Feb. 24, 1970 R. L. COOK ET AL 3,496,617

TECHNIQUE FOR CURVING PIEZOELECTRIC CERAMICS

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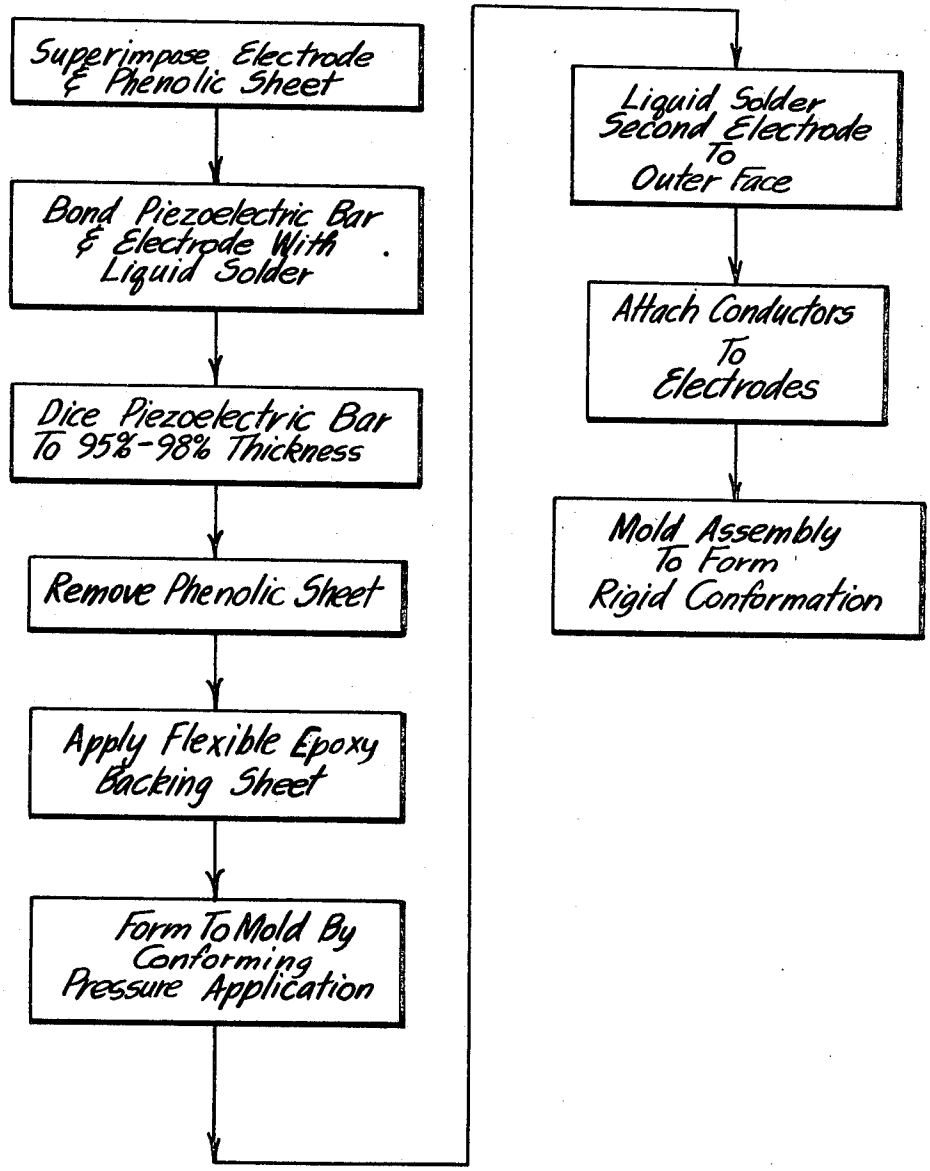
FIG. 1



RUFUS L. COOK
JESSE L. BEALOR, JR.
INVENTORS

BY William L. Skell
Agent
Don O. Doty
Attorney

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FIG. 2

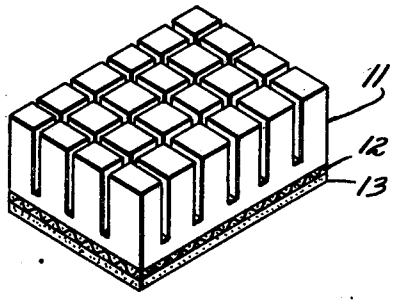
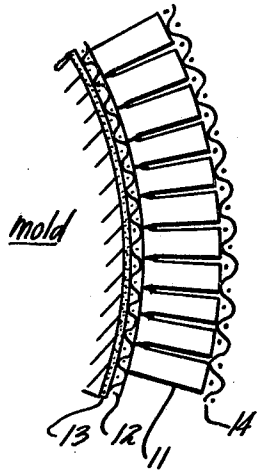


FIG. 3



RUFUS L. COOK
JESSE L. BEALOR, JR.
INVENTORS

BY William + Skell
Agent
Don D. Doty
Attorney

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TECHNIQUE FOR CURVING PIEZOELECTRIC CERAMICS

Rufus L. Cook and Jesse L. Bealor, Jr., Panama City, Fla., assignors to the United States of America as represented by the Secretary of the Navy

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ABSTRACT OF THE DISCLOSURE

A method of processing a curved face piezoelectric transducer in which a diced crystal sheet with one electrode attached is formed into a curved configuration by fracturing the crystal, a second electrode is applied, and the assembly is then made rigid.

