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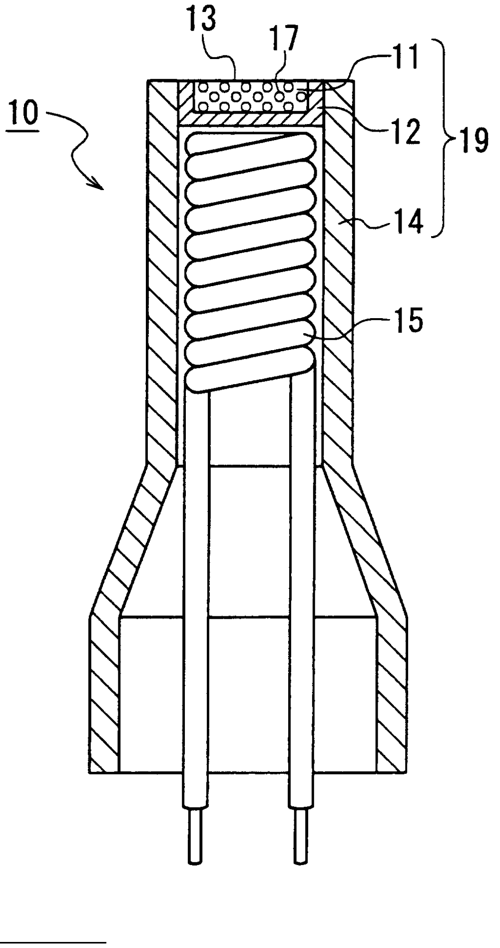
## (54) Cathode subassembly and color crt equipped therewith

(57) A cathode subassembly for color CRTs is provided, which exhibits scarcely the degradation of electron emission capability for at least ordinary lifetime of color CRTs even at a high current density greater than 1 A/cm$^2$ while it has an equivalent activation time and an equivalent operating temperature to those of former oxide cathodes. The cathode subassembly is comprises (a) a porous cathode pellet (11) formed by a sintered body containing Ni, scandium oxide ($Sc_2O_3$), and an electron-emissive material; the body being made by sintering a mixture of a Ni powder, a scandium oxide ($Sc_2O_3$) powder, and an electron-emissive material powder using a HIP process; the pellet having an electron emission surface; and (b) a pellet support (12) for supporting the pellet; the support having a part in contact with the pellet; the part being made of an alloy containing Ni as its main ingredient and at least one metal selected from the group consisting of chromium (Cr), tantalum (Ta), molybdenum (Mo), zirconium (Zr), tungsten (W), and cobalt (Co); the at least one metal selected from the group consisting of Cr, Ta, Mo, Zr, W, and Co serving as a reducing agent for the electron-emissive material. Preferably, the electron-emissive material is a carbonate generated by co-precipitation of Ba, Sr, and Ca.

FIG. 2



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## Description

## BACKGROUND OF THE INVENTION

### 1. Field of the Invention

**[0001]** The present invention relates to a cathode subassembly and a color Cathode-Ray Tube (CRT) and more particularly, to a cathode subassembly having a long lifetime even at large operating currents, and a color CRT equipped with the subassembly.

### 2. Description of the Related Art

**[0002]** Nowadays, almost all color CRTs comprise so-called "oxide cathodes". As known well, oxide cathodes include a cathode base made of a specific metallic material and a porous oxide film that covers the surface of the base. The metallic material of the base contains nickel (Ni) as its main ingredient and a trace of reducing agent such as silicon (Si) and magnesium (Mg). The porous oxide film is made of oxide of alkaline-earth metal including barium (Ba) and has a thickness of approximately 50 μm to 100 μm.

**[0003]** Oxide cathodes can be easily activated, operated at a comparatively low temperature of approximately 800 °C, and produced at low cost. Thus, they have been used widely and practically.

**[0004]** The following is a description about a prior-art oxide cathode including a cathode subassembly, which is designed for color CRTs.

**[0005]** Fig. 1 shows a prior-art oxide cathode including a cathode subassembly. As shown in Fig. 1, a prior-art oxide cathode 70 comprises a cathode base 71 made of a metallic material containing Ni as its main ingredient (i.e., Ni-based material) and a trace of reducing agent such as Si and Mg. The base 71 is in the form of a cap. The top surface of the base 71, which serves as an electron emission surface, is covered with a porous oxide film 72 made of oxide of alkaline-earth metal including Ba. The film 72 has a thickness of approximately 50 μm to 100 μm.

**[0006]** A cathode sleeve 73 is inserted into the inside of the base 71 on the opposite side to the oxide film 72. The sleeve 73 is fixed to the base 71 by welding. A heater 74 is incorporated into the sleeve 73 to heat the cathode 70 itself. The base 71, the film 72, and the sleeve 73 constitute a cathode subassembly 79 and therefore, it is said that the cathode 70 is comprised of the subassembly 79 and the heater 74. The reference numeral 75 denotes the interface between the base 71 and the film 72.

**[0007]** The prior-art cathode subassembly 79 has a disadvantage that the normal lifetime of several tens of thousands hours decreases to several thousands hours or shorter at a high operating current density of approximately 1 A/cm$^2$ or greater. In other words, the electron emission capability (i.e., emissivity) of the subassembly 79 tends to degrade drastically after the subassembly 79 operates for several thousands hours at a high operating current density of approximately 1 A/cm$^2$ or greater. This is almost only one disadvantage of the prior-art oxide subassembly 79. It is supposed that the emissivity degradation of the subassembly 79 is induced by the following cause.

**[0008]** When the cathode base 71 is heated up to approximately 800 °C by the heater 74, Si and Mg contained in the base 71 (which serve as the reducing agent) thermally diffuse within the base 71 and then, react with barium oxide (BaO) contained in the porous film 72 at the interface 75. Thus, the following chemical reactions (1) and (2) occur.

$$BaO + (1/2)Si \rightarrow Ba + (1/2)SiO \qquad (1)$$

$$BaO + Mg \rightarrow Ba + MgO \qquad (2)$$

**[0009]** As a result of the reactions (1) and (2), Ba atoms having a low work function are generated and therefore, electrons are emitted from the Ba atoms. In this case, however, SiO and MgO, which are generated as by-products of the reactions (1) and (2), are deposited at the interface 75 in the form of layer. Thus, an intermediate layer (not shown) made of SiO and MgO is formed at the interface 75.

**[0010]** The intermediate layer is obstructive to the flow of the electrons through the subassembly 79 due to its high electrical resistance. Also, the intermediate layer is obstructive to the contact of Si and Mg in the base 71 with the film 72 and as a result, the reactions (1) and (2) are restrained from continuing. Because of these two reasons, the electron emissivity of the prior-art subassembly 79 degrades as the operation time becomes longer.

**[0011]** The above-described mechanism for the emissivity degradation does not have a direct relationship with the operating current density. However, if the operating current density is greater than 1 A/cm$^2$, the emissivity degradation is accelerated due to the following reason.

**[0012]** When the operation current density of the cathode subassembly 79 is high, the intermediate layer is formed rapidly just after the start of the operation. Thus, the subassembly 79 is caused to operate at a high current density in spite of existence of the resistive intermediate layer, producing Joule heat at the intermediate layer. Due to the Joule heat thus produced, the interface 75 has a temperature higher than the operating temperature by several tens degrees, which is kept during operation. As a result, the reactions (1) and (2) progress excessively and the intermediate layer grows excessively thicker. The series of these phenomena are accelerated because of their positive feedback behavior. This is the mechanism for the above-described electron-emissivity degradation in the prior-art cathode subassembly 79.

**[0013]** In the old days where the size of color CRTs was small and the operating current density was low, the lifetime of oxide cathodes did not induce any problem. On the contrary, nowadays, color CRTs have become larger in size and have been used at high operating currents such as 1 A/cm$^2$ or higher. Thus, the above-described disadvantage of short lifetime has become conspicuous. To solve the disadvantage, various improvements have been performed to make the lifetime of oxide cathodes longer at such the high operating currents as above.

**[0014]** For example, the Japanese Non-Examined Patent Publication No. 64-5417 published in January 1989, discloses an improved oxide cathode including a porous film made by mixing oxide of rare-earth metal such as scandium oxide ($Sc_2O_3$) into oxide of alkaline-earth metal including Ba. This improved cathode has a longer lifetime at the above-described high operating current density than the former oxide cathodes. However, it has not been sufficient for practical use.

**[0015]** Another improved oxide cathode is disclosed in the Japanese Non-Examined Patent Publication No. 9-106750 published in April 1997. This improved oxide cathode comprises a cathode base, a porous film made by mixing oxide of rare-earth metal such as $Sc_2O_3$ into oxide of alkaline-earth metal including Ba, and a layer of metal such as tungsten (W) located between the base and the film. This improved cathode has a longer lifetime at the above-described high operating current density than the former oxide cathodes. However, it has not been sufficient for practical use, too.

**[0016]** The improved oxide cathodes disclosed in the Publication Nos. 64-5417 and 9-106750 have an advantage that the operating temperature at the above-described high operating current density is approximately equal to the former cathodes.

**[0017]** On the other hand, there have been trials to incorporate impregnated cathodes into color CRTS. As known well, impregnated cathodes have been usually used for microwave tubes and have been confirmed to operate for a long time at the above-described high operating current density. Since the electron emissivity of impregnated cathodes scarcely degrades even at a high current density, there arises no problem relating to lifetime. In this case, however, impregnated cathodes have a serious disadvantage that the activation time is long, the operating temperature is high, and the fabrication cost is high, all of which are not seen in oxide cathodes. The long activation time requires making the aging line in the CRT fabrication system longer. The high operating temperature requires some improvement of the heater, change of the material for the cathode subassembly, and some enhancement of heat resistance of the electron gun. These requirements or problems are quite difficult to be solved practically.

