Aug. 21, 1962 M. WASSERMAN 3,050,420

RESISTOR

Filed Feb. 27, 1959

Fig. 1

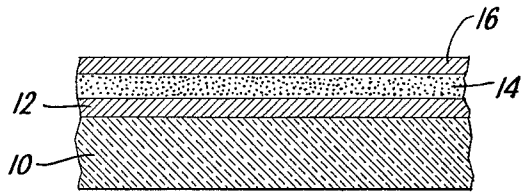
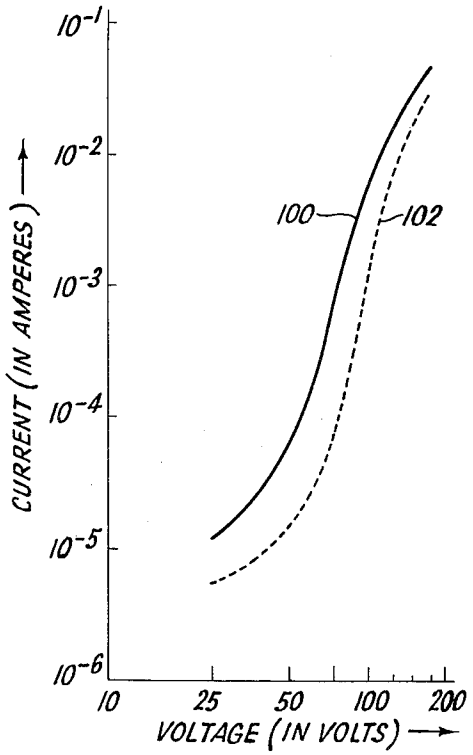


Fig. 2



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RESISTOR

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3 Claims. (Cl. 117—201)

My invention relates to electrical resistors and more particularly relates to resistors having a non-linear voltage current characteristic.

Non-linear resistors find a wide range of applications in the electronic arts. I have invented a new type of non-linear resistance wherein the resistance decreases as the voltage applied across the resistor increases. This device possesses considerable uniformity over large areas and is relatively insensitive to changes in atmospheric conditions.

In accordance with the principles of my invention, cadmium sulfide powder is mixed with a glass frit. A coating of this mixture is applied to one surface of a supporting electrode, as for example a transparent electrically conductive glass substrate. The coated electrode is then heated to fuse the frit and bond the powder to the substrate. A second electrode, as for example tin oxide, is then applied over the fused coating.

When an alternating or direct voltage is applied between the two electrodes, and the current flowing through the device is measured, it was found that the voltage-current characteristics were non-linear (i.e. did not satisfy Ohm's law). More particularly, as the voltage was increased by a relatively small amount, the resistance decreased very sharply.

Although cadmium sulfide can be photoconductive, the cadmium sulfide powder utilized in my invention is essentially non-photoconductive. It is known that cadmium sulfide activated with copper can be photoconductive. However, I have found that when the copper activator is either entirely absent or is present in only a small amount, the resultant powder is suitable for the purposes of my invention.

An illustrative embodiment of my invention will now be described with reference to the accompanying drawing wherein

FIG. 1 is a cross sectional view of a non-linear resistor in accordance with my invention; and

FIG. 2 is a graph of the current-voltage characteristics of the non-linear resistor of FIG. 1.

Referring now to FIG. 1, there is shown a glass plate **10**, one surface of which is covered with a transparent electrically conductive tin oxide film **12**. A layer **14** of cadmium sulfide powder embedded in a glass enamel is applied over film **12** and a second conductive film **16** (tin oxide) is applied over layer **14**.

In this example, the layer **14** contains between 50%–15% by weight of glass. Further, the cadmium sulfide is activated with about 2.3×10^{-4} gram atoms of copper per mole of sulfide. The layer **14** was about 9 mils thick.

A 60 cycle alternating voltage variable in steps from 25 volts R.M.S. to 175 volts R.M.S. was applied between conductive films **12** and **16**. With the resistor in the illuminated state, the voltage was varied in this manner. It was found that the current increased from about 10^{-5} amperes at 25 volts to about 4×10^{-2} amperes at 175 volts as shown by curve **100** in FIG. 2.

The same test was repeated with the resistor maintained in the dark. It was found that as the voltage increased from 25 volts to 175 volts, the current increased from about 5×10^{-6} amperes to about 3×10^{-2} amperes as shown by curve **102** in FIG. 2.

It will be noted that curves **100** and **102** have essentially the same shape but differ in absolute value, since the copper activated cadmium sulfide powder is slightly photoconductive. When the copper content is reduced, the two curves approach each other and ultimately coincide.

A process for producing cadmium sulfide powder is set forth in the copending application of G. Morrison et al., Serial No. 792,977, filed February 13, 1959. The powder utilized in my invention can be produced by this process as long as the copper content does not exceed a concentration of about 2.4×10^{-4} gram atoms per mole.

The resistor can be fabricated by first coating a glass sheet with a tin oxide conductive film in known manner. A suspension of cadmium sulfide powder and frit in a suitable vehicle, such as a mixture of hexylene glycol and isopropyl alcohol, can then be applied, as for example by spraying, over the conductive film. The structure thus formed can be fired at a temperature falling within the range 575°–700° C. for a period of about four minutes to fuse the frit and bind the powder to the glass. A second tin oxide coating can then be applied over the fused frit to complete the structure. If desired, several layers of mixed powder and frit can be applied sequentially, one layer over the other, as long as each layer is fired prior to application of the next layer. The total thickness of the layer or layers normally ranges between 3–15 mils.

Further details of a process of this type can be found in my Patent 2,937,353, issued May 17, 1960. The process set forth in this copending application utilizes photoconductive cadmium sulfide powders. However, as long as the copper concentration is adjusted within the limits taught herein, the process of said copending application can be used herein.

What is claimed is:

1. A non-linear resistor comprising a layer of essentially non-photoconductive cadmium sulfide powder embedded in glass enamel, first and second electrodes secured to opposite surfaces of said layer, said sulfide powder containing up to 2.4×10^{-4} gram atoms of copper per mole of sulfide.

2. A non-linear resistor comprising a layer of essentially non-photoconductive cadmium sulfide powder embedded in glass enamel, first and second electrodes secured to opposite surfaces of said layer, said sulfide powder containing up to 2.4×10^{-4} gram atoms of copper per mole of sulfide, said layer containing between 50%–15% by weight of glass enamel and between 50%–85% by weight of powder.

3. A non-linear resistor comprising a layer of essentially non-photoconductive cadmium sulfide powder embedded in glass enamel, first and second electrodes secured to opposite surfaces of said layer, said sulfide powder containing up to 2.4×10^{-4} gram atoms of copper per mole of sulfide, said layer containing between 50%–15% by weight of glass enamel and between 50%–85% by weight of powder, said layer having a thickness ranging between 3–15 mils.

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