied to one surface of said sheet, and a transparent protective layer covering said layer of ionic-crystal material and air excludingly sealed to said sheet around the ionic-crystal material, at least one of said protective layer and sheet being pervious to cathode rays.

7. A transparent electron-sensitive record carrier comprising a transparent grainless layer of ionic-crystal material of the type which changes color under electron bombardment, said layer being sealed against access of air between two transparent films of electrically insulating material at least one of said films being pervious to cathode rays.

8. A transparent electron-sensitive record carrier in the form of a laminated film comprising a transparent grainless layer of ionic-crystal material of the type which changes color under electron bombardment hermetically sealed in an air free state between two layers of air-impervious transparent material, at least one of said two last mentioned layers being pervious to cathode rays.

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