FIG. 1

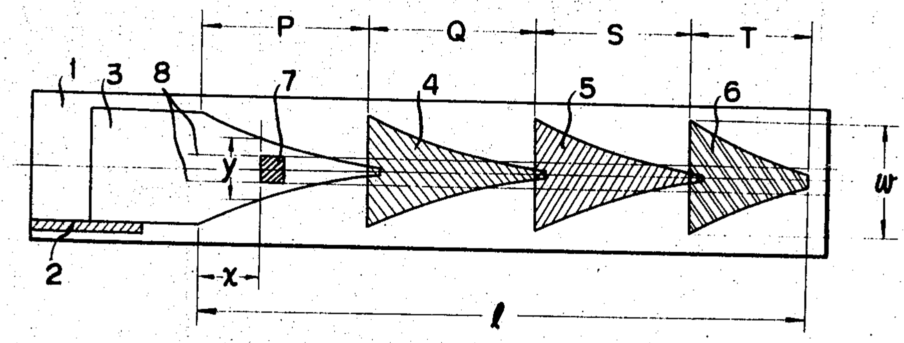


FIG. 2

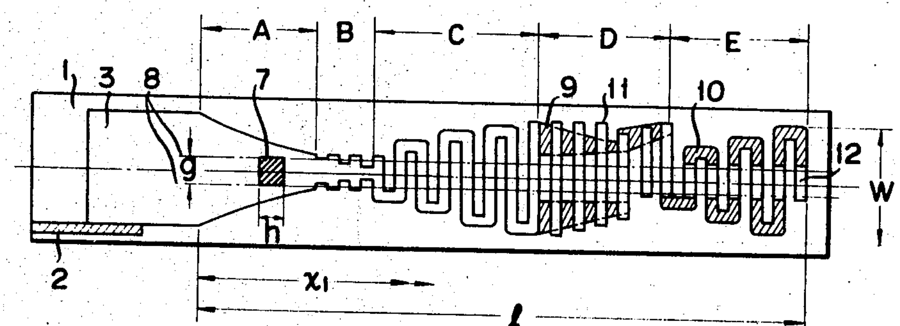
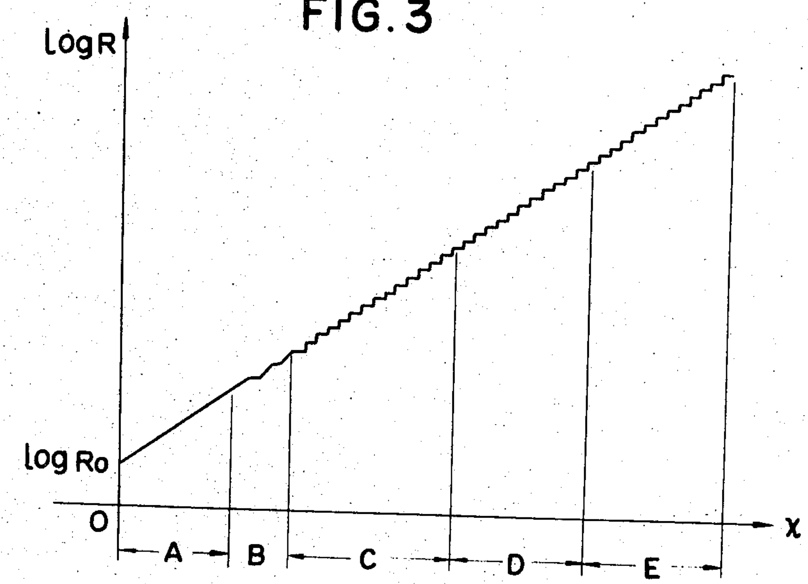


FIG. 3



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VARIABLE RESISTANCE ELEMENT WITH MULTIPLE PATTERNS FOR MEASURING INSTRUMENTS

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U.S. Cl. 338—120 8 Claims

ABSTRACT OF THE DISCLOSURE

A variable resistance element is provided in which a film of material of known resistivity is deposited on a suitable plate in varying widths, a portion of the film being in a general serpentine pattern. A slidable contact of suitable width and height engages the resistance film and is movable relative thereto in a given path for varying the resistance value in a small step-wise manner. A resistance element of extended range may be provided by the addition of resistance film areas between incomplete loops of the serpentine pattern or added to complete the loops, the material of the second film having a higher resistivity than the first film. The slide preferably, engages only those portions of the first resistance film in the predetermined path.

This invention relates to a variable resistance element particularly useful in measuring instruments, in which a thin film of resistance material is deposited on a suitable base and a sliding contact engages the resistance film and is movable relative thereto to vary the ohmic value of the element.

