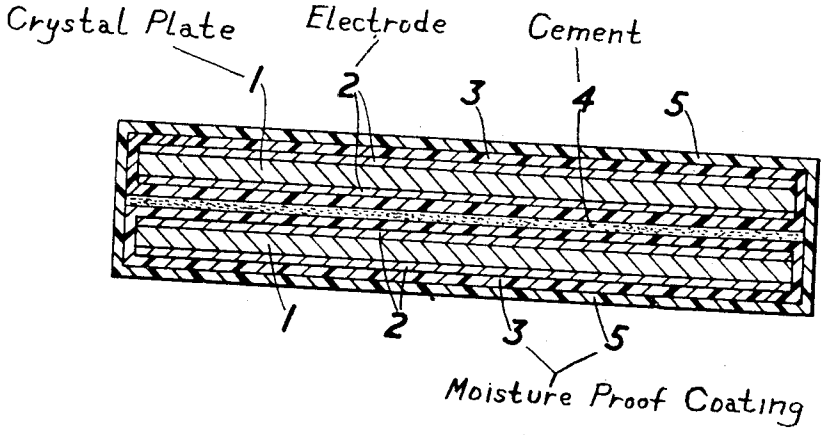
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PIEZO-ELECTRIC DEVICES

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PIEZO-ELECTRIC DEVICES

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This invention relates to piezo-electric devices of the type employing two or more layers of material which are secured together. More particularly, this invention relates to an improved method of making a multi-layer piezo-electric device and also to the improved device produced by such method.

A well known piezo-electric assembly, widely used in transducers such as microphones, gramophone pickups, sound reproducers and like, is a "Bimorph" construction in which two plates of a piezo-electric substance, having electrodes on their surfaces, are cemented together. More complicated constructions using three or more piezo-electric elements secured together are also known; for the purpose of this present specification the term "Bimorph" is to be taken as including not only the two-element assembly, but also the more complicated ones.

It is important that the performance of piezo-electric devices should not deteriorate with time and with certain materials which have desirable piezo-electric properties this requires that the piezo-electric assembly should be adequately sealed against the entrance of moisture and the sealing must be effected while the assembly is dry.

The drying and sealing of Bimorph assemblies is difficult in some cases owing to the fact that the piezo-electric material is crystalline and may contain water of crystallisation and may be hygroscopic. The problem is most acute with Rochelle salt, which is the piezo-electric material most used for transducers because of its high piezo-electric efficiency.

Some indication of the difficulty of moisture-proofing Rochelle salt Bimorphs can be seen from the properties of the material itself. At 20° C. crystalline material is stable in an atmosphere of which the relative humidity lies in the range of 36 to 85%; outside this range the material will either dehydrate or dissolve. With increasing temperature this safe range of humidity narrows considerably; at 57° C. Rochelle salt dissociates irreversibly.

In the past Rochelle salt Bimorphs have been made by cementing the crystal elements together, suitable electrodes being provided, and thereafter coating the Bimorph by a metallic and/or paint-like coating of a moisture-proof nature. Despite this, the resulting Bimorphs show considerable variation, from sample to sample, of insulation resistance and dielectric constant and, as a result, considerable variations of stability and permanence in use.

The present invention is concerned with a method of manufacturing piezo-electric Bimorphs which have improved resistance to the ingress of water, and which have in consequence improved durability and stability, and can be used in rather more adverse circumstances than devices of known type. The invention can be applied satisfactorily to the manufacture of Bimorphs employing Rochelle salt or other materials, but since Rochelle salt presents the greatest difficulties in practice it is with that material the greatest advantage is obtained.

An improved Bimorph made in accordance with the method is shown in vertical section in the accompanying drawing.

In accordance with the invention in the manufacture of a Bimorph, adjacent faces of the component plates of the Bimorph are provided with a close adherent layer of a moisture-proof material, extending at least to the edges of the surface, before the said surfaces are secured together. Preferably the Bimorph is made by taking two plates of the assembly, providing an electrode means on at least one surface of each of said plates, coating said plates completely with a moisture-proof coating, and thereafter securing said surfaces together.

The present invention has arisen from long and careful investigations into the electrical characteristics of commercially made Bimorphs. These Bimorphs consist of two similar rectangular crystal plates which after the single plates have been electroded, are cemented together with a melt of Rochelle salt. The cement is prepared by melting Rochelle salt in its water of crystallisation and supercooling the melt. The resulting high viscous melt is a mixture of potassium and sodium tartrate which being highly hygroscopic avidly absorbs water from the atmosphere or from its surrounds. Thereafter, the composite assembly is coated with a moisture-proof compound so as to prevent the ingress of moisture.

In use, any penetration of the moisture-proof coating leads to more or less failure of the transducer, and so much research has gone into the preparation and application of the coating. Notwithstanding this, in the large numbers of transducing elements made, examples of low insulation resistance still occur.