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

In the are of transducer manufacture it is frequently desired to produce a transducer having a curved face. Such transducers are useful to obtain desired response patterns and specified directivity patterns. In the past, such curved face transducers have been made by careful fitting of individual crystal elements on a suitable mounting. Such assembly methods, while compatible with laboratory use, are prohibitively time consuming and require too great a degree of mechanical skill to permit economical manufacture in quantities needed for universal employment in the sonar and related underwater fields. The prior art, in order to obtain the aforesaid directivity and response of the expensive and scarce transducer, frequently employed special transducer housings or phased arrays of planar transducers.

Another problem prevalent in hand constructed curved face transducers was the lack of uniformity between units. Although produced to meet the same design standard, the many precision measurements and positioning steps used in the manufacture of a curved face transducer caused accumulative errors in each transducer produced, such that a considerable variation in performance between units was found to exist. Such variations cause operational problems and require lengthy calibration procedures.

The manufacture of a curved face transducer by grinding or otherwise figuring the surface of a piezoelectric crystal array or single crystal results in a transducer of mediocre quality because of problems in maintaining the very exacting tolerances in thickness. Further, any convenient grinding means is limited to easily generated curves of revolution and generally conic curves.

Considering the aforementioned state of the prior art, this invention has as its object the economical manufacture of a curved face piezoelectric transducer of high uniformity.

More particularly, this invention has as its object the manufacture of a piezoelectric transducer having a curved face arrangement using an especially manufactured planiform piezoelectric element.

A further object of this invention is the manufacture of a curved face piezoelectric transducer, including the steps of curving a planiform sheet to an aconic shaping surface.

Other objects and many of the attendant advantages will be readily appreciated as the subject invention becomes better understood by reference to the following detailed description, when considered in conjunction with the accompanying drawings wherein:

FIG. 1 is a block diagram or flow sheet of the steps employed in the practice of this invention.

FIG. 2 shows the transducer stock after dicing.

FIG. 3 illustrates a hypothetical edge view of the transducer stock in curved configuration.

Referring to FIG. 1, which shows a flow sheet, or block diagram, of the steps used in the practice of the method of this invention, the first step in the production of the improved transducer is the contiguous placement of an electrode stock and a rigid phenolic backing sheet. The electrode may be on any suitable conducting sheet or web material such as, in one preferred embodiment, a mesh of nickel wire having a thickness of 0.002 inch. The phenolic sheet is used as a mechanical stabilizing support and is non-critical in dimension. Sheets having a thickness between 0.00 and 0.031 inch have been employed successfully.

The electrode stock material is next wet with a layer of liquid solder to prepare the electrode to receive the piezoelectric crystal and also to affix the electrode to the phenolic sheet. A bar or sheet of piezoelectric material of the desired thickness and having parallel faces with silvered surfaces is placed on this liquid solder layer. The piezoelectric material may be barium or lead titanate, lead niobate, or any known electrostrictive material. The solder is allowed to cure thereby bonding the electrode-phenolic sheet to the piezoelectric material. The bond, both mechanical and electrical, may be enhanced with the application of pressure during curing of the solder bond. This pressure may be applied by conventional means known in the laminating arts or simply by the application of a weight resting on the piezoelectric bar or sheet.

The next, or third, step in the production of the curved face transducer includes the cutting of the piezoelectric-material-electrode-phenolic-sheet lamina to form a plurality of posts of a specified shape which extend nearly, but not completely, through the layer of piezoelectric material, depths of cut ranging between 95% and 98% of the material thickness have proven satisfactory. This cutting, known in the art as dicing, may be performed with an suitable crystal working means, a circular, high-speed, diamond saw and an endless-wire cutting tool having been employed by the inventors successfully. The size, shape, and number of posts cut are determined as design parameters dependent upon directivity, frequency, and material coupling desired in the final transducer, and are determined by the spacing and configuration of the individual cuts. Such considerations are understood, normal design parameters appreciated by persons skilled in the transducer art and, of themselves, form no direct part of this invention.

The next step in the practice of the method of the invention is the removal of the phenolic backing sheet. This removal may be accomplished employing mechanical means such as a sharp edged prying tool, or by the use of a chemical solvent, if desired.