In conventional variable resistance elements provided for measuring instruments, a film of resistance material is applied to an insulating base plate by any one of the known processes such as, printing, vacuum deposition, sputtering, etching, etc. A slidable contact is provided for the film and movable along a guide or track. To provide a variable resistance element of useful range, such conventional elements have relied upon a changing thickness of the resistance film, or films of different resistivity interconnected end to end. As will hereinafter appear such conventional variable resistance elements have certain deficiencies which the present invention overcomes.

The present invention will be described referring to embodiments shown in the attached drawing comparing to the conventional device shown in the drawing. In the drawing:

FIG. 1 is a plan view of a conventional device;

FIG. 2 is a plan view of an embodiment of this invention; and

FIG. 3 is a diagram showing the resistivity of the embodiment of FIG. 2.

Referring now to FIG. 1 of the drawing, a conventional resistance element is disclosed in which a base plate **1** has deposited thereon a terminal **2** and resistance film areas **3**, **4**, **5** and **6**. It will be noted that the areas **3**, **4**, **5** and **6** are generally triangular in shape, the apex of one area overlapping and being connected electrically to the base of the adjacent area. A sliding contact **7** is provided for moving relative to the various resistance film areas in a path defined by the lines **8**. The desired functional change of the ohmic value of the resistance element is obtained by varying the width W of the film area. To extend the range of a conventional resistance element

shown in FIG. 1, in addition to varying the width of the area of the resistance film, the thickness of the film coating may also be varied. It will be noted in FIG. 1 that the resistance element is divided into sections P, Q, S and T, each section including one of the varying width resistance area **3**, **4**, **5** and **6** respectively. In such an element the resistivity of the material used for area **4** is higher than that used for area **3**; and for area **5** the resistivity of the material is higher than the resistivity of the material for area **4**, and the material for area **6** is of a higher resistive value than that of area **5**.

In FIG. 1, if the thickness of the deposit of the resistance film area **3** is constant and the resistivity of the area is given as $a_3\Omega/\square$ and the width of the resistance film at the position of x is set to be $y=f(x)$ then; the resistivity thereof when the sliding contact is at the position of x becomes approximately

$$R=a_3\int_0^x \frac{dx}{y}+R_0 \qquad (1)$$

In the above formula R_0 is the resistance when x is 0. The following is an example of the functional resistance.

$$\log R/RO=kx \qquad (2)$$

In the above formula k=constant
From the Formula 2,

$$dR/dx=kR \qquad (3)$$

can be derived, and also from the Formula 1,

$$dR/dx=a_3/y \qquad (4)$$

can be derived, and therefore from the Formulae 3 and 4

$$kR=a_3/y \qquad (5)$$

can be obtained. In other words, the possible resistance range when x is equal to P can be determined by the width of y at the position x. There is necessarily a restriction in the production of resistance films as to the width such film may take. To extend the range of values it is necessary to serially connect the film area **4** which could be deposited at a different thickness than that of area **3**, or film area **4** could be deposited from a material having a higher resistivity than that used for area **3**. With deposits made of different materials and different thicknesses production costs are increased. In addition, a resistance element made of different materials and/or thicknesses of film do not provide a smooth and continuous change in the resistance value, particularly in those area where the resistance films of different thicknesses and different materials are serially joined. Thus the changes which do occur when the sliding contact moves from one resistance area to the other makes such a resistance element unsuitable for small measuring instruments particularly when such an element is used in exposure meter circuit.

The object of this invention is to provide a variable resistance element for measuring instruments in which wide range of resistance values is obtainable in a continuous small step-wise fashion throughout its entire range.

In accordance with this invention a resistance element is provided in which the width of the resistance film area is reduced or tapered, the range of the element being extended through the use of a saw-tooth pattern and a serpentine pattern of loops with increasing width of the resistance film. The range of the element is further extended by transverse spaced strips of film, the spaces between the ends of the strips being filled in or interconnected by film strips of a material having a higher resistivity than the first film; the sliding contact being confined to a guide so that the sliding contact engages the resistance film made of the first material in all positions.

Referring now to FIG. 2 of the drawings, the same reference numerals are used for the same elements as illustrated in FIG. 1. The resistance element according to the invention is divided into sections A, B, C, D and E. The same resistance material that is deposited to form the area **3** is used to deposit the square tooth pattern in section B, the serpentine pattern in section C and the transversely disposed, spaced film elements **11** and **12** in sections D and E, respectively. The sliding contact **7** has vertical width g and horizontal length h, the horizontal width being such that as the sliding contact is moved in its path **8**, the contact will engage the next tooth, loop or transverse element as it is moved along before leaving the resistance film element it is passing over. It will be noted from FIG. 2 that the spaces between the outer ends of the transverse elements **11** are filled in by a resistance film **9**, of varying width and area, the material of the resistance film **9** having a higher resistivity than the material for film area **3**. In section D of the resistance element, it will be noted that the areas between both ends of the elements **11** are filled in on the left side of the section while on the right side of the section only the areas between the upper ends of the elements are filled in with the higher resistivity film. At the beginning of section D, the elements **11** while of varying lengths are approximately equal, but the transverse elements at the other end of section D vary considerably in length. In section E, the resistance film **10** is illustrated as completing serpentine loops with the short transverse elements **12** extending across the path **8** of the sliding contact **7**. As previously indicated, the material for those areas designated **9** and **10** in the drawings is the same and is formed from material having a higher resistivity than that used in forming the elements **3** and **12**.