**[0018]** As explained above in detail, to meet the requirements of high operating current density, oxide cathodes have been improved on one hand, and impregnated cathodes have been applied to color CRTs on the other hand. However, the above-described improved oxide cathodes still have a problem that the lifetime at high operating current density is not sufficient for practical use. Impregnated cathodes have a problem of long activation time, high operating temperature, and high fabrication cost. Thus, neither of the improved oxide cathodes and impregnated cathodes is able to replace the prior-art oxide cathode 70 shown in Fig. 1.

## SUMMARY OF THE INVENTION

**[0019]** Accordingly, an object of the present invention is to provide a cathode subassembly that exhibits scarcely the degradation of electron emissivity during the ordinary lifetime of color CRTs even at a high operating current density greater than 1 A/cm$^2$ while it has an equivalent activation time and an equivalent operating temperature to those of conventional oxide cathodes, and a color CRT equipped with the subassembly.

**[0020]** Another object of the present invention is to provide a cathode subassembly in which excellent electron emissivity can be implemented through simplified fabrication processes, and a color CRT equipped with the subassembly.

**[0021]** The above objects together with others not specifically mentioned will become clear to those skilled in the art from the following description.

**[0022]** According to a first aspect of the present invention, a cathode subassembly is provided, which comprises:

(a) a porous cathode pellet formed by a sintered body containing Ni, scandium oxide ($Sc_2O_3$), and an electron-emissive material;

the body being made by sintering a mixture of a Ni powder, a scandium oxide ($Sc_2O_3$) powder, and an electron-emissive material powder using a HIP process;
the pellet having an electron emission surface; and

(b) a pellet support for supporting the pellet;

the support having a part in contact with the pellet;
the part being made of an alloy containing Ni as its main ingredient and at least one metal selected from the group consisting of chromium (Cr), tantalum (Ta), molybdenum (Mo), zirconium (Zr), tungsten (W), and cobalt (Co);
the at least one metal selected from the group consisting of Cr, Ta, Mo, Zr, W, and Co serving as a reducing agent for the electron-emissive material.

**[0023]** The inventors have researched diligently for a long time what mechanism induces the degradation of electron emissivity of oxide cathodes at high operating current density. As a result of this, they have succeeded to develop an improved oxide cathode subassembly having a novel structure that exhibits scarcely the degradation of electron emissivity for the ordinary lifetime of color CRTs even at a high operating current density greater than 1 A/cm$^2$.

**[0024]** Specifically, as described above in summary, the cathode subassembly according to the invention comprises a porous cathode pellet formed by a sintered body containing Ni, $Sc_2O_3$, and an electron-emissive material, and a pellet support for supporting the pellet. The body is made by sintering a mixture of a Ni powder, a $Sc_2O_3$ powder, and an electron-emissive material powder using a HIP process. The support has a part in contact with the pellet. The part is made of an alloy containing Ni as its main ingredient and at least one metal selected from the group consisting of Cr, Ta, Mo, Zr, W, and Co. The at least one metal selected from the group consisting of Cr, Ta, Mo, Zr, W, and Co serves as a reducing agent for the electron-emissive material.

**[0025]** The porous cathode pellet, which serves as the cathode base, is formed by the sintered body containing Ni, $Sc_2O_3$, and the electron-emissive material. Thus, the pellet has a grid-shaped structure or organization similar to that of Ni, in other words, it has a lot of open pores. The pores of the pellets are filled with the electron-emissive material and $Sc_2O_3$. Accordingly, the total area of the interface between the pellet (i.e., the cathode base) and the electron emissive-material drastically increases and at the same time, the thickness of the intermediate layer formed at the interface per unit area drastically decreases.

**[0026]** Because of the thickness decrease of the intermediate layer, the formation process of the intermediate layer is not accelerated even at a high operating current density greater than approximately 1 A/cm$^2$. Also, $Sc_2O_3$ filled into the pores has a function of preventing the intermediate layer from being formed and therefore, the formation of the intermediate layer itself can be suppressed. As a result, the electron emissivity degrades scarcely even at such a high operating current density as above for at least the ordinary lifetime of color CRTs.

**[0027]** Moreover, since the electron emission is accomplished through the same mechanism as that of ordinary oxide cathodes, the advantage of short activation time and low operating temperature is maintained.

**[0028]** The at least one metal selected from the group consisting of Cr, Ta, Mo,. Zr, W, and Co for the part of the support serves as a reducing agent for the electron-emissive material. Thus, the reaction of reducing the electron-emissive material filled into the pores is accelerated, providing an excellent electron emission characteristic along with simplified fabrication processes.

**[0029]** Furthermore, the at least one metal selected from the group consisting of Cr, Ta, Mo, Zr, W, and Co produces no intermediate layer having a high electrical resistance through the reducing reaction of the electron-emissive material. Thus, the degradation of the electron emissivity can be further suppressed.

**[0030]** As describe above, with the cathode subassembly according to the first aspect of the invention, the above-described objects can be accomplished.

**[0031]** According to a second aspect of the present invention, a color CRT is provided, which comprises the cathode subassembly according to the first aspect. It is needless to say that the above-described objects can be accomplished in the CRT.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0032]** In order that the present invention may be readily carried into effect, it will now be described with reference to the accompanying drawings.

**[0033]** Fig. 1 is a schematic, cross-sectional view showing the structure of a prior-art oxide cathode, which incorporates an oxide cathode subassembly.

**[0034]** Fig. 2 is a schematic, cross-sectional view showing the structure of an oxide cathode before the cathode decomposition process, which incorporates an oxide cathode subassembly according to an embodiment of the invention.

**[0035]** Fig. 3 is a schematic, cross-sectional view showing the structure of the oxide cathode after the cathode decomposition process, in which the electron-emissive material film is formed on the electron emission surface of the pellet.

**[0036]** Fig. 4 is a graph showing the relationship between the decomposition time and the decomposition temperature of the cathode subassembly according to the embodiment of the invention.

**[0037]** Fig. 5 is a graph showing the relationship between the drive voltage and the emission current of the cathode subassembly according to the embodiment of the invention and the prior-art cathode assembly.

**[0038]** Fig. 6 is a graph showing the initial temperature characteristic of the cathode subassembly according to the embodiment of the invention as a function of the maximum cathode current.

**[0039]** Fig. 7 is a graph showing the change of the maximum cathode current of the cathode subassembly according to the embodiment of the invention as a function of the operation time.

## DETAILED DESCRIPTION OF THE INVENTION

**[0040]** The present invention will be described in detail below while referring to the drawings attached.

**[0041]** With the prior-art oxide cathodes disclosed in the Japanese Non-Examined patent Publication Nos. 64-5417 and 9-106750, which have been previously referred to in BACKGROUND OF THE INVENTION, the intermediate layer is decomposed by adding a reaction to the reactions (1) and (2) to decelerate the progress of the series of phenomena, thereby suppressing the degradation of electron emissivity.

**[0042]** Unlike this, the inventors found the fact that the progress of the series of phenomena was not accelerated due positive feedback even at a high operating current density greater than 1 A/cm$^2$ without adding any reaction to the reactions (1) and (2), if the thickness of the intermediate layer was made much thinner than the prior-art oxide cathodes. The reason of this fact was supposed that due to the small thickness of the intermediate layer, the amount of Joule heat generated at the intermediate layer was a little and the intermediate layer was not heated excessively, thereby preventing the positive feedback.

**[0043]** With the prior-art oxide cathode subassembly 79 shown in Fig. 1, the thickness of the intermediate layer is approximately expressed as the quotient of the total amount (i.e., total volume) of SiO and MgO generated by the reactions (1) and (2) by the area of the interface 75. Thus, the wider the area of the interface 75 grows, the smaller the thickness of the intermediate layer becomes. However, as seen from Fig. 1, the area of the interface 75 is approximately equal to the surface area of the electron emission surface of the cathode base 71. As a consequence, the area of the interface 75 cannot be increased drastically without changing the structure of the subassembly 79.

**[0044]** Unlike this, with the cathode subassembly according to the invention, the "porous cathode pellet" is used instead of the cathode base 71, where the pellet is made of a porous sintered body. The micro pores existing in the pellet (i.e., the body) are filled with the electron-emissive material. Thus, the inner walls of all the pores in the pellet serve as the interface of the electron-emissive material. As known well, in general, the total surface area of a porous sintered body is several thousands or several tens thousands times as much as the surface area of a flat plate with an equal size to the body. This means that the area of the interface of the electron-emissive material is several thousands or several tens thousands times as much as that of the prior-art subassembly 79. In other words, the thickness of the intermediate layer of the subassembly of the invention is several thousandths or several tens thousandths of that of the prior-art subassembly 79, which decreases drastically the Joule heat generated at the intermediate layer per unit area. Accordingly, the interface of the electron-emissive material is not heated excessively and the above-described positive feedback behavior is stopped, thereby preventing the progress of the series of phenomena from being accelerated.

**[0045]** On the other hand, the electron emission mechanism or principle of the subassembly of the invention is the same as that of the prior-art subassembly 79. Specifically, Ba atoms having low work function are generated through the reactions (1) and (2) and the Ba atoms thus generated emit electrons. As a result, the activation time and the operating temperature are equivalent to those of the prior-art subassembly 79.

**[0046]** Next, the method of filling the electron-emissive material into the pores of the pellet in the invention is explained below.

