July 12, 1938. C. A. BIELING 2,123,227

PIEZOELECTRIC DEVICE

Filed June 26, 1935

FIG. 1

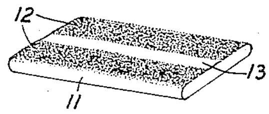


FIG. 6

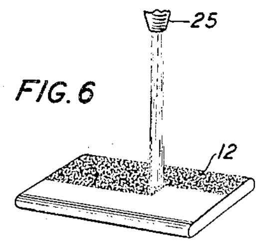


FIG. 2

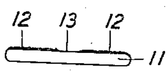


FIG. 3

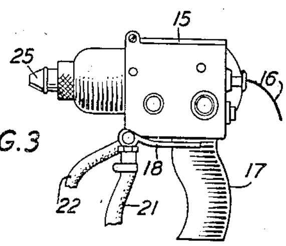


FIG. 4

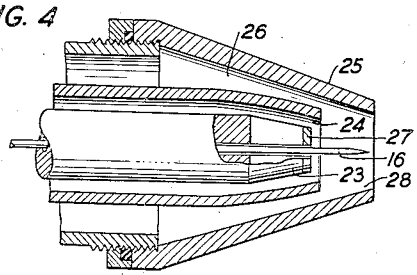


FIG. 5

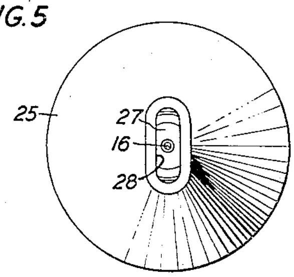
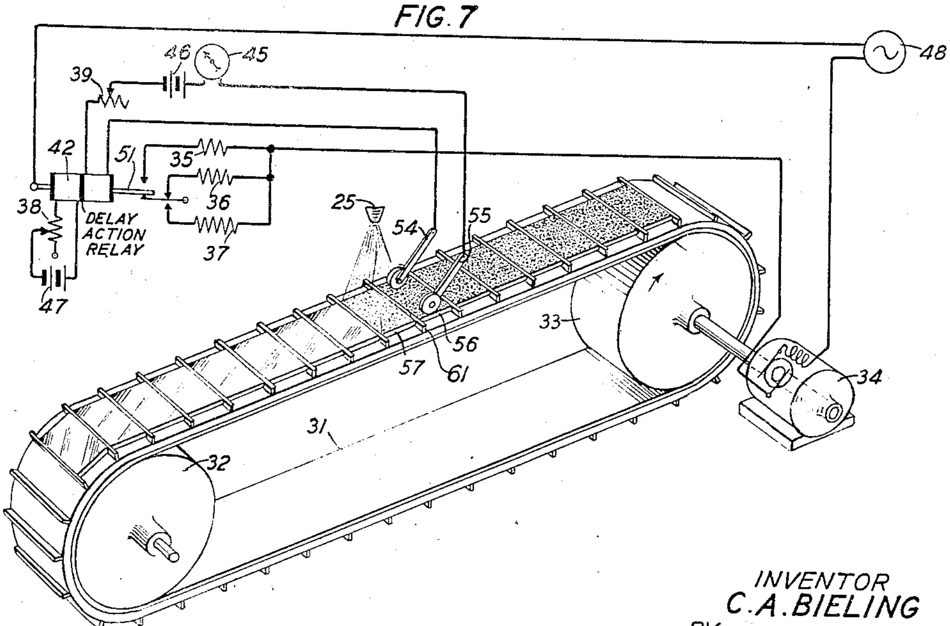


FIG. 7



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UNITED STATES PATENT OFFICE

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PIEZOELECTRIC DEVICE

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Application June 26, 1935, Serial No. 28,414

5 Claims. (Cl. 171—327)

This invention relates to piezoelectric elements and particularly to metallic coatings for such elements.

An object of the invention is to improve the performance of piezoelectric crystals.

Another object of the invention is to facilitate the conductive association of piezoelectric crystals with electrical circuits.

A more specific object of the invention is to provide a metallic coating on the surface of a piezoelectric crystal.

