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Attorney Docket No. 84866

LOW VOLTAGE PIEZOELECTRIC COMPOSITE FOR TRANSDUCER APPLICATIONS

STATEMENT OF GOVERNMENT INTEREST

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.

BACKGROUND OF THE INVENTION

(1) Field of the Invention

This invention generally relates to an acoustic transducer's electromechanical substrate.

More particularly, the invention relates to a piezoelectric polymer composite substrate enabling an array of transducers capable of being used with lower voltage than prior art transducers.

(2) Description of the Prior Art

Several underwater sonar applications exist for high intensity steered directional acoustic beams. A major drawback for piezocomposite constructs is the relatively high drive voltages required to attain significant acoustic intensity per unit area. This is due to the material's intrinsic broadband characteristics and the fact that typical designs operate below resonance where the impedance phase angle is stable. Phase stability is required for broadband waveform generation and reception. The disadvantage of operating off resonance is that higher voltages are required to produce the equivalent acoustic intensity.

United States Patent Nos. 4,227,111 and 4,412,148 refer to piezoelectric polymer composite substrates that can be used to construct broadband transducers and arrays for sonar applications. The segmentation of the piezoelectric phase and the decoupling characteristics of the backfill polymer enable large transducer apertures operating in a pure thickness mode of vibration.

An electrostriction transducer having intermediate electrodes is shown in Sato et al., United States Patent No. 4,633,120. The active layer of the transducer is either lead zirconium-titanate or lead magnesium-niobate. This material is incorporated in a polymer slurry which is applied to a substrate such as a Mylar(t) film. A several hundred micron thick active layer is provided. Conductors such as wires are joined directly to contacts positioned between different active layers. The resulting transducer is provided for use in a print head. No provision is made for joining a massive number of co-fired multi-layered structures in a piezoelectric polymer composite substrate.

It should be understood that the present invention would in fact enhance the functionality of the above patent by providing an active substrate consisting of piezoelectric columns within a polymer composite capable of operating at lower voltages.

SUMMARY OF THE INVENTION

In accordance with one aspect of this invention, there is provided a piezoelectric substrate having three or more odd numbers of stacked piezoelectric regions that could bused to construct an array of transducers. Upper and lower contacts are disposed on the end of a stack of piezoelectric regions and intermediate contacts are disposed between the regions. The upper contact is electrically joined by a first trace to a first intermediate contact between the second and third piezoelectric regions. The lower contact is electrically joined by a second trace to a second intermediate contact between the first and second piezoelectric regions. Insulating material is positioned between the first and second trace and the piezoelectric regions. The upper and lower contacts are disposed over the ends of a plurality of piezoelectric stacks or the upper and lower contacts can be segmented for individually addressing the stacks. The insulating material insulates piezoelectric columns from each other.

BRIEF DESCRIPTION OF THE DRAWINGS

The appended claims particularly point out and distinctly claim the subject matter of this invention. The various objects, advantages and novel features of this invention will be more fully apparent from a reading of the following detailed description in conjunction with the accompanying drawings in which like reference numerals refer to like parts, and in which:

FIG. 1 is a top view of a single piezoelectric ceramic rod;

FIG. 1A is a cross sectional view of the piezoelectric ceramic rod of FIG. 1 taken along section line A-A;

FIG. 2 is a side view of a single rod;

FIG. 3 is a two dimensional arrangement of rods sharing common electrodes;

FIG. 4 is a two dimensional arrangement of rods having independent electrodes that can form an array of transducer elements; and

FIG. 5 is a diagram showing layered deposition of the elements used to make this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 shows the top view of a single co-fired piezoceramic pillar 10, in this case a rod of square cross-section. A cross-sectional view of this pillar 10, taken along section line A-A, is shown in FIG. 1A. This is shown configured for placement in a 1-3 piezoelectric ceramic polymer composite substrate. As shown, the structure has three active piezoelectric ceramic layers 12A, 12B, and 12C with four conductive electrodes 14A, 14B, 14C and 14D addressing the three piezoelectric ceramic layers 12A, 12B, and 12C. Piezoelectric ceramic layers 12A, 12B, and 12C can be constructed from typical ferroelectric materials such as lead zirconate titanate or lead titanate. A top electrode 14A is positioned on the upper surface of pillar 10. Top electrode 14A is in communication with lower intermediate electrode 14C via first trace 16A. A bottom electrode 14D is positioned on the bottom surface of pillar 10.