**[0047]** It is not easy to fill the pores in the porous pellet with the emission material. A first method to meet this need is to employ the so-called "fused impregnation method" that has been usually used to produce well-known impregnated cathodes. In this method, a porous pellet is kept in contacted with an electron-emissive material and then, they are heated up to a specific temperature at which the emissive material is fused. In this state, the fused emissive material is automatically impregnated into the pores of the pellet utilizing the capillarity.

**[0048]** The reason why the fused impregnation method can be applied to the production of impregnated cathodes is that the melting point of the cathode base is sufficiently higher than that of the electron-emissive material. For example, if the cathode base is made of a sintering body of W and the electron-emissive material is barium-calcium aluminate (Ba-Al aluminate), the base has a melting point of approximately 3300 °C and the emissive material has a melting point of approximately 2500 °C. This means that the melting point of the base is higher than that of the emissive material by about 800 degrees. However, as referred previously, the impregnated cathode of this example has a disadvantage of long activation time and high operating temperature (e. g., about 1000 °C). This disadvantage is caused by the kind of materials (i.e., W and Ba-Al aluminate) used and thus, it is extremely difficult to be solved.

**[0049]** Not to lose the characteristics of short activation time and low operating temperature of the prior-art oxide cathodes, the base needs to be made of an alloy containing Ni as its main ingredient (i.e., Ni-based alloy) and the electron-emissive material needs to be an oxide of alkaline-earth metal containing Ba (i.e., Ba-containing alkaline-earth metal oxide) . In this case, however, the fused impregnation method is unable to be applied, because the Ni-based alloy and the Ba-containing alkaline-earth metal oxide have approximately equal melting points of about 1400 °C.

**[0050]** A second method of filling the pores of the porous pellet with the electron-emissive material is to mix uniformly a powder of Ni-based alloy and a powder of Ba-containing alkaline-earth metal oxide and to sinter them in a vacuum or nitrogen ($N_2$) atmosphere at high temperature. In this case, however, there is a problem that no electrons are emitted from the pellet. This is due to the fact that barium oxide (BaO) contained in the pellet reacts with moisture existing in the atmosphere air to change to barium hydroxide ($Ba(OH)_2$) in the production processes of the pellet or color CRTs according to the following chemical equation (3).

$$BaO + H_2O \rightarrow Ba(OH)_2 \qquad (3)$$

**[0051]** As known well, $Ba(OH)_2$ never generates Ba atoms through any reducing reactions similar to the above-identified reactions (1) and (2). Thus, it is natural that no electron is emitted from the porous cathode pellet produced by the sintered body at a temperature of about 800 °C. However, there is a possibility that the pellet emits electrons at a temperature of about 800 °C if all the process steps from making the pellet to mounting the pellet on a color CRT are carried out in a moisture-less atmosphere (e.g., nitrogen atmosphere). This idea is not realistic, because it necessitates extremely large-scale facilities. As a result, the second method is unable to be applied as well.

**[0052]** Here, turning to the prior-art oxide cathode 79 shown in Fig. 1, it is seen that the chemical reaction (3) is cleverly prevented from occurring in the cathode 79 as follows.

**[0053]** Specifically, a carbonate of Ba-containing alkaline-earth metal (i.e., Ba-containing alkaline-earth metal carbonate) is used instead of a Ba-containing alkaline-earth metal oxide. Since the Ba-containing alkaline-earth metal carbonate is stable in the atmospheric air, any reaction similar to the reaction (3) does not occur. The Ba-containing alkaline-earth metal carbonate is coated on the surface of the base 71 and then, it is heated up to 800 °C to 1000 °C in a vacuum atmosphere for the cathode decomposition process. Due to the heat thus applied, the following reaction (4) occurs, resulting in BaO from barium carbonate ($BaCo_3$).

$$BaCO_3 \rightarrow BaO + CO_2\uparrow \qquad (4)$$

**[0054]** Since BaO is produced in the vacuum atmosphere, it does not react with moisture in the atmospheric air and it does not change to $Ba(OH)_2$ according to the reaction (3). As a result, the porous film 72 of the Ba-containing alkaline-earth metal oxide is formed on the base 71.

**[0055]** Any other alkaline-earth metals than Ba in the base 71 cause similar reactions to the reaction (4). However, they are omitted here because they are not important for the invention.

**[0056]** The inventors intended to combine the method of changing the Ba-containing alkaline-earth metal carbonate to the Ba-containing alkaline-earth metal oxide in the prior-art oxide cathode 79 with the thought of filling the pores of the porous pellet with the electron-emissive material. As a result, they discussed the following method.

**[0057]** Specifically, a powder of Ni-based alloy and a powder of Ba-containing alkaline-earth metal carbonate are uniformly mixed together and then, they are sintered in a vacuum or nitrogen atmosphere at high temperature. In this method thus discussed, the sintering temperature needs to be set at 1000 °C or higher because the melting point of the Ni-based alloy is about 1400 °C. However, as known well, if the Ba-containing alkaline-earth metal carbonate is heated up to 1000 °C, it is decomposed completely according to the equation (4), resulting in BaO. BaO thus produced is further turned to Ba(OH)2 according to the equation (3). Therefore, the pellet thus obtained has the same problem (i.e., no electron emission occurs) as that of the pellet produced by the above-identified second method. This means that the method of combining the method of the prior-art oxide cathode 79 with the thought of filling the pores of the porous pellet with the electron-emissive material cannot be adopted for this purpose.

**[0058]** Next, the inventors paid attention to gaseous $CO_2$ generated frog BaCO3 according to the reaction (4). In other words, they noticed the fact that the reaction (4) does not progress according to the Le Chatelier's law if the sintering process for the $BaCO_3$-containing powder mixture is performed under high pressure. This means that if the $BaCO_3$-containing powder mixture is subjected to a sintering process under a specific high pressure, the Ni-based alloy can be sintered without decomposition of the Ba-containing alkaline-earth metal carbonate.

**[0059]** To implement the sintering process under high pressure, the inventors paid attention to the so-called HIP method, an example of which is disclosed by the inventors in the Japanese Non-Examined Patent Publication No. 8-50849 published in February 1996. In the sintered body disclosed in the Publication No. 8-50849, the electron-emissive material is kept in the form of carbonate and therefore, the electron emission characteristic does not deteriorate through the wet cutting, wet polishing, cleaning, and drying (at 300 °C or lower) processes. Thus, there is an advantage that the sintered body can be processed to form the pellet without severe restrictions and that manufacturing lines for the pellet can be constituted easily.

**[0060]** In the sintered body disclosed in the Publication No. 8-50849, the electron-emissive material filled into the pores of the sintered body is not limited to Ba-containing alkaline-earth metal carbonate. Also, it is not essential for Ba-containing alkaline-earth metal carbonate to be decomposed to Ba-containing alkaline-earth metal oxide.

**[0061]** Due to the subsequent researches, the inventors found the following facts:

(i) Ba-containing alkaline-earth metal carbonate is essential as the electron-emissive material.

(ii) It is essential for Ba-containing alkaline-earth metal carbonate to be decomposed to be Ba-containing alkaline-earth metal oxide.

(iii) Carbonate generated by co-precipitation of Ba, Sr, and Ca (i.e., Ba/Sr/Ca co-precipitation carbonate) is most preferred as the Ba-containing alkaline-earth metal carbonate. A preferred molar ratio of Ba, Sr, and Ca is Ba : Sr : = Ca = (45 to 65) : (30 to 50) : (2 to 15).

(iv) Ba-containing alkaline-earth metal oxide needs to form a film covering the emission surface of the pellet in the cathode decomposition process. Ba/Sr/Ca co-precipitation oxide is most preferred for this purpose.

**[0062]** As explained previously with reference to the equations (1) and (2), a reducing agent is necessary to reduce BaO. In the technique disclosed in the above-identified Publication No. 8-50849, the reducing agent is subjected to the HIP process along with the Ni-based alloy-powder and the electron-emissive material powder. In this case, however, it was found that part of the reducing agent does not exhibit any desired reducing action. This is because part of the reducing agent has reacted with the Ni powder during the HIP process and as a result, it has already been deactivated when the pellet is in the operation on a color CRT. To compensate the reducing action thus weakened, the inventors developed a novel structure including a reducing-agent supplying layer between the cathode pellet and the pellet support (e.g., a cathode cap), which is disclosed in the Japanese Non-Examined Patent Publication No. 9-63459.

**[0063]** The cathode structure disclosed in the Publication No. 9-63459 has a disadvantage that the fabrication processes are complicated although it exhibits a desired reducing action. To eliminate this disadvantage, the inventors continued researches and found that if a Ni-based alloy containing the reducing agent is located at part of the pellet support that is contacted with the pellet, the reactions (1) and (2) are caused as desired due to the reducing agent contained in the Ni-based alloy. For example, the pellet support itself might be made of a Ni-based alloy containing the reducing agent. If so, a desired reducing action can be exhibited while the fabrication processes were simplified.

**[0064]** As the reducing agent contained in the Ni-based alloy, at least one metal selected from the group consisting of Cr, Ta, Mo, Zr, W, and Co was preferred. It was preferred that the compounding ratio of the reducing agent was set in the range from 1 wt% to 33 wt% with respect to Ni, because the electron emission, mechanical, and thermal characteristics were enhanced. From the viewpoint of accessibility and cost, Cr was most preferred and its compounding ratio was preferably set in the range from 19 wt% to 30 wt% with respect to Ni.