It will be noted from FIG. 2 that the region in which resistance films can be provided is restricted to the length l and the width W. In the section A of FIG. 2, the form of the resistance area **3** is very similar to the form of the resistance area **3** in FIG. 1. In this section, the change in the vertical width of the film provides a functional or logarithmic resistance value. In section B of the resistance elements, the change in resistance is brought about by the square tooth form of the deposited film, the deposited layer being for the most part in engagement with the sliding contact **7** as it moves along its path.

The resistance film of section B is extended into section C by a serpentine pattern of increasing amplitude, the distance between the loops being held approximately constant. From section C to section D, the range of the resistance element is extended by the transverse elements **11** connected to the areas of the resistance film **9** made of the second material, the areas **9** being of decreasing width comparable to the film area in section A. From section D to section E, the range of resistance values is still further extended by the serpentine pattern made up of the elements **10** and **12**, the material for the elements **12** being the same as that provided for the film area **3**, the amplitude of the loops increasing as in section C. Thus a wide range of resistance value is obtained having a logarithmic variation as seen in FIG. 3.

In constructing the film patterns illustrated in sections D and E of the resistance element, the resistance film **3** may be deposited either partially or wholly over the surfaces of the film areas **9** and **10**, or the two film areas could be connected by abutting one against the other.

It will be readily appreciated that the resistance films provided in areas A through E may be deposited at one and the same time, while the resistance film elements **9** and **10** may be deposited by a second process. When the change in resistance of the section P of FIG. 1 is compared with the change in resistance of sections A, B and C of FIG. 2, such changes are quite extensive although the resistance film in sections A, B and C of FIG. 2 is made of the same material as that in section P of FIG. 1. The extended range by adding sections D and E of FIG. 2 is quite extensive when compared with the extended ranges added by section Q of FIG. 1. Sections P and Q of FIG. 1 and sections A through E of FIG. 2 are made of two materials having different resistive values as herein before explained. Thus through the use of only two resistive materials the range of resistive values of an element is materially extended.

The following are the numerical examples. When the following conditions such as

$$w=3 \text{ mm.}$$

the minimum width of the resistance film=0.05 mm.,

$$g=0.3 \text{ mm.}$$

$$h=0.5 \text{ mm.}$$

the width of the film pattern=0.05 mm. the pitch separation of the film pattern=0.1 mm.

$$0.05 \text{ mm.} \leqslant y \leqslant 3 \text{ mm.}$$

$$R_0=12\Omega$$

resistivity per unit area of resistance film **3** $a_3=4.5\Omega/\square$, the form of the function of the variable resistance=in FIG. 1, $\log R/R_0=x/8$, and in FIG. 2 $\log R/R_0=x_1/8$, are given, the following values can be obtained.

IN THE CASE OF FIGURE 1

	Zone			
	P	Q	S	T
Range of resistance	12Ω–720Ω	720Ω–43KΩ	43KΩ–2.6MΩ	2.6–36MΩ
Magnification in each section	60_x	60_x	60_x	14_x
Resistivity per unit area	4.5Ω/□	270Ω/□	16KΩ/□	22KΩ/□
Kind of resistance (Accumulation)	1	2	3	4

IN THE CASE OF FIGURE 2

	Zone			
	A, B	C	D	E
Range of resistivity	12Ω–720Ω	720Ω–20KΩ	20Ω–720KΩ	720kΩ–36MΩ
Magnification	60_x	28_x	36_x	50_x
Resistivity per unit area	4.5Ω/□		9KΩ/□	
Kind of resistivity (Accumulation)	1		2	

As is apparent from the above given data, in the case of the variable resistance from 120Ω to 20KΩ through 720Ω, two kinds of resistance films must be employed in accordance with the conventional system (FIG. 1), but in accordance with this invention it can be obtained by using only one kind of resistance film. In the case of the variable resistance from 12Ω to 720KΩ, through 43KΩ, in FIG. 1 three kinds of resistance films are required, while in the FIG. 2, two kinds of resistance-films are required. On the other hand, in the case of 12Ω to 36MΩ through

2.6MΩ in FIG. 1 four different film materials are required, and in FIG. 2 only two film materials are required. Moreover, when the resistance film is formed by vacuum evaporation, it is difficult to prepare a thin film beyond 10KΩ/□. In accordance with the conventional system the resistance up to 1.6MΩ can be obtained at best, but in accordance with this invention it is possible to obtain a resistance ranging as high as 40MΩ.