Pillar 10 is polarized so that an electrode having a positive polarity is in contact with a positively polarized portion of pillar 10. For example, if top electrode 14A is positive then the top surface of ceramic layer 12A is positively polarized, and the bottom surface of ceramic layer 12A is negatively polarized where it is in contact with top intermediate electrode 14B. The bottom electrode 14D would then have a negative polarity. Ceramic layer 12C bottom surface is negatively polarized where it contacts bottom electrode 14D. Ceramic layer 12C top surface is positively polarized where it contacts lower intermediate electrode 14C because electrode 14C has a positive polarity. Intermediate ceramic layer 12B has a top surface that is negatively polarized and in contact with upper intermediate electrode 14B. Bottom surface of ceramic layer 12B is positively polarized and in contact with electrode

14C. Thus, polarized ceramic regions should be in contact with electrodes having a like polarization.

FIG. 2 provides a side view of pillar 10 showing top electrode 14A, trace 16A and bottom electrode 14D. Bottom electrode 14D is in communication with upper intermediate electrode 14B via second trace 16B. An electrical insulator material 18 is used to isolate traces 16A and 16B from the pillar 10. Electrical insulation between the traces and the pillar 10 prevents leakage of currents across the individual ceramic layers. Thus, top electrode 14A and lower intermediate electrode 14C can be associated with one electrical pole, and bottom electrode 14D and upper intermediate electrode 14B can be associated with the other electrical pole. Electrodes 14A, 14B, 14C, and 14D and traces 16A and 16B can be made from any electrically conductive material. It is envisioned that top electrode 14A and bottom electrode 14D are formed from continuous depositions of conductive material so that one top electrode or bottom electrode can contact a multiplicity of ceramic layers 12A and 12C, and a multiplicity of traces 16A and 16B respectively forming a multiplicity of co-fired assemblies.

As arranged above, top electrode 14A and upper intermediate electrode 14B are in electrical contact with active ceramic layer 12A. In a passive mode, compression of active ceramic layer 12A results in generation of a differential voltage between electrode 14A and electrode 14B. In an active mode, application of a differential voltage across ceramic layer 12A results in movement of this layer. In the same manner, active ceramic layer 12B is joined for communication with electrodes 14B and 14C, and active ceramic layer 12C is joined for communication with electrodes 14C and 14D. Because more electrodes are provided, a lower voltage applied between 14A and 14D can give the same displacement of pillar 10.

FIG. 3 shows a panel 20 having a plurality of pillars 10 arranged over a planar surface. Pillars 10 are supported in panel 20 by insulating material 18. Insulating material 18 can be a dielectric polymer matrix or an elastomeric material. In this embodiment, top and bottom electrodes 14A and 14D are extended over the upper and lower surfaces of the entire panel 20. A plurality of first traces 16A make contact with top electrode 14A, and a plurality of second traces 16B make contact with bottom electrode 14D. As above, each first trace 16A is in contact with one lower intermediate electrode 14C. Each second trace 16B is in contact with one upper intermediate electrode 14B. While the panel shown here has two traces 16A and 16B for each pillar 10, it is understood that each trace 16A and 16B can be in communication with multiple electrodes in multiple pillars 10. In FIG. 3, pillars 10 are shown arranged in offset rows; however, other patterns of arrangement are possible for efficient utilization of the space.

An alternative embodiment of the invention is shown in FIG. 4. Panel 20' has a top electrode 22A and a bottom electrode 22B associated with each pillar 10. As above, top electrode 22A is joined to a first trace 16A which electrically connects top electrode 22A with one lower intermediate electrode 14C. Bottom electrode 22B is electrically joined to upper intermediate electrode 14B via second trace 16B. This arrangement allows independent addressing of the pillars 10. In view of these two embodiments any number of groups of pillars can be independently addressed.

Panels 20 and 20' can be manufactured by the fused deposition of ceramics (FDC) method as shown in FIG. 5. Utilizing this method hundreds of columns can be generated in two orthogonal directions. The example shown above is a composite with 1-3 connectivity (rods in two directions), but the method could also be used to fashion a composite with 2-2 connectivity (plates in one direction).