**[0065]** If Cr is mixed into a Ni-based alloy in such a way that the compounding ratio is in the range from 19 wt% to 30 wt% with respect to Ni, the reduction reaction of BaO is given by the following equation (5).

$$\alpha\ \mathrm{BaO} + \beta\ \mathrm{Cr} \rightarrow \mathrm{Ba_3(CrO_4)_2} + \gamma\ \mathrm{Ba} \qquad (5)$$

**[0066]** Fortunately, the by-product $Ba_3(CrO_4)_2$ produced by the reaction (5) scarcely forms any intermediate layer with high electrical resistance, which is unlike the by-products SiO and MgO produced by the reactions (1) and (2). Thus, the effect that the resistive intermediate layer is scarcely formed is added to the effect that the thickness of the intermediate layer is decreased to several thousandths or several tens thousandths because of the increased total area of the interface between the electron-emissive material and the pellet. As a result, the electron emission performance degradation is further suppressed.

**[0067]** It is preferred that the thermal expansion coefficient (i.e., linear expansion coefficient) of the pellet (i.e., the sintered body) is set in the range from $12 \times 10^{-6}$ /K to $20 \times 10^{-6}$ /K within the temperature range from 30°C to 800°C. In this case, a conspicuous advantage is given to the pellet support whose compounding ratio of Cr is in the range from 19 wt% to 30 wt% with respect to Ni. This is because the support of this sort has a thermal expansion coefficient (i.e., linear expansion coefficient) of $13.3 \times 10^{-6}$ /K to $15 \times 10^{-6}$ /K within the temperature range from 30 °C to 800°C, which is approximately equal to that of the pellet. Thus, no thermal strain occurs between the pellet and the support, thereby ensuring the stability and reliability of the cathode subassembly.

**[0068]** The inventors disclosed a cathode pellet containing rare-earth metal oxide (e.g., scandium oxide, $Sc_2O_3$) in the above-identified Publication No. 8-50849. The inventors further disclosed a method of producing a sintered body in the Japanese Non-Examined Patent Publication No. 11-40046 published in February 1999, in which a Ni powder and a rare-earth metal oxide powder are uniformly mixed together, the mixture is heated in a hydrogen ($H_2$) atmosphere, an electron-emissive material is mixed with the mixture thus heated, and the mixture containing the emissive material is subjected to an HIP process, thereby forming a sintered body. Here, the inventors disclose novel effects that have not been disclosed in these two publications below.

**[0069]** Specifically, when scandium oxide ($Sc_2O_3$) is selected from various rare-earth metal oxides, it is preferred that the mixing ratio of $Sc_2O_3$ with respect to the sum of the electron-emissive material powder and the Ni powder is in the range from 1 wt% to 7 wt%. This limitation is closely related to the fact that the electron-emissive material film with a thickness of 20 μm to 150 μm is formed on the emission surface of the pellet in the cathode decomposition process, which is explained below in detail.

**[0070]** Before the cathode decomposition process, the emission surface of the pellet is smooth like a mirror surface and no film is located thereon. During the decomposition process, the electron-emissive material (e.

g., Ba/Sr/Ca co-precipitation oxide) contained in the porous pellet seeps from the emission surface by way of the pores. When this process is completed, the emission surface is covered with the film of the electron-emissive material.

**[0071]** The inventor found that the electron-emissive material film thus formed on the emission surface was approximately inversely proportional to the amount of $Sc_2O_3$ added to the pellet. This is a novel effect that have not been disclosed in the above-identified Publication Nos. 8-50849 and 11-40046 and other publications or documents. If the amount of $Sc_2O_3$ is less than 1 wt%, the emissive material film has a thickness of greater than 150 μm. If the amount of $Sc_2O_3$ is greater than 7 wt%, the emissive material film has a thickness of less than 20 μm. When the emissive material film has a thickness of greater than 150 μm, the electrons generated in the pellet are difficult to be emitted toward the outside through the film, decreasing the electron emission. When the emissive material film has a thickness of less than 20 μm, the number of the electrons generated at the emission surface is poor or short, decreasing the electron emission as well. Accordingly, it is preferred that the emissive material film has a thickness of 20 μm to 150 μm, which is realized by setting the amount of $Sc_2O_3$ to be in the range from 1 wt% to 7 wt%.

**[0072]** The surface roughness ($R_{max}$) of the emission surface of the pellet is preferably set at 3 μm or less. This means that the emission surface is specular, in other words, it is substantially a mirror-finished surface. This generates the following advantages.

**[0073]** The sintered body has a minute grid-like structure of Ni and its pores are filled with the emissive material and the $Sc_2O_3$ . The body is sliced or punched to have a specific shape and a specific size, thereby forming the pellet. Since Ni is a tough metal, so-called sags tend to be formed on the cross section of the body, covering part of the section. Thus, the pores into which the emissive material and the $Sc_2O_3$ are filled are covered with the sags. In this state, even if the emissive material (i.e., Ba/Sr/Ca co-precipitation oxide) is decomposed during the decomposition process, the decomposed emissive material is unable to emit electrons from the emission surface. This means that the emissive material film is unable to be formed on the whole surface and that the sags need to be removed entirely from the emission surface. This problem is solved by polishing the emission surface of the pellet to have a surface roughness of 3 μm or less.

**[0074]** A proper weight ratio of the electron-emissive material powder to the Ni powder is determined by the electron emission characteristic of the pellet and the mechanical strength of the sintered body. Specifically, if the amount of the emissive material powder is excessively small, as understood easily, the number of electrons to be emitted is small, resulting in low electron emission performance. On the other hand, if the amount of the emissive material powder is excessively large, the amount of Ni particles for constituting its grid-like structure is short, resulting in insufficient mechanical strength of the body for forming the pellet. Taking these facts into consideration, it is preferred that the weight ratio of the emissive material powder to the Ni powder is in the range from 40 wt% to 96 wt%.

**[0075]** The proper average particle diameter of the Ni powder and the electron-emissive material (i.e., Ba/Sr/Ca co-precipitation carbonate) powder is determined by the mechanical strength of the sintered body and the pore size of the grid-shaped structure. Specifically, if the average particle diameter of the Ni powder is excessively large, the grid-like structure of the body is coarse to thereby lower its mechanical strength. In this case, a pellet is difficult to have a desired shape and a desired size by mechanical processing. If the average particle diameter of the Ni powder is excessively small, the grid-like structure of the body is dense and as a result, the pores are difficult to communicate with the outside. In this case, the emissive material filled into the closed pores does not contribute to the electron emission. Taking these facts into consideration, it is preferred that the average particle diameter of the Ni powder is in the range from 0.8 μm to 9 μm.

**[0076]** It is preferred that the average particle diameter of the Ba/Sr/Ca co-precipitation carbonate powder is approximately equal to that of the Ni particle, because the electron emission characteristic is improved. The reason of this is assumed in the following way.

**[0077]** The size of the pores is approximately equal to the average particle diameter of the Ni powder. Thus, if the average particle diameter of the Ba/Sr/Ca co-precipitation carbonate powder is approximately equal to that of the Ni particle, the Ba/Sr/Ca co-precipitation carbonate particles are filled into the pores neither too much nor too little. This eliminates generation of abnormal crystal strain in the Ba/Sr/Ca co-precipitation carbonate particles, which is favorable. As a result, it is preferred that the average particle diameter of the Ba/Sr/Ca co-precipitation carbonate powder is in the range from 0.9 μm to 7 μm.

**[0078]** A Ni powder produced from nickel carbonyl by the so-called "carbonyl method" (which may be termed the "thermal decomposition method") is most preferred for the invention. The word "nickel carbonyl" is another name of $Ni(CO)_4$ which is produced by the reaction between Ni and carbon monoxide (CO) at a temperature of 420 K or lower. Since nickel carbonyl decomposes to Ni and CO at a temperature of 453 K or higher, high-purity Ni is produced from crude Ni using this reaction. This method has ever been extensively used for this purpose. The high-purity Ni thus produced is termed "carbonyl nickel". According to the inventors' research, a powder of carbonyl nickel was most preferred from the viewpoint of electron emission capability or characteristics. The reason of this result has not been clarified completely. However, it is assumed that a trace of carbon (C), which is generated from CO, is present in Ni as impurity and that the trace of C affects the electron emission capability.

**[0079]** It is preferred that the density of the sintered body is 82 % of the theoretical density (which is calculated under the supposition that the sintered body contains no pores) or higher, which is due to the following reason.

**[0080]** If the density of the sintered body is less than 82 % of the theoretical density, the grid-like structure of Ni does not have a sufficient mechanical strength and therefore, there is a tendency that the sintered body does not have a desired size. Moreover, density measurement is convenient for examining whether or not the sintering process has been normally completed by the HIP method.

**[0081]** The following explanation is given to a preferred embodiment of the present invention made with reference to Figs. 2 to 7.

**[0082]** Fig. 2 shows a cathode including a cathode subassembly according to an embodiment of the invention, which is designed for color CRTs.

**[0083]** As shown in Fig. 2, a cathode 20 comprises a cathode sleeve 14 with an approximately cylindrical shape, a cap-shaped pellet support 12 fixed to the top of the sleeve 14 by welding, and a circular-plate-shaped cathode pellet 11 fixed to the support 12 by welding. The support 12 is entirely located in the sleeve 14. The pellet 11 is entirely located in the depression of the support 12. The pellet 11, the support 12, and the sleeve 14 constitute a cathode subassembly 19 according to the embodiment of the invention.

**[0084]** The pellet 11 is formed by a sintered body made of the mixture of a Ni powder, a $Sc_2O_3$ powder, and an electron-emissive material powder. Specifically, these three powders are mixed uniformly to form a specific powder body or powder mixture. The powder body or mixture thus formed is then sintered and integrated using a HIP process, forming a sintered body. Thereafter, the sintered body is subjected to a proper mechanical processing to have a specific size and a specific shape, thereby forming the pellet 11. For this reason, the pellet 11 has a porous structure similar to the grid-like structure of Ni and contains a lot of micro pores in its inside. The pores are filled with $Sc_2O_3$ and the electron-emissive material. The pellet 11 has a function of the cathode base 71 of the prior-art cathode 70 shown in Fig. 1.