Piezoelectric crystals are, as is well known, commonly used as elements in electrical circuits where a constant frequency is essential and are of increasing importance in connection with wave filters and similar electrical networks. When the piezoelectric elements are used in such electrical circuits, it is necessary, of course, that some means be provided whereby the piezoelectric element may be operatively associated with the circuit. It is common practice to provide for this purpose a metallic coating on one or more of the surfaces of the piezoelectric crystal element, this coating being electrically connected to the crystal surface to which it is applied. The desired conductors of the circuit may then be attached, for example by soldering, to the coatings. These coatings are commonly referred to as the electrodes of the crystal.

Certain somewhat stringent requirements exist with respect to coatings of the nature referred to above. For example, for some purposes in order that the coating may perform its role of an electrode satisfactorily, it must extend evenly over the surface of the crystal and must be in intimate contact therewith. Moreover, the process of applying the coating must be such that the structure of the crystal is not damaged. The coating, in addition to its use as an electrode may be utilized to regulate certain characteristics of performance of the crystal, as outlined for example in Hulbert United States Patent 1,848,630 and the process of applying the coating should therefore be of such a nature that the thickness of the coating be uniform and easily regulated within narrow limits.

According to a feature of the invention the metallic coating is applied to the surface of a piezoelectric crystal element by the spraying process commonly referred to as the "Schoop" process. It has been found that a coating applied by this process meets the requirements referred to above in an economical and otherwise satisfactory manner particularly with respect to Rochelle salt crystals although the process may also be used to advantage in coating other types of piezoelectric crystal elements. Methods previously followed in the application of electrode coatings to piezoelectric crystal elements have proven generally unsatisfactory when used in connection with Rochelle salt crystals. In some instances where the known method involved considerable heat, dehydration of the crystal resulted while, in instances of methods involving less heat, it was found difficult to obtain a firm adherence between the coating and the crystal. However with respect to the "Schoop" process, the Rochelle salt body is not damaged in any way thereby, the resulting coating adheres satisfactorily and the electrical characteristics of the piezoelectric device produced thereby are such that the device is particularly adaptable for use in electrical filters and similar circuits. The value of "r", for example, is comparatively low while the value of "Q" is substantially higher than that obtained with Rochelle salt piezoelectric elements, the electrodes of which have been applied by other known methods. (The terms "r" and "Q" are derived from consideration of the so-called equivalent electrical circuit of the piezoelectric device which circuit is considered to comprise an inductance in series with a capacity C_1 and shunted by a capacity C_0, "r" being the ratio of C_0 to C_1 and "Q" being the ratio of the reactance to the resonance resistance of the equivalent circuit referred to. The theory and derivation of the equivalent electrical circuit of piezoelectric devices is explained on page 45 of "Quartz Resonators and Oscillators" by P. Vigoureux published by His Majesty's Stationery Office, London.)

In accordance with another feature of the invention refinements are introduced in the design of the "pistol" used whereby it is better adapted to the application of the coating in the accurate and easily regulated manner required.

In accordance with an additional feature of the invention a novel conveying arrangement is utilized for feeding the crystal plates to the spraying device whereby the thickness of the coating may be automatically controlled within certain narrow limits.

A thorough understanding of the invention and of the various advantageous features thereof may be gained from consideration of the following detailed description and the annexed drawing in which:

Fig. 1 is a perspective view of a piezoelectric crystal plate, the surface of which has been coated by the process contemplated by the present invention;

Fig. 2 is an end view of the crystal shown in Fig. 1;

Fig. 3 is a side elevation of a Schoop's pistol of the type adapted for the coating process contemplated;

Fig. 4 is an enlarged sectional view of the nozzle of the pistol shown in Fig. 3;

Fig. 5 is an end view of the nozzle end shown in Fig. 4;

Fig. 6 is a perspective view of a piezoelectric crystal in the process of being coated; and

Fig. 7 is a schematic showing of a conveying arrangement adapted to be used in the coating process contemplated by the invention.

Referring now to the drawing, a piezoelectric plate is shown in Fig. 1 which may be, for example, of the Rochelle salt type. A metallic electrode coating 12 is shown applied to the upper major surface of the plate, a portion 13 of the plate being left uncoated, thereby effectively separating the coating 12 into two distinct sections. If desired a coating of similar or different pattern may be applied to the lower major surface of the plate as well as to the ends and sides thereof.

As shown most clearly in Fig. 2, certain of the edges of the plate have been rounded out, it having been found that this procedure is effective in preventing fracturing of the coating and chipping of the crystal itself during the preparation and use of the plate.