The FDC method utilizes a numerically controlled multi-nozzle 30 head in communication with reservoirs 32A, 32B, 32C and 32D of various thixotropic materials of interest as shown in FIG. 4. Nozzle 30 can precisely dispense these materials over a two-dimensional grid 34. Materials can include green ceramic, metallic compounds, and other polymers. The build-up over multiple layers is accomplished by lowering the two-dimensional grid 34 and depositing layer 36 upon layer 36 to create a multiple layer pre-form 38. This pre-form 38 will typically include the piezoceramic layers 12A, 12B and 12C; the intermediate electrodes 14B and 14C; insulating material 18 and the traces 16A and 16B for a plurality of pillars 10.

Once deposition of the pre-form 38 is complete the pre-form 38 is subjected to a low temperature burn out to remove the plasticizer in the sprayed material. Pre-form 38 is then fired to sinter the ceramic particles. The pre-form 38 may be back-filled with a polymer to hold the pillars together while mechanically decoupling the piezoceramic pillars 10 from each other. This can be the same insulating material as insulating material 18 or a different insulating material. The top and bottom electrodes 14A and 14D can the be applied to the outside of the finished composite substrate. The pillars 10 are polarized by a number of methods dependent upon the piezoelectric material utilized.

An alternative approach, quasi-multi-layering, involves applying conductive stripes around the pillars. This is similar to conventional striped ceramic cylinders. The realization of this method would be complicated and perhaps not as cost effective as the disclosed method. Additionally, the field impressed on the surface doesn't couple completely to the internal volume of the active material.

In view of the above detailed description, it is anticipated that the invention herein will have far reaching applications other than those described herein.

This invention has been disclosed in terms of certain embodiments. It will be apparent that many modifications can be made to the disclosed apparatus without departing from the invention. Therefore, it is the intent of the appended claims to cover all such variations and modifications as come within the true spirit and scope of this invention.

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LOW VOLTAGE PIEZOELECTRIC COMPOSITE FOR TRANSDUCER APPLICATIONS

ABSTRACT OF THE DISCLOSURE

A piezoelectric ceramic polymer composite is provided with piezoelectric ceramic pillars having intermediate electrodes. These intermediate electrodes reduce the voltage necessary to achieve a given polarizing electric field within the piezoelectric ceramic pillars. Upper and lower electrodes are provided on the surfaces of the composite substrate. These electrodes are electrically joined to the intermediate electrodes by insulated electrical traces. The piezoelectric ceramic phase geometry may include either 1-3 (rods) or 2-2 (bars) connectivity. The number of electrode pairs is limited only by the fabrication process. The lateral distribution of these piezoelectric pillars is decoupled using a polymer backfill material. Upper and lower electrodes can be partitioned to form an array of transducer elements.