**[0085]** The support 12 is made of an alloy that contains Ni as its main ingredient and at least one metal selected from the group consisting of Cr, Ta, Mo, Zr, W, and Co as a reducing agent for the electron-emissive material.

**[0086]** A heater 15 is mounted in the sleeve 14 to heat the cathode subassembly 19. The heater 15 has the same configuration as used for ordinary oxide cathodes.

**[0087]** With the cathode subassembly 19 having the above-described configuration according to the invention, the pellet 11 has the porous or grid-like structure or organization and the pores 17 of the pellet 11 are filled with the emissive material and $Sc_2O_3$. The emissive material is in contact with the pellet 17 at the inner walls of the pores 17. Thus, the area of the interface between the emissive material and the pellet 11 is increased drastically and at the same time, the thickness of the intermediate layer formed at the interface per unit area drastically decreases.

**[0088]** Similar to the prior-art subassembly 79, an intermediate layer (not shown) is formed at the interface between the emissive material and the pellet 11 during operation. However, because of the increased area of the interface, the thickness of the intermediate layer per unit area is drastically decreased. Thus, the formation process of the intermediate layer does not accelerated even at a high operating current density greater than approximately 1 A/cm$^2$. Also, the $Sc_2O_3$ filled into the pores 17 prevents the formation of the intermediate layer and therefore, the formation of the intermediate layer itself can be suppressed. Accordingly, the electron emission capability (i.e., emissivity) degrades scarcely even at such a high operating current density as above for at least the ordinary lifetime of color CRTs.

**[0089]** Moreover, since the electron emission is accomplished through the same mechanism as that of ordinary oxide cathodes, the advantage of short activation time and low operating temperature is maintained.

**[0090]** The at least one metal selected from the group consisting of Cr, Ta, Mo, Zr, W, and Co, which is an ingredient of the material of the support 12, serves as a reducing agent for the emissive material. Thus, the reaction of reducing the emissive material filled into the pores 17 is accelerated, providing an excellent electron emission characteristic along with simplified fabrication processes.

**[0091]** The at least one metal selected from the group consisting of Cr, Ta, Mo, Zr, W, and Co does not form a resistive intermediate layer during the reducing reaction of the electron-emissive material. Thus, the degradation of the emission capability or emissivity can be suppressed further.

**[0092]** Preferably, the pellet 11 is formed by a sintered body produced in such a way that the weight ratio of the emissive material powder with respect to the Ni powder is set in the range from 40% to 96%, the average particle diameter of the Ni powder is set in the range from 0.8 μm to 9 μm, and the Ni powder is generated by decomposition of nickel carbonyl using the carbonyl method. In this case, an excellent electron emission characteristic can be accomplished and at the same time, a high mechanical strength to be resistant to the mechanical process for producing the pellet 11 from the sintered body can be ensured.

**[0093]** It is preferred that the density of the pellet 11 is equal to or higher than 82% of its theoretical density. This is because the mechanical strength is insufficient if it is less than 82% of the theoretical density.

**[0094]** Preferably, the thermal expansion coefficient (i.e., linear expansion coefficient) of the pellet 11 is set in the range from 12 × $10^{-6}$ /K to 20 × $10^{-6}$ /K. If the thermal expansion coefficient of the pellet 11 is within this range, it is approximately equal to the thermal expansion coefficient (i.e., linear expansion coefficient) of the support 12 and therefore, thermal strain occurring between the pellet 11 and the support 12 is suppressed. Thus, the stability and the reliability of the subassembly 19 can be ensured.

**[0095]** In the alloy for the support 12, preferably, the weight ratio of the at least one metal selected from the group consisting of Cr, Ta, Mo, Zr, W, and Co with respect to that of'Ni is set in the range from 1 % to 33 %. In this case, the electron emission, mechanical, and thermal characteristics can be enhanced. In particular, Cr is more preferred because Cr is easily accessible at low cost. The weight ratio of Cr with respect to that of Ni is preferably set in the range from 19 % to 30 %.

**[0096]** As the electron-emissive material powder, a powder of carbonate generated by co-precipitation of Ba, Sr, and Ca (i.e., Ba/Sr/Ca co-precipitation carbonate) is preferably used. In this case, it is preferred that the powder of the carbonate has an average particle diameter in the range from 0.9 μm to 7 μm, which is approximately the same as that of the Ni powder. There is an additional advantage that the pores 17 are filled with the emissive material neither too much nor too little and as a result, no abnormal strain occurs in the emissive material, providing an excellent electron emission characteristic. Additionally, in this case, it is preferred that Ba, Sr, and Ca have a molar ratio that Ba is from 45 to 65, Sr is from 30 to 50, and Ca is from 2 to 15 (i.e., Ba : Sr : Ca = (45 - 65) : (30 - 50) : (1 - 15)). This is because a film 23 made of the electron-emissive material is easily formed on the emission surface 13 of the pellet 11 after the cathode decomposition process, as shown in Fig. 3.

**[0097]** As explained above, the pellet 11 is formed by mechanically processing the sintered body to have a specific shape and therefore, sags (not shown) made of Ni tend to be formed on the electron emission surface 13 of the pellet 11. Since the Ni sags are usually formed to cover the surface 13, there is a problem that part of the pores 17 on the surface 13 are closed to prevent the emissive material from emitting toward the outside. To solve this problem and to facilitate the formation of the film 23 of the emissive material, it is preferred that the surface 13 is polished until it has a surface roughness ($R_{max}$) of 3 μm or less, thereby removing the sags.

**[0098]** On the other hand, in the decomposition process of the cathode 10 to be carried out after incorporating the cathode 10 into color CRTs, the emissive material in the pellet 11 is thermally decomposed to protrude gradually from the emission surface 13 by way of the pores 17. As a result, as shown in Fig. 3, the film 23 is formed by the decomposed emissive material on the surface 13.

**[0099]** To enhance the electron emission capability, it is preferred that the film 23 has a thickness of 20 μm to 150 μm. If it is thicker than 150 μm, the electrons generated in the inside of the pellet 11 are difficult to penetrate the film 23 to the outside, reducing the number of electrons to be emitted. On the other hand, if it is thinner than 20 μm, the number of electrons generated on the surface 13 is insufficient, decreasing the number of electrons to be emitted as well.

**[0100]** The film 23 having a thickness of 20 μm to 150 μm can be realized by setting the weight ratio of the $Sc_2O_3$ powder with respect to the combination of the emissive material and Ni powders to be in the range from 1% to 7% in the sintered body for the pellet 11.

EXAMPLES

**[0101]** The inventors produced practically the cathode pellet 11 according to the invention and conducted some tests in the following way.

**[0102]** First, the cathode pellet 11 was produced in the following steps (i) to (iv).

> (i) A Ni powder having an average particle diameter of 5 μm, a $Sc_2O_3$ powder, and a powder of carbonate generated by co-precipitation of Ba, Sr, and Ca (i.e., Ba/Sr/Ca co-precipitation carbonate powder) having an average particle diameter of 1 μm to 2 μm and a molar ratio of Ba : Sr : Ca being equal to 50 : 40 : 10 were provided. 100g of the Ni powder, 6g of the $Sc_2O_3$ powder, and 60g of the Ba/Sr/Ca co-precipitation carbonate powder were uniformly mixed together, forming a powder mixture.
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> (ii) The powder mixture thus formed was subjected to a press forming process at room temperature, forming a shaped body.
>
> (iii) The shaped body thus formed was placed in a glass capsule and then, the air in the capsule was evacuated to form a specific vacuum atmosphere in the capsule. The pressure in the capsule was set in the order of $10^{-4}$ Pa. Simultaneous with the evacuation, the gaseous substances existing in the body and the capsule were degassed at approximately 500 °C.
>
> (iv) The capsule including the shaped body was placed in a HIP machine to sinter the body. The sintering condition was that the highest pressure was set at 150 Mpa, the highest temperature was set at 1100 °C, and the holding period at the highest temperature was set at 30 minutes.

**[0103]** In the sintering process, only the Ni powder was practically sintered to form a grid-like structure containing a lot of particles 17. The $Sc_2O_3$ powder and the Ba/Sr/Ca co-precipitation carbonate powder were not sintered and kept in the pores 17 of the Ni structure. The pores 17 were formed to communicate with each other and thus, they are termed "open pores". The substances and gasses existing in the pores 17 can move or flow among the adjoining pores 17 and can reach the surface of the sintered body. During the sintering process, since the above-described high pressure (i.e., 150 Mpa at the highest) was applied to the body, there is no possibility that the Ba/Sr/Ca co-precipitation carbonate powder is decomposed to be Ba/Sr/Ca oxides.

> (v) After cooling the HIP machine, the capsule was taken out of the machine and then, the sintered body was taken out of the capsule. The sintered body had a density equal to 85% of the theoretical density and a coefficient of linear expansion of 13.0 $\times$ $10^{-6}$ /K at room temperature, 13.5 $\times$ $10^{-6}$ /K at 100 °C, 13.6 $\times$ $10^{-6}$ at 200 °C, 15.5 $\times$ $10^{-6}$ at 500 °C, and 18.0 $\times$ $10^{-6}$ at 800 °C.
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> (vi) The sintered body was sliced with a diamond blade, forming wafers with a thickness of 0.5 nm. This slicing process was performed using the method disclosed in the Japanese Non-Examined Patent Publication No. 9-147742 published in 1997 by the inventors. The surface of each wafer was polished with a diamond slurry, forming a polished wafer with a thickness of 0.22 mm and a surface roughness of 1 μm. Then, each polished wafer was punched with a die punching metal mold made of cemented carbide, forming circular-plate-shaped cathode pellets 11 with a diameter of 1.1 mm and a thickness of 0.22 mm.