A flexible epoxy backing sheet is next joined to the lamina in the place formerly occupied by the rigid phenolic sheet. This joining is effected by the use of a chemical bonding agent such as a contact cement known as "Eastman 910," for example. The epoxy sheet may also be formed in situ by using a liquid known as "Scotch Cast 8." Other known methods of providing the epoxy sheet may be employed as recognized by one proficient in the transducer art, the requirements that layer be flexible, resilient, and possess a low rate of moisture absorption being the only criteria to be satisfied.

FIG. 2 illustrates, not to scale, the assembled, diced piezoelectric crystal **11**, electrode **12**, and epoxy backing sheet **13**. It has been discovered that the individual posts of this assembly may be sheared apart without separation from the electrode or epoxy sheet by a slight wedging action from a tapered-angle blade. It is, of course, pos-

sible to employ other shearing devices, and for larger production runs a suitable wedging type device could be devised to separate several rows of posts at one time.

The diced, sheared crystal array may now be mounted on a curved form in such a fashion that individual posts project at right angles to the surface of the form, which may be a mold part. Because of their uniform thickness the opposite faces of the posts lie in a similar curve. The curve may be any desired configuration including other than figures of revolution or conics. A gentle yielding pressure means, such as afforded by a hand, is used in the assembly. If the form or mold is not to be a permanent part of the transducer, a temporary adhesive is used between the epoxy sheet and the form. If the form is to be a permanent part of the transducer, a similar joining technique to that used in affixing the epoxy sheet to the crystal array may be used.

In the next step, a second electrode, shown as **14** in FIG. 3, is soldered to each post of crystal array **11** using an air-drying liquid solder. The second electrode is generally of the same construction as the electrode previously applied.

Electrical conductors are next applied to the two electrodes using conventional fasteners or electrical joining techniques if the device is to be completely encased. The electrodes may serve as external conductors, if desired, in some applications.

The entire assembly may next be molded, potted, or encased in an acoustically transparent compound and shaped to fit enclosures or other environmental placements.

Either of the curved faces may be used as a radiator or receiver of acoustic energy and, therefore, concave or convex faced transducers may be made according to the teaching of this invention.

This invention results in a transducer not readily obtainable by prior art methods. These transducers are applicable to a wide range of uses and have given improved results over prior art constructions in many of these applications. Uses of the device include high frequency sonar surveillance and detection devices, bottom following devices, depth indicator devices, directional scanning systems, bottom formations determining devices, to mention a few. These results are obtained by using conventional planar stock materials and material working techniques and are demonstrably better and more uniform than the results obtained with the more costly and cumbersome prior art devices.

Obviously, other embodiments and modifications of the subject invention will readily come to the mind of one skilled in the art having the benefit of the teachings presented in the foregoing description and the drawings.

What is claimed is:

1. The method of manufacture of an improved transducer comprising the steps of:

mounting a first planar electrode on a rigid support,
mounting a sheet of piezoelectric material on said electrode,
cutting said piezoelectric material into posts with a height slightly less than that of the thickness of the piezoelectric material,
removing the rigid support,
applying a flexible support to said first electrode,
shearing the posts apart in such a manner to leave the posts attached to the electrode and flexible support,
mounting the flexible support, with posts attached, on a suitably shaped form,
attaching a second electrode to said piezoelectric posts,
encasing said mounted posts and two-electrode assembly in an acoustically transparent medium.

2. A method as in claim **1** wherein said mounting of said first electrode includes the step of adhering said first electrode and said rigid support with liquid solder.

3. A method according to claim **1** where the step of mounting said sheet of piezoelectric material includes the application of pressure sufficient to ensure mechanical and electrical bonding.

4. A method according to claim **2** where the step of mounting said sheet of piezoelectric material includes the application of pressure sufficient to ensure mechanical and electrical bonding.

5. A method according to claim **1** in which said cutting includes sawing cuts of a depth between 95% and 98% of the thickness of the piezoelectric material.

6. A method according to claim **4** in which said cutting includes sawing cuts of a depth between 95% and 98% of the thickness of the piezoelectric material.

7. A method according to claim **1** in which said flexible support is cemented to said first electrode.

8. A method according to claim **6** in which said flexible support is cemented to said first electrode.

9. A method according to claim **1** further comprising the step of attaching conductors to said first and second electrodes before encasing the assembly.

10. A method according to claim **8** further comprising the step of attaching conductors to said first and second electrodes before encasing the assembly.

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JOHN F. CAMPBELL, Primary Examiner

R. W. CHURCH, Assistant Examiner

U.S. Cl. X.R.

29—413, 583, 600, 624, 627; 264—272; 310—8.6, 9.7; 317—101; 333—72