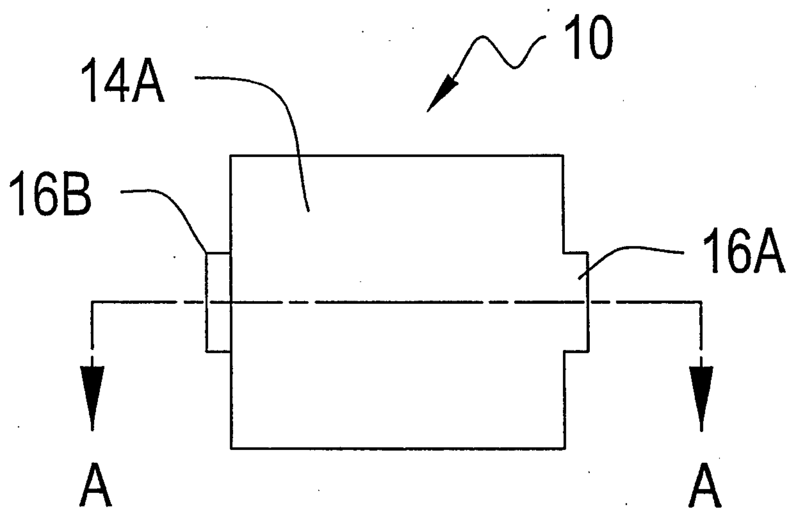

FIG. 1

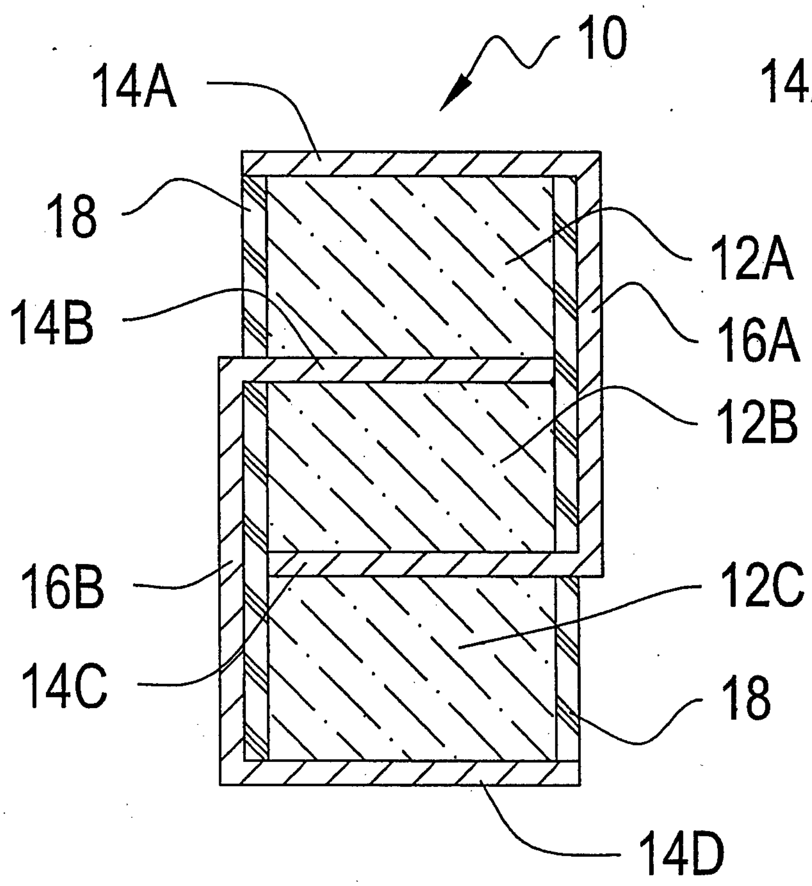

FIG. 1A

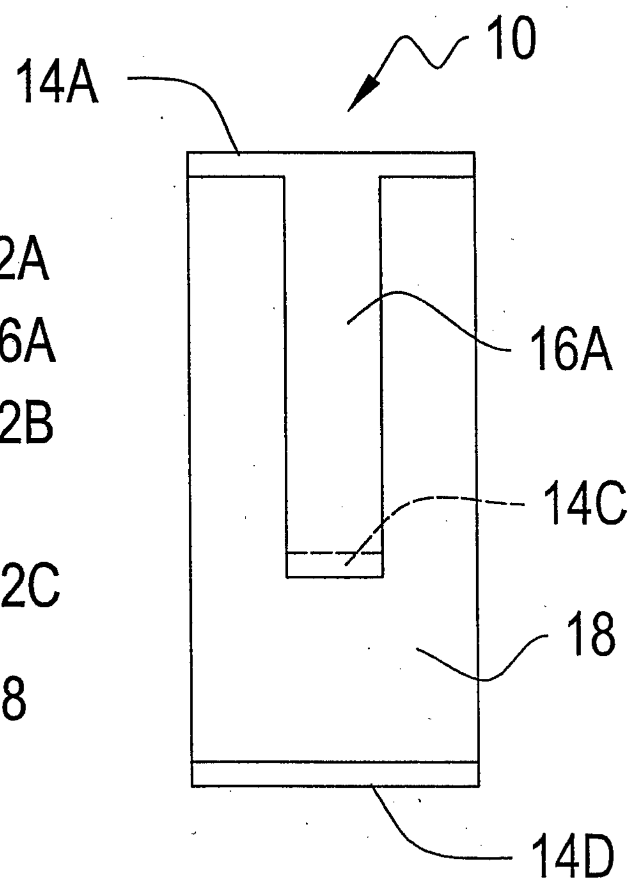

FIG. 2