Careful analysis and observation which we have made of transducing elements of low resistance have shown that a Bimorph of this type, when subjected to adverse atmospheric conditions, shows signs of breakdown first in the region of the cement layer starting at the edge of the layer, and progressing further over the whole area of the cemented surfaces.

The Rochelle salt crystal looses water of crystallisation at a relative humidity of 36% or under at room temperature, due to the higher vapour pressure in the crystal. The dehydration is visible by the appearance of a deposit of white powder starting on the surface of the crystal. It has been found that the deposit of white powder starts first adjacent the edges of the cement layer indicating that the Rochelle salt cement is more sensitive to the ambient atmospheric conditions than the crystal itself. At a relative humidity of 85% or more and at room temperature the crystal absorbs water and is irreversibly dissolved. The dissolution proceeds slowly and is interrupted when the humidity falls below 80% and a white powdery layer, which is in fact of microcrystalline structure, is deposited on the surface of the crystal also starting first on the edge of the cement layer. This deposit examined with the naked eye resembles a dehydrated layer and is often mistaken as such one. In both cases the effective specific inductive capacity falls progressively with the rate of deterioration of the crystal.

In carrying out the invention in practice, instead of moisture-proofing the composite Bimorph after the component elements have been cemented together, the elements are individually moisture-proofed, at least over the area of the cemented surfaces and any adjacent edges of the crystal and preferably over the whole of the crystal surfaces, before the elements are cemented together. Since electrodes must in most cases be applied to the adjacent surfaces of the elements, and it is highly desirable that there should be the smallest possible separation be-

tween the electrode and the surface, the electrode is applied before the moisture-proof layer.

The elements of the Bimorph must be firmly cemented together, so as to withstand the mechanical stresses imposed upon it in use, and in accordance with another feature of the invention the cement used for this purpose is chemically affine to the coating.

In fabricating Bimorphs in accordance with the invention the crystal plates are first cut and worked to the correct size and shape, and are provided with appropriate electrodes. These steps are the same as those customarily adopted, and will be familiar to those skilled in the art. Thus the plates can be first roughly sawn from a crystal block and then milled or ground to shape; the electrodes may be of foil, or may be an evaporated or like thin metallic layer applied to the crystal.

In fabricating Bimorphs the electroded single plates are coated with the varnish to give an adherent film of at least 0.0005 inch thickness. The plates are coated and dried at a temperature of 20° to 22° C. and 40% to 50% relative humidity.

The coating varnish is preferably prepared of synthetic resins of high dielectric values and low rates of water absorption such as to name only a few: fully or partly polymerised polyester resins such as diallyl phthalate, polystyrene resins, polyvinyl resins, polyvinyl copolymer resins, polyaryl ethylene oxide resins, polyacrylic resins, chlorinated diphenyl resins alone, or a mixture of a copolymerisation product of such resins with or without the addition of modifying agents such as plasticisers like dibutyl or di-octyl phthalate, tri-cresyl phosphate or dibutyl sebacate, tackifying resins such as ester gums, polyisobutylene resins, abietic acid esters etc., fillers and pigments such as talc, silica or titanium dioxide, catalysts such as benzoyl peroxide, tertiary butyl hydroperoxide, pentaethylene diamine, etc.

The coated and dried crystal plates are cemented together to form a Bimorph or multiplate crystal element with an affine cement or by wetting the coated surfaces with a suitable solvent or with the corresponding monomer. To expedite the drying or setting time it is also possible to use instead of the cement a thin foil of the material in question as an interlaminate between the crystal plates. By this method of fabrication the foil or the coated surfaces of the crystals are wetted with a solvent or corresponding monomer and stuck together in the tacky phase.

The resulting bond has to be rigid within the temperature range of the crystal and has to exhibit a high shear strength.

Examples will now be given of suitable compositions for the moisture-proof coatings and of the chemically affine cements for use in conjunction with them. The proportions are parts by weight.

A moisture-proof coating material is prepared as follows:

Example 1

Copolymer resin of 70% styrene and 30% butyl acrylate	16.40
Chlorinated diphenyl specific gravity 1.530 to 1.630	1.60
Xylene	40.00
Butyl acetate	34.00
Ethyl lactate	2.00
Titanium dioxide	3.50
Colloidal silica	2.50
	100.00

The single crystal elements with the electrodes applied firmly to the adjacent surfaces are individually dip coated with the solution which on evaporation of the solvents, will provide a film round the element. The required thickness of the coating which should be at least 0.0005 inch is achieved from the dipping solution and by adjusting the viscosity and the temperature of said solution.

The coated and dried crystal plates are cemented together to form a Bimorph or multiplate crystal with an affine cement which can be formulated for instance:

Example 2

Polystyrene resin	21
Conmarone resin	4
Ethyl acetate	45
Carbon tetrachloride	30
	100

The cement is thinly applied to the adjacent surfaces of the elements which are to be bonded together, and the assembly left to dry under a clamping device.