**[0104]** Subsequently, the cathode 10 was produced using one of the cathodes 11 thus produced. On the other hand, a nichrome plate (Ni: 80 wt%, Cr: 20 wt%) with a thickness of 50 μm was subjected to a drawing process, forming a cap-shaped metal part with an inner diameter of 1.1 mm and a depth of 0.2 mm. This metal part was used as the pellet support 12. Moreover, a nichrome plate (Ni: 80 wt%, Cr: 20 wt%) with a thickness of 50 μm was subjected to another drawing process, forming a cylindrical metal part with an inner diameter of 1.2 mm to 2.0 mm and a length of 8 mm. This metal part was used as the sleeve 14.

**[0105]** The cathode 10 was fabricated in the following way.

**[0106]** First, the pellet 11 was inserted into the support 12. Then, the support 12 including the pellet 11 was inserted into the top end of the sleeve 14. The top end of the sleeve 14 was subjected to a resistance welding process, thereby fixing the pellet 11 and the support 12 onto the top end of the sleeve 14. Thus, the cathode subassembly 19 was fabricated.

**[0107]** Finally, the heater 15 was inserted into the sleeve 14 through its bottom end. Thus, the cathode 10 having the configuration shown in Fig. 2 was completed.

**[0108]** Following this step, the cathode 10 was mounted on a color CRT by an ordinary method and then, it was subjected to an ordinary decomposition process for decomposing the pellet 11 according to a specific temperature change profile shown in Fig. 4 for about five minutes. Through the decomposition process, the Ba/Sr/Ca co-precipitation carbonate contained in the pellet 11 was decomposed due to applied heat, producing Ba/Sr/Ca oxides. Part of the Ba/Sr/Ca oxides thus produced were gradually emitted from the emission surface 13 by way of the micro pores 17 existing in the pellet 11. As a result, the film 23, which had a thickness of 50 μm and which was made of the Ba/Sr/Ca oxides, was formed on the surface 13, as shown in Fig. 3.

**[0109]** At this stage, the previously-described reaction (5) did not progress sufficiently and therefore, little electron emission was observed. Then, the pellet 11 thus decomposed was subjected to an activation process at 1080 °C for 15 minutes to thereby accelerate the reaction (5). As a result, sufficient Ba atoms with a low work function were generated and sufficient electron emission was observed. The result thus observed is shown in Figs. 5 and 6.

**[0110]** Fig. 5 shows the initial emission current characteristic as a function of the drive voltage of the prior-art cathode subassembly 79 and the cathode subassembly 19 of the invention. The abscissa denotes the drive voltage (V) and the ordinate denotes the emission current (μA).

**[0111]** As seen from Fig. 5, substantially no difference exists between the initial emission current characteristics of the subassemblies 79 and 19, in other words, the subassembly 19 of the invention has substantially the same initial emission current characteristic as that of the prior-art subassembly 79. Taking the fact that the prior-art subassembly 79 is fully resistant to practical use into consideration, it is found that the subassembly 19 of the invention has a fully resistant property to practical use on the initial emission current characteristic.

**[0112]** Fig. 6 shows the initial temperature characteristic of the cathode subassembly 19 of the invention. The abscissa denotes the cathode temperature Tk (°C) and the ordinate denotes the maximum cathode current MIk (μA).

**[0113]** As seen from Fig. 6, the maximum cathode current MIk is saturated at 780 °C, in other words, the operating temperature of the cathode subassembly 19 is 780 °C. This is approximately the same as that of the prior-art subassembly 79. Thus, it is sufficient that the heat resistance of the sleeve 14 is equivalent to that of sleeve 73 of the prior-art subassembly 79 and accordingly, the sleeve 73 can be applied to the sleeve 13. Since the operating temperature of the subassembly 19 is the same as that of the assembly 79, any thermal measure is unnecessary to the electron gun assembly. These points are useful merits in practical use.

**[0114]** Fig. 7 shows the change of the maximum cathode current MIk of the cathode subassembly 19 of the invention, which was obtained by continuously operating the subassembly 19 at a current density of 3 A/cm$^2$ for 21,000 hours. The abscissa denotes the operation time (hour) while the ordinate denotes the ratio of the maximum cathode current MIk to its initial value.

**[0115]** As seen from Fig. 7, the maximum decrease of the current MIk is less than 5 % for 21,000 hours. Taking such a small decrease of the current MIk into consideration, it can be said that the brightness on the screen and focusing performance (i.e., resolution) are approximately equal to their initial values after the operation for 21,000 hours. Moreover, the subassembly 19 is never used to operate continuously under such a severe condition of a current density of 3 A/cm$^2$ even in large-sized color CRTs. Thus, it is seen that recognizable degradation of electron emission does not observed on the color CRT screen at least for its ordinary operation period.

**[0116]** As explained above, with the cathode subassembly 19 according to the embodiment of the invention, the electron emission capability (i.e., emissivity) degrades scarcely even at a high operating current density greater than approximately 1 A/cm$^2$ for at least the ordinary lifetime of color CRTs. This means that color CRTs equipped with the subassembly 19 do not exhibit any recognizable degradation of brightness and focus on the screen for a long time and that they are suitable to large-sized televisions or computer displays.

**[0117]** In the above-explained example of the invention, the whole support 12 is formed by an alloy containing Ni as its main ingredient and at least one metal selected from the group consisting of Cr, Ta, Mo, Zr, W, and Co. However, the invention is not limited to this configuration. It is sufficient that part of the support 12, which is contact with the pellet 11, is formed by an alloy containing Ni as its main ingredient and at least one metal selected from the group consisting of Cr, Ta, Mo, Zr, W, and Co. In this case, needless to say, approximately the same advantages as those of the above-described embodiment are given.

**[0118]** While the preferred forms of the present invention have been described, it is to be understood that modifications will be apparent to those skilled in the art without departing from the spirit of the invention. The scope of the present invention, therefore, is to be determined solely by the following claims.

## Claims

**1.** A cathode subassembly comprising:

(a) a porous cathode pellet formed by a sintered body containing Ni, scandium oxide ($Sc_2O_3$), and an electron-emissive material;

said body being made by sintering a mixture of a Ni powder, a scandium oxide ($Sc_2O_3$) powder, and an electron-emissive material powder using a HIP process;
said pellet having an electron emission surface; and

(b) a pellet support for supporting said pellet;

said support having a part in contact with said pellet;
said part being made of an alloy containing Ni as its main ingredient and at least one metal selected from the group consisting of chromium (Cr), tantalum (Ta), molybdenum (Mo), zirconium (Zr), tungsten (W), and cobalt (Co);
the at least one metal selected from the group consisting of Cr, Ta, Mo, Zr, W, and Co serving as a reducing agent for said electron-emissive material.

**2.** The subassembly according to claim 1, wherein a weight ratio of said electron-emissive material powder to said Ni powder is in a range from 40 wt% to 96 wt%.

**3.** The subassembly according to claim 1, wherein a mixing ratio of $Sc_2O_3$ with respect to the sum of said electron-emissive material and said Ni powder is in a range from 1 wt% to 7 wt%.

**4.** The subassembly according to claim 1, wherein an average particle diameter of said Ni powder is in a range from 0.8 $\mu$m to 9 $\mu$m.

**5.** The subassembly according to claim 1, wherein said Ni powder is produced from nickel carbonyl by a carbonyl method.

**6.** The subassembly according to claim 1, wherein a weight ratio of the at least one metal selected from the group consisting of Cr, Ta, Mo, Zr, W, and Co with respect to that of Ni is set in a range from 1 % to 33 %.

**7.** The subassembly according to claim 1, wherein Cr is selected from the group consisting of Cr, Ta, Mo, Zr, W, and Co; and wherein a weight ratio of Cr with respect to that of Ni is set in a range from 19 % to 30 %.

**8.** The subassembly according to claim 1, further comprising a film formed on said electron emission surface of said pellet;

wherein said film is made of said electron-emissive material and has a thickness of 20 $\mu$m to 150 $\mu$m.

**9.** The subassembly according to claim 1, wherein said electron-emissive material is a carbonate generated by co-precipitation of Ba, Sr, and Ca.

**10.** The subassembly according to claim 9, wherein said carbonate generated by co-precipitation of Ba, Sr, and Ca has a specific molar ratio of Ba, Sr, and Ca that Ba : Sr : Ca - (45 to 65) : (30 to 50) : (2 to 15).

**11.** The subassembly according to claim 9, wherein an average particle diameter of said carbonate generated by co-precipitation of Ba, Sr, and Ca is in a range from 0.9 μm to 7 μm.

**12.** The subassembly according to claim 8, wherein said electron-emissive material is a mixture of oxides of Ba, Sr, and Ca.

**13.** The subassembly according to claim 12, wherein said oxides of Ba, Sr, and Ca have a specific molar ratio of BaO, $Sr_2O_3$, and CaO that BaO : $Sr_2O_3$ : and Cao = (45 to 65) : (30 to 50) : (2 to 15).

**14.** The subassembly according to claim 1, wherein a density of said sintered body is equal to 82 % of its theoretical density or higher.

**15.** The subassembly according to claim 1, wherein a coefficient of linear expansion of said sintered body is in a range from $12 \times 10^{-6}$ /K to $20 \times 10^{-6}$ /K within a temperature range from 30 °C to 800 °C.