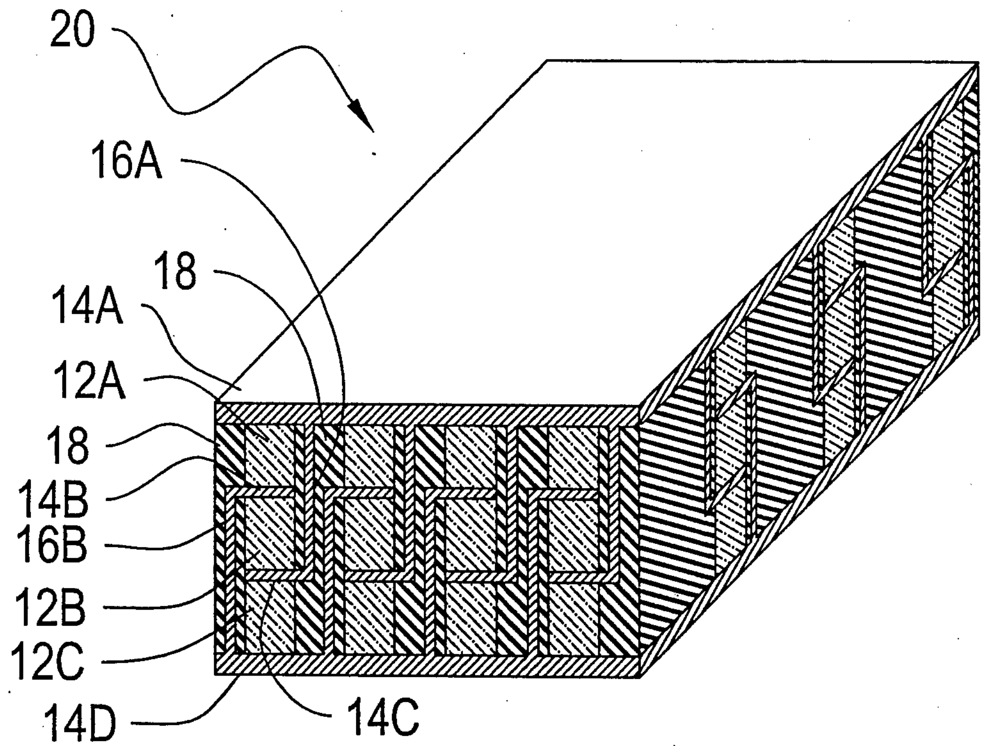
20
16A
18
14A
12A
18
14B
16B
12B
12C
14D
14C

FIG. 3

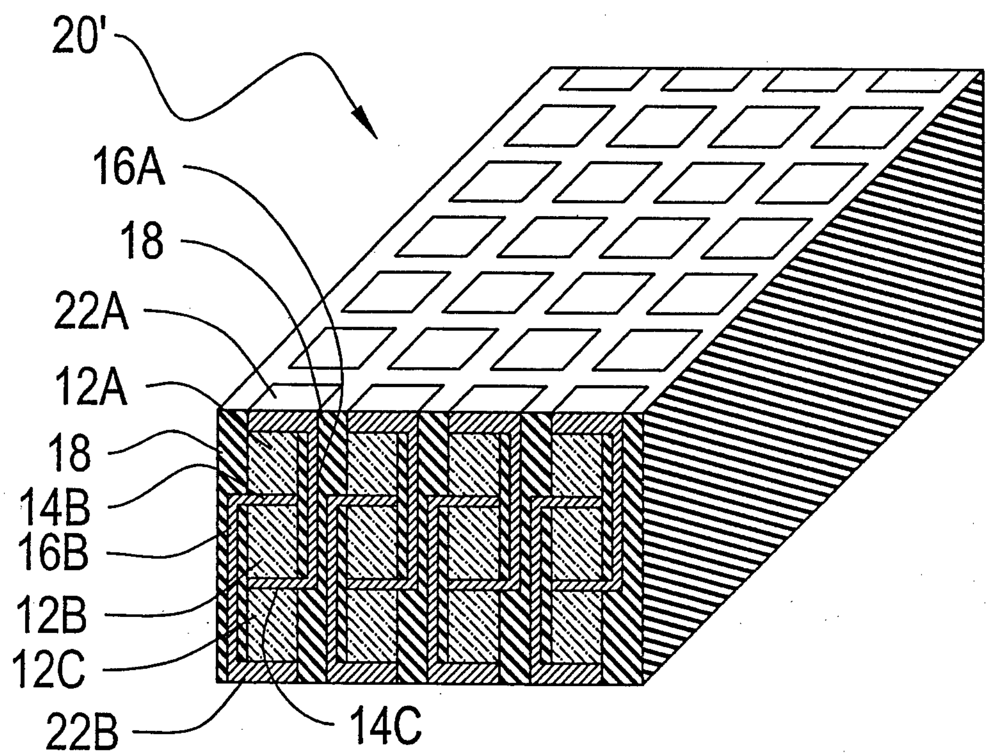
20'
16A
18
22A
12A
18
14B
16B
12B
12C
22B
14C