In accordance with the invention the coating 12 is preferably applied to the plate by means of a Schoop's pistol of the general type shown in Fig. 3. This pistol comprises a casing 15 which encloses a feeding mechanism (not shown) to which wire 16 is supplied. A pistol-grip handle 17, control trigger 18 and supply pipes 21 and 22 are also provided.

In accordance with the usual method of operation of the pistol, the wire 16 is fed through an opening in nozzle 23 (Fig. 4) and is reduced to a liquid state by an oxy-hydrogen flame formed by the combustion of these gases in chamber 24. The metal particles are then projected through orifice 28 of cap 25 at a high velocity, air, supplied under pressure through chamber 26, forcing the particles out through the orifice.

According to a feature of the invention orifice 28 provided in cap 25 is not round but is, as shown most clearly in Fig. 5, elongated or flattened. It has been found that the provision of an orifice of this particular shape greatly enhances the value of the pistol for fine work such as that involved in crystal coating as it permits the application of the particles in a thin well defined pattern much as if a small paint brush were used. Coatings may therefore be applied in separate distinct sections as shown in Fig. 1, whereas the use of circular orifices of the type previously provided on Schoop's pistols does not permit this fine definition of pattern.

Further, referring again to Fig. 4, the operation of the pistol has been improved and made more adaptable to fine work such as crystal coating by providing a tip 27 on nozzle 23 which is of a material that is not damaged by the intense heat of the oxy-hydrogen flame. It has been found after considerable investigation that materials having a composition similar to that of the commercial material known as "Carballoy" are suitable for the tip. In Schoop's pistols of the type previously used, it has been observed that the tips became damaged in use by the flame and soon presented a distorted orifice. While this did not prove particularly troublesome in coarse work, it practically precluded the use of the pistol for finer work such as crystal coating as it is paramount, if uniform particle size and definite coating thickness are to be attained, that the orifices of the nozzle and of the cap remain the same.

It has been observed further that, with respect to the type of pistols previously used, the uniformity of the coating was destroyed due to the nozzle partially clogging particularly at low velocities. Applicant has found, after considerable investigation that this trouble can be overcome by providing a particularly smooth surface, such as obtained, for example, by chromium plating, on the inside surface of cap 25.

Fig. 6, which shows a piezoelectric plate in the process of being coated, well illustrates the adaptability of a pistol provided with the refinements referred to above to fine work such as crystal coating. As shown the particles are projected in a definite well defined pattern thereby permitting the production of separate section coatings of the nature shown in Fig. 1. The thickness of the coating produced, moreover, is uniform and easily regulated.

Referring now to Fig. 7 there is shown, schematically, a conveying arrangement adaptable for use in the crystal spraying process referred to above. The arrangement contemplates the provision of a conveyor belt 31 which is supported on drums 32 and 33. A driving motor 34, fixed resistances 35, 36 and 37, variable resistances 38 and 39, polarized relay 42, meter 45, batteries 46 and 47 and a power source 48 are also included.

It will be noticed that one or more of the three fixed resistances 35, 36 or 37 is included in the operating circuit of driving motor 34, the particular resistance or resistances included depending upon the position of armature 51 of relay 42. When armature 51 is in the neutral position of Fig. 7, resistance 36 is included in the motor circuit, when the armature is biased in the "down" position resistance 37 is included in the circuit and when the armature is biased in the "up" position resistances 35 and 36 in parallel are included in the motor circuit. The circuit is so arranged that, when resistance 36 is included in the motor circuit, motor 34 will operate at a predetermined "normal" speed. When the higher resistance 37 is included, however, the speed of the motor will decrease and when resistances 35 and 36 are included in parallel the resulting lower effective resistance in the motor circuit will result in an increase in the operating speed of the motor.

The left-hand winding of relay 42 is energized by current from battery 47, the strength of this energizing current being varied as desired by operation of rheostat 38 while the right-hand winding of the relay is energized by current from battery 46, the strength of this current being varied by operation of rheostat 39. The last mentioned energizing circuit includes contact members 54 and 55, each of which is provided with a roller which is adapted to be placed in engagement with a coated piezoelectric plate. The coating of the plate may in this way be associated with the energizing circuit for the right-hand winding of relay 42. The arrangement of the relay circuit is such that, if the resistance of a coating be within certain predetermined limits thereby indicating the correct coating thickness, the current flowing in the energizing circuit will be such that armature 51 will not be moved from its normal position shown in Fig. 1. Should, however, the resistance of the coating be less than the predetermined minimum, thereby indicating a coating of too great a thickness, the increase of current flowing through the right-hand winding of relay 42 will cause armature 51 to swing to the "up" position in which position, as pointed out above, resistances 35 and 36 in parallel are connected in the motor circuit and the speed of motor 34 is increased. Conversely, should the resistance of the coating exceed the predetermined maximum limit thereby indicating a coating of insufficient thickness, armature 51 is moved to the "down" position and the higher resistance 37 is brought into the motor circuit.