**16.** The subassembly according to claim 1, wherein a surface roughness ($R_{max}$) of said electron emission surface of said pellet is set at 3 μm or less.

**17.** The subassembly according to claim 1, wherein a weight ratio of said electron-emissive material powder to said Ni powder is in a range from 40 wt% to 96 wt%;

and wherein a mixing ratio of said $Sc_2O_3$ with respect to the sum of said electron-emissive material and said Ni powder is in a range from 1 wt% to 7 wt%;
and wherein an average particle diameter of said Ni powder is in a range from 0.8 μm to 9 μm;
and wherein said Ni powder is produced from nickel carbonyl by a carbonyl method;
and wherein Cr is selected from the group consisting of Cr, Ta, Mo, Zr, W, and Co and a weight ratio of Cr with respect to that of Ni is set in a range from 19 % to 30 %;
and wherein said electron-emissive material is a carbonate generated by co-precipitation of Ba, Sr, and Ca and said having a specific molar ratio of Ba, Sr, and Ca that Ba : Sr : Ca - (45 to 65) : (30 to 50) : (2 to 15).

**18.** The subassembly according to claim 1, wherein a weight ratio of said electron-emissive material powder to said Ni powder is in a range from 40 wt% to 96 wt%;

and wherein a mixing ratio of said $Sc_2O_3$ with respect to the sum of said electron-emissive material and said Ni powder is in a range from 1 wt% to 7 wt%;
and wherein an average particle diameter of said Ni powder is in a range from 0.8 μm to 9 μm;
and wherein said Ni powder is produced from nickel carbonyl by a carbonyl method;
and wherein Cr is selected from the group consisting of Cr, Ta, Mo, Zr, W, and Co and a weight ratio of Cr with respect to that of Ni is set in a range from 19 % to 30 %;
and wherein said electron-emissive material is a carbonate generated by co-precipitation of Ba, Sr, and Ca;
and wherein said carbonate has a specific molar ratio of Ba, Sr, and Ca that Ba : Sr : Ca = (45 to 65) : (30 to 50) : (2 to 15) and an average particle diameter in a range from 0.9 μm to 7 μm;
and wherein a density of said sintered body is equal to 82 % of its theoretical density or higher;
and wherein a coefficient of linear expansion of said sintered body is in a range from $12 \times 10^{-6}$ /K to $20 \times 10^{-6}$ /K within a temperature range from 30 °C to 800 °C.