FIG. 4

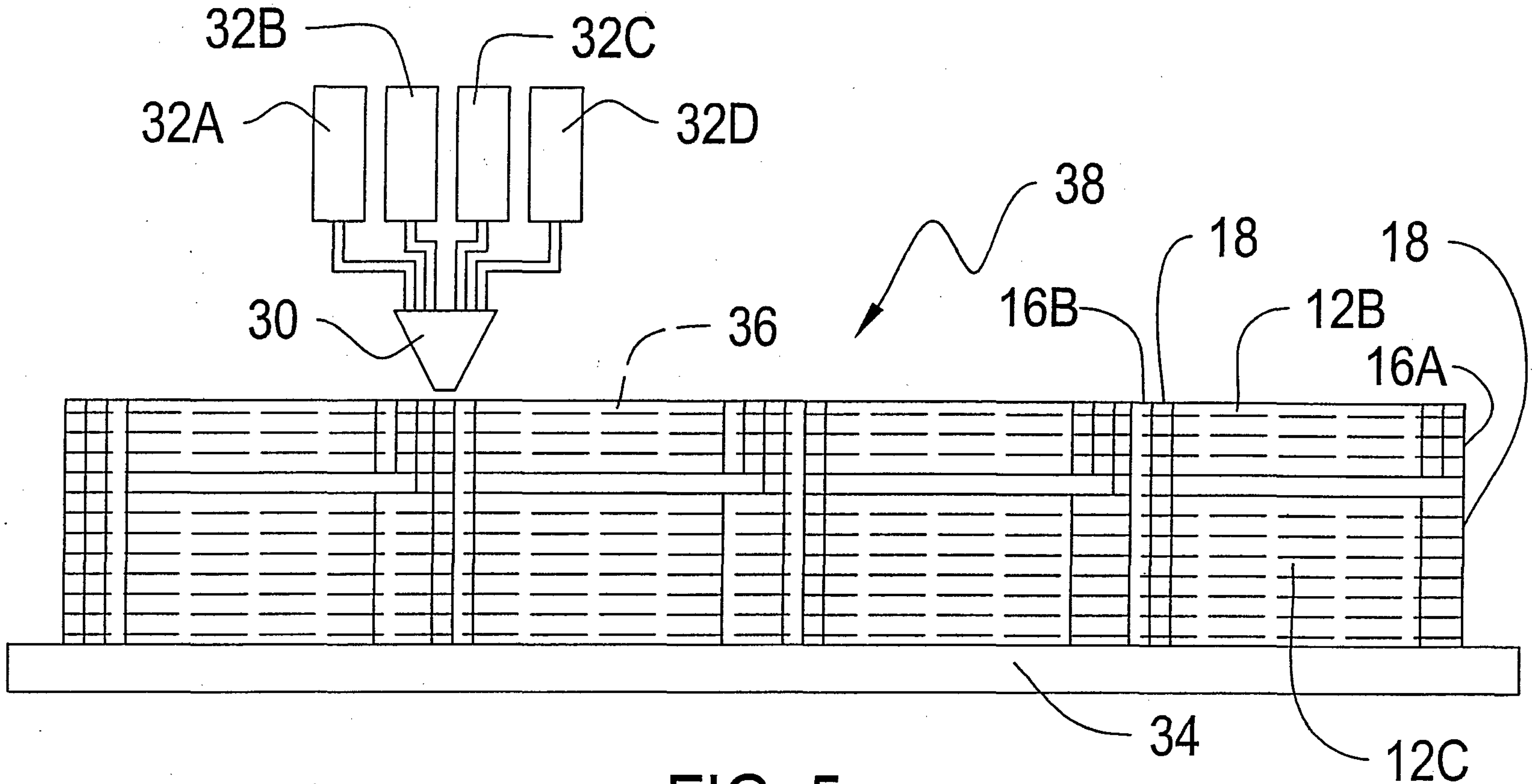

FIG. 5