In order to illustrate the operation of the arrangement of Fig. 7, let us assume that piezoelectric plate 56 has been coated and that plate 57 is in position under the spray emanating from nozzle 25 of the Schoop's pistol. In order to simplify the description, it is assumed that the nozzle is so adjusted in this instance that the path of the particles sent forth is sufficiently extended to cover the entire plate. Parts of the plate to be left free of the coating may in such an instance be protected by a mat.

The energizing circuits for the right-hand and left-hand windings of relay 42 having been properly adjusted by manipulation of respective rheostats 39 and 38, members 54 and 55 are placed in contact with the coating of plate 56 and driving motor 34 is set into operation thereby causing rotation of drum 33 and movement of belt 31 and plate 57 under the spray of metal particles projected by the gun. Assuming, first, that the thickness of the coating on plate 56 is correct within the predetermined limits, the resistance of the energizing circuit of right-hand winding of relay 42 remains such that armature 51 is not moved from its normal position, the resistance of the motor circuit is not changed and the motor continues at the predetermined "normal" speed.

Assuming, however, that the thickness of the coating on plate 56 is too great, obviously the speed at which the belt is moving should be increased so that plate 57 and the plates following it will be moved through the spray at an increased speed in order that the thickness of the coating applied to these plates may be "cut down". This desired increase in speed is automatically attained as the decreased resistance in the energizing circuit of the right-hand winding of relay 42 due to the undue thickness of the coating results in moving armature 51 to the "up" position, in which position, as previously pointed out, resistances 35 and 36 in parallel are connected into the motor circuit. The resulting drop in the resistance of the motor circuit results in an increase in speed of motor 34 and a corresponding increase in the speed of the conveying belt.

Had the coating thickness been found insufficient the proper remedy would, of course, have been to decrease the speed of the belt in order that the subsequent plates might receive a coating of proper thickness. In such an instance the increase of resistance in the energizing circuit of the right-hand winding of relay 42 would be effective to swing armature 51 to the "down" position, thereby connecting resistance 37 in the motor circuit. The magnitude of resistance 37 is higher than that of resistance 36 and the increase of resistance in the motor circuit would, of course, cause a decrease in the operating speed of motor 34.

Insulating strips 61 are placed on the belt between each two adjacent piezoelectric plates. Contact members 54 and 55 engage these strips after leaving one plate and before engaging the subsequent plate. While a momentary interruption of the energizing circuit of the right-hand winding of relay 42 results from engagement of the contact members with these insulating strips, relay 42 is slow-to-operate and the armature does not change its position during the comparatively short time the circuit is interrupted.

While certain specific embodiments of the invention have been selected for detailed description, the invention is not, of course, limited in its application to the specific embodiments described. These embodiments should be considered illustrative of the invention rather than restrictive thereof.

What is claimed is:

1. A piezoelectric crystal plate having metallic coating formed integral therewith and having a rounded edge between a major and another surface thereof to prevent fracturing said coating, the coating on said major surface comprising an electrode for said plate.

2. A piezoelectric crystal plate having metallic coating formed integral therewith, an edge of said plate being rounded between two surfaces thereof to prevent fracturing of said coating.

3. A piezoelectric crystal plate having metallic coating formed integral therewith, an edge of said plate being rounded between two surfaces thereof to prevent fracturing of said coating, the coating on at least one of said surfaces being separated into a plurality of sections to form a plurality of electrodes.

4. A piezoelectric crystal plate having metallic coating formed integral therewith, an edge of said plate between a major and another surface thereof being rounded to prevent fracturing of said coating.

5. A piezoelectric crystal plate having metallic coating formed integral therewith, an edge of said plate between a major and another surface thereof being rounded to prevent fracturing of said coating, the coating on said major surface being separated into a plurality of sections to form a plurality of electrodes.

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