**19.** A color CRT comprising the subassembly according to claim 1.

FIG. 1
PRIOR ART

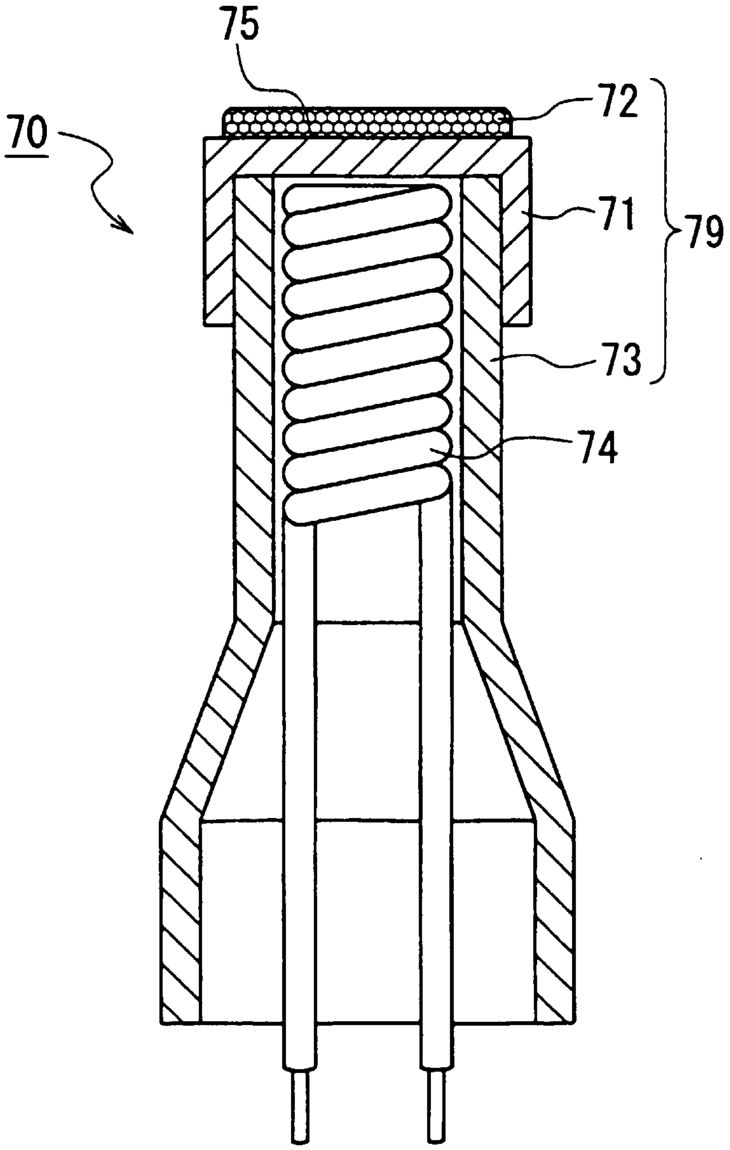


FIG. 2

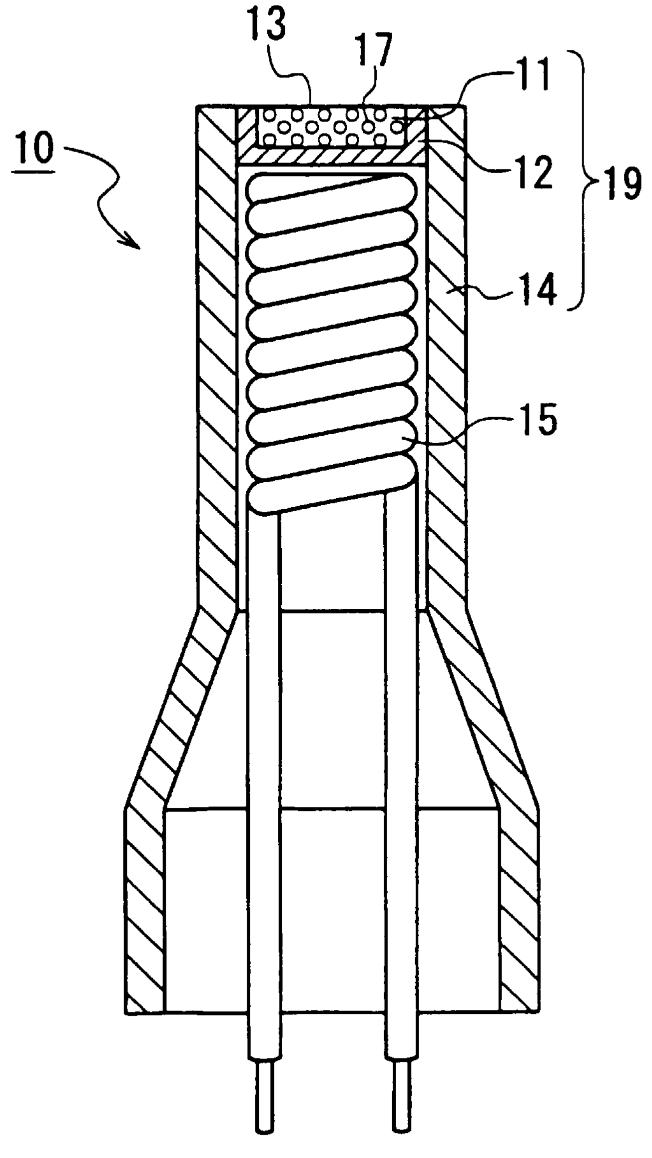


FIG. 3

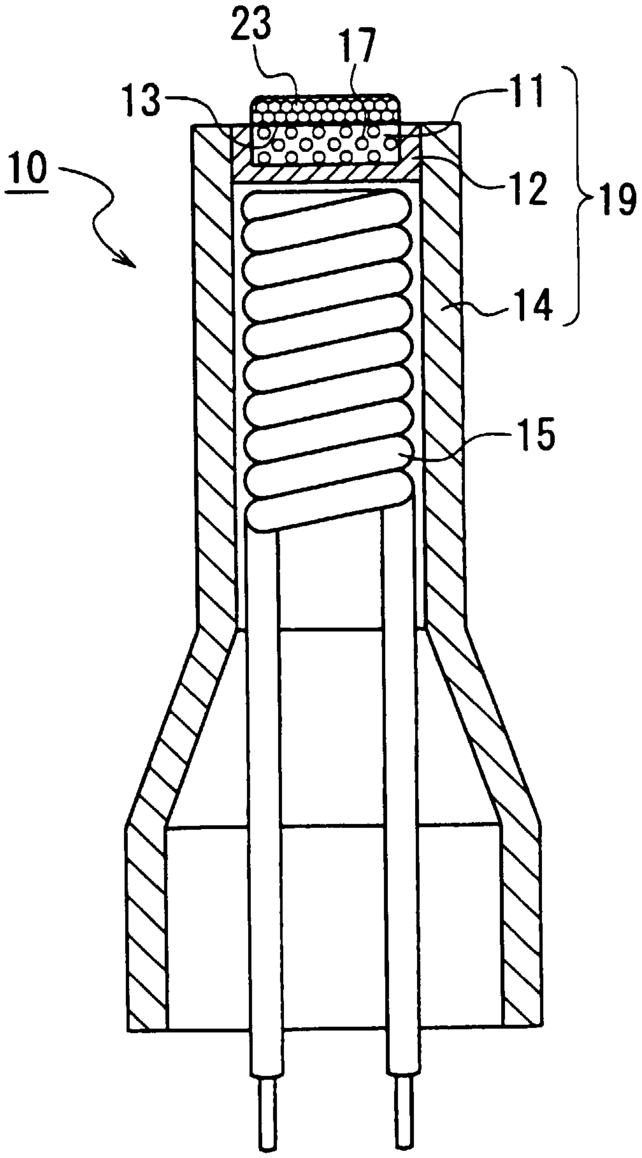


FIG. 4

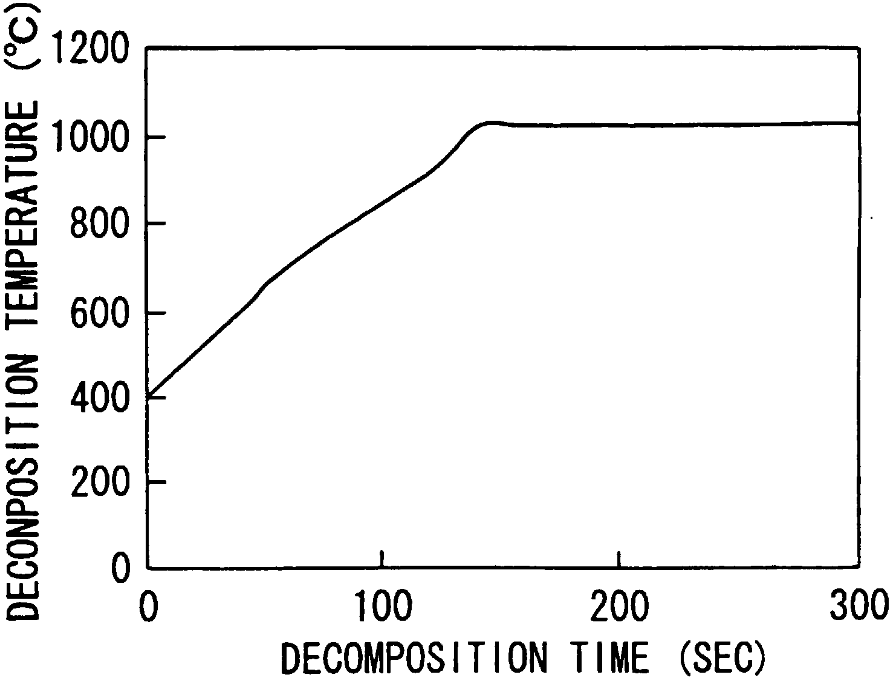

DECONPOSITION TEMPERATURE (°C)
1200
1000
800
600
400
200
0
0
100
200
300
DECOMPOSITION TIME (SEC)

FIG. 5

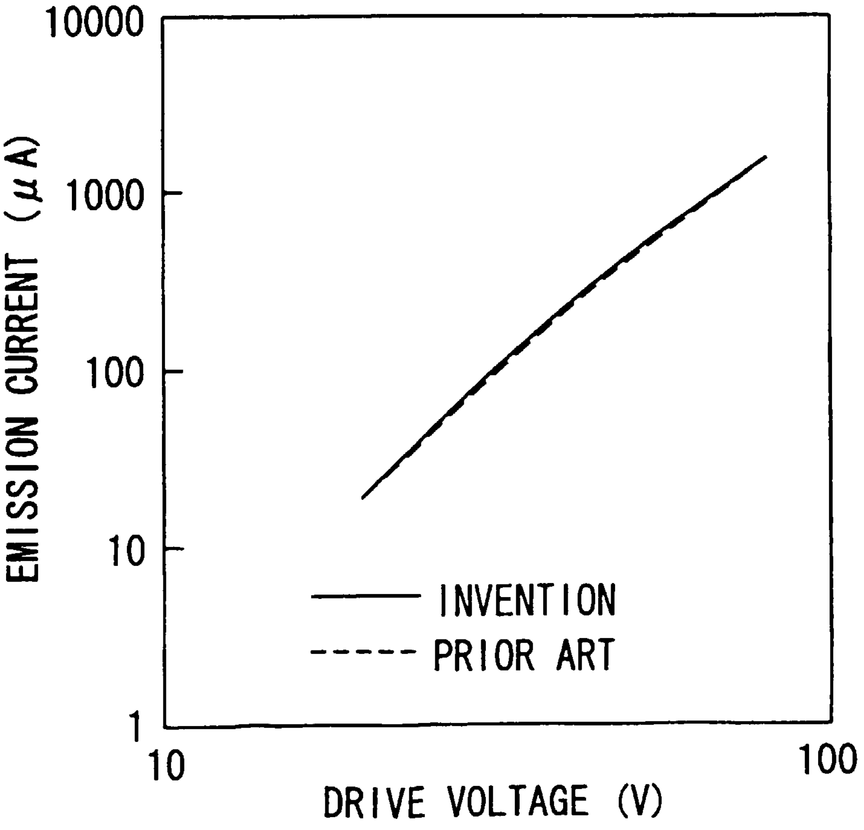

EMISSION CURRENT (μA)
10000
1000
100
10
1
10
100
DRIVE VOLTAGE (V)
INVENTION
PRIOR ART

FIG. 6

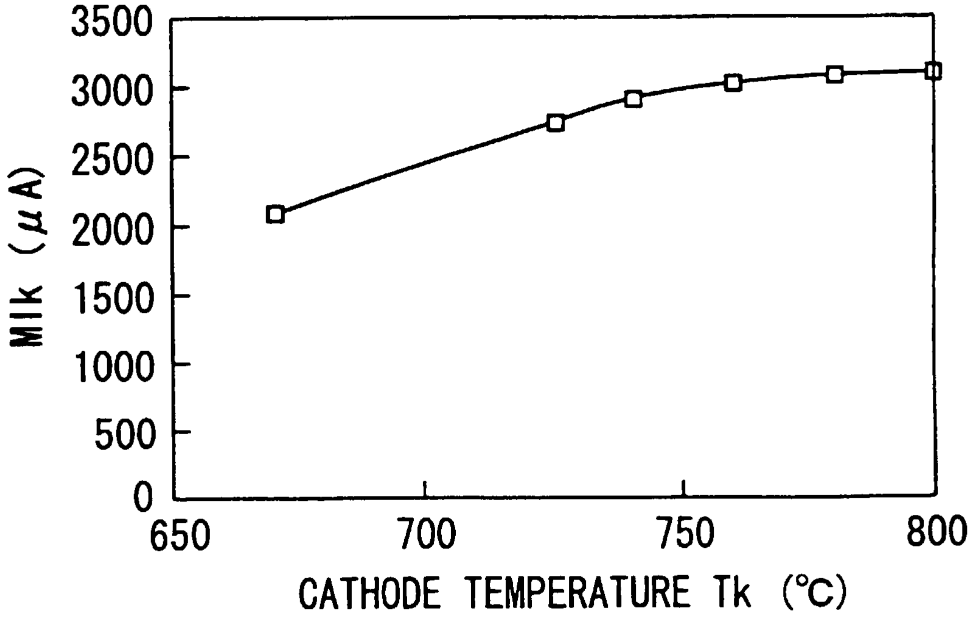
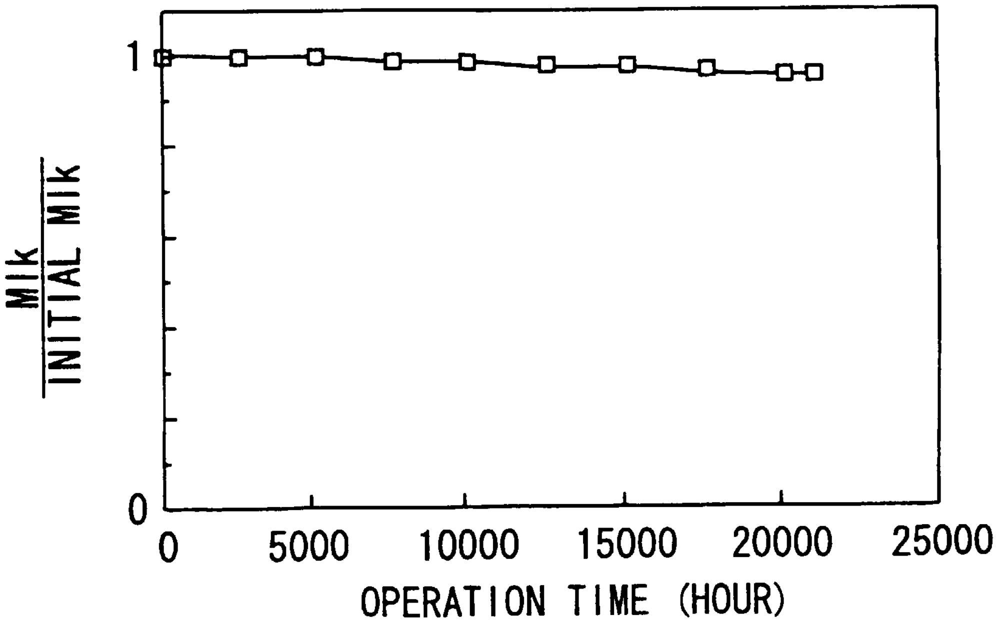

Mlk (μA)
3500
3000
2500
2000
1500
1000
500
0
650
700
750
800
CATHODE TEMPERATURE Tk (℃)

FIG. 7


Mlk / INITIAL Mlk
1
0
0
5000
10000
15000
20000
25000
OPERATION TIME (HOUR)