FIG. 3 shows the relative resistance value relative to the contact displacement distance x as related to the sections in sections C through E of FIG. 2. The small stepwise changes in the resistance value as provided by this invention permits practical use of the invention in small measuring instruments. As apparent from FIG. 2, the portions of the resistance film within the path **8** of the sliding contact are of the same material, so that a uniform thickness of deposit may be maintained. The thickness of the film may thus be selected for durability to withstand the frictional wear generated by the sliding contact.

Any changes resulting from frictional wear of the film or the sliding contact would not seriously effect the resistance values obtainable since such changes are uniform throughout the entire range of contact movement. The resistance film **9** and **10** may be of less durable quality since the sliding contact does not engage these areas. With a durable material forming the film **9**, and the resistance engaged by the sliding contact, any change due to wear would only be between two of the transverse elements **11** representing but one step in the resistance values obtainable. The same would be true if the film **10** were engaged by the sliding contact in section E.

It becomes apparent that with the arrangement of the first resistance film in a triangularly formed area wherein the width gradually decreases and then is formed into a saw-toothed pattern which in turn becomes serpentine in form with loops of increasing amplitude, that a logarithmic variable resistance is provided. To extend the range of resistance values obtainable from sections A, B, and C, the first resistance film is deposited as spaced strips beginning in section D, with the second resistance film deposited between such strips, the areas of the second film decreasing in width in the same manner as the first resistance film in section A. The second resistance film is further used to complete the serpentine loops in section E, the width or amplitude of the loops gradually increasing. There is thus provided a variable resistance element having a wide range, logarithmic variation of resistance values with the displacement of the contact.

What is claimed is:

1. A variable resistance element, comprising
- a base plate of insulating material,
- a first film of a known resistivity per unit area on said base plate in patterns of different configurations in different sections of the base plate,
- a contact movable relative to the first resistance film in a predetermined path and engaging the first resistance film, and
- a second resistance film of a resistivity other than that of the first film on the base plate and connected to the first film in selected sections of the base plate, the second resistance film being outside the path of the contact.

2. A variable resistance element, comprising
- a base plate of insulating material,
- a first film of resistance material having a known resistivity per unit area deposited on said base in different patterns in different sections of the base plate,
- a terminal member connected to one end of the resistance film in a first section of the base plate,

- the pattern of the resistance film being triangular in the first section and saw-toothed in a second section of the base plate, the saw-toothed pattern being integral at one end with the apex of the triangular film pattern, the film pattern in a third section being serpentine and integral at one end with the other end of the saw-toothed film pattern, and
- a sliding contact movable relative to the resistance film and engaging the film, in a predetermined path, the width of the contact being approximately equal to the width of the saw-toothed pattern and the length of the contact being slightly greater than the distance between the loops of the serpentine pattern transverse of the predetermined path.

3. A variable resistance element according to claim **2**, wherein the first resistance film is deposited in a fourth section of the base plate in spaced strips transverse to the predetermined path of the contact and engageable thereby, and
- a second film of resistance material having a different resistivity per unit area than the first film and deposited on the base plate between the spaced resistance strips and integral therewith.

4. A variable resistance element according to claim **3**, wherein the first resistance film is deposited in a fifth section of the base plate in spaced strips transverse to the predetermined path of the contact and engageable thereby, the spaced strips being slightly longer than the width of the predetermined path, the second film of resistance material being deposited to join the ends of the transverse spaced strips of the first film to form therewith a serpentine configuration.

5. A variable resistance element according to claim **3**, wherein the spaced strips of the first resistance film in the fourth section are of unequal lengths, the second resistance film between the spaced strips being between both outer ends of the strips adjacent the third section and between the outer ends of the strips on one side of the predetermined path of the contact adjacent the fifth section.

6. A variable resistance element according to claim **2**, wherein the loops of the serpentine pattern of the first resistance film in the third section are of increasing amplitude.

7. A variable resistance element according to claim **3**, wherein the loops of the serpentine pattern of the first resistance film are of increasing amplitude, and the second resistance film between the spaced resistance strips in the fourth section is of decreasing width.

8. A variable resistance element according to claim **4**, wherein the loops of the serpentine pattern of the first resistance film in the third section are of increasing amplitude, the second resistance film between the spaced resistance strips in the fourth section is of decreasing width and the second resistance film completing the serpentine configuration in the fifth section forms loops of increasing amplitude.

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