A further example illustrates the use of an acrylic resin solution for coating and cementing the crystals.

Polyacrylate solutions alone or in combination with other resins such as for instance chlorinated rubber or polyvinyl resins have or impart a good wet strength to the coating with the result that an improved resistance to atmospheric conditions is obtained.

Such a coating for dipping can be formulated as follows:

Example 3

Copolymer resin of 50% butyl methacrylate and 50% methyl methacrylate	12.00
Chlorinated rubber	2.00
Chlorinated diphenyl specific gravity 1.530	1.50
Methyl ethyl ketone	65.00
Diacetone alcohol	16.00
Titanium dioxide	1.50
Talc	2.00
	100.00

An affine cement for bonding the crystal plates together consists of a polymethyl methacrylate resin dissolved in its monomer which has been catalysed, as for instance:

Example 4

Polymethyl methacrylate resin	20.00
Methyl methacrylate monomer	79.90
Tertiary butyl hydroperoxide	0.10
	100.00

Alternatively to cementing, a foil of 0.0015 inch thickness of an affine resin can be used, which will reduce the drying time of the assembly.

For instance one surface of the crystal plate coated to formula Example 1 is wetted with a styrene monomer and immediately pressed against a polystyrene foil. The second crystal plate is treated in the same way and attached to the opposite side of the foil. The foil can be of the same size as the crystal plates or of larger size and cut to size of the crystal elements after the assembly has dried.

Crystal plates coated to Example 3 can be interlaminated with a polymethyl methacrylate foil after the crystal surfaces have been wetted with the corresponding monomer or a low boiling solvent such as methylene chloride.

The crystal element as described is finally coated all over with a polyblend composition of low water vapour permeability as described in British patent application No. 9,222/50. It will be understood that the customary connecting leads will be made to the electrodes, and that these leads will be connected together as necessary. For example, the leads to the main electrodes can be joined together, and those to the outer electrodes joined together to form a suitable transducer element.

The Bimorph assembly made in accordance with the improved method is shown in the accompanying drawing. The two plates of piezo-electric material such as Rochelle

salt crystal are indicated by numeral **1**. Each plate has applied thereto on each face thereof an electrode layer **2**, and after the electrode layers have been applied, each plate together with its electrode layers is coated on all sides with one of the moisture-proof materials which have been described, this moisture proof coating being indicated by numerals **3**. After the coating **3** has dried, the two coated plates **1** are then cemented together by a cement layer **4**, the composition of the cement being in accordance with one of the examples previously described. After the two coated plates have been cemented together, the assembly is then finally coated all over with a layer of moisture-proof material indicated by numeral **5**.

I claim:

1. The method of producing a moisture proof piezo-electric transducer assembly comprising a pair of plates of piezo-electric material joined together in face to face relation which comprises the steps of applying an electrode to one face of each plate, then applying a coating of moisture-proofing material to all surfaces of said electroded plates, and then cementing the moisture proofed electroded faces of said plates together.

2. The method of producing a moisture-proof piezo-electric transducer assembly in accordance with claim 1, wherein the coating applied to said members is a chemical compound, and said cement is chemically affine to said compound.

3. The method of producing a moisture-proof piezo-electric transducer assembly in accordance with claim 2, wherein said coating material includes a polymerised synthetic resin.

4. The method of producing a moisture-proof piezo-electric transducer assembly in accordance with claim 3, wherein said resin includes co-polymerised synthetic resin.

5. The method of producing a moisture-proof piezo-electric transducer assembly in accordance with claim 3, wherein said resins are applied in incompletely polymerised form, with a catalyst.

6. The method of producing a moisture-proof piezo-electric transducer assembly in accordance with claim 3, wherein said resin includes plasticisers.

7. The method of producing a moisture-proof piezo-electric transducer assembly in accordance with claim 3, wherein said resin includes pigments.

8. The method of producing a moisture-proof piezo-electric transducer assembly in accordance with claim 3, wherein said resin includes fillers.

9. The method of producing a moisture-proof piezo-electric transducer assembly in accordance with claim 1, wherein said elements are cemented together by means including a film of material chemically affine to said coating, said film being wetted with a solvent.

10. The method of producing a moisture-proof piezo-electric transducer assembly in accordance with claim 1, wherein said elements after being cemented together, are further coated with moisture-proof coating.

11. A moisture-proof piezo-electric transducer assembly comprising a pair of piezo-electric members of crystalline salt type, electrode means attached to a face of each of said members, a coating of moisture-proof material individually enclosing each member and its associated electrode means, and cement chemically affine to said coatings uniting said electroded faces of said pair of coated piezo-electric members and their attached electrode means in an assembly.

12. A moisture-proof piezo-electric transducer as recited in claim 11, in combination with a coating of moisture-proof material enclosing said assembly.

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