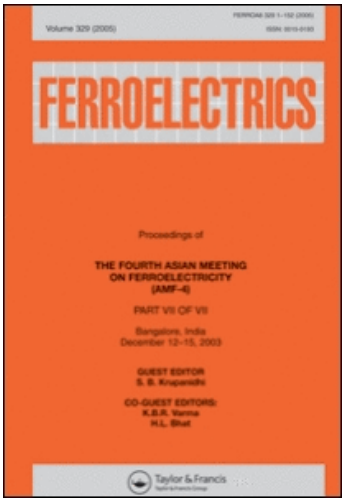

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Modified 1-3 Ceramic/Epoxy Piezocompsite and Cylinder Array Transducer

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Modified 1–3 Ceramic/Epoxy Piezocompsite and Cylinder Array Transducer

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The modified 1–3 piezocomposites were prepared in order to improve the stability of underwater acoustic transducers. The composite consists of 1–3 ceramic/epoxy composite and ceramic plate with series pattern. It was fabricated by dicing PZT ceramic along mutually perpendicular directions on the flat and then filling epoxy into grooves. In the paper, the cylinder transducer array made of modified 1–3 composite was fabricated. The performance of the transducer was investigated. The resonance frequency is 72 kHz when the diameter of the transducer is 85 mm. The transmitting voltage response reached 139 dB at 72 kHz, the receiving sensitivity was -212 ± 4 *dB in the frequency range of 20 kHz to 60 kHz, the directivity pattern was omnidirectional in horizontal direction and with beam width of* 12° *in vertical direction.*

Keywords Modified 1–3 piezocomposites; transducer array; performance

1. Introduction

Piezoelectric ceramic-polymer 1–3 composites consisting of aligned piezoelectric ceramic rods within a continuous polymer matrix are currently being used in actuators, sensors, advanced underwater transducers, and ultrasonic transducers for acoustic imaging and medical applications because it owns many good characteristics, such as lower acoustic impedance, broadband and high sensitivity [1]. But 1–3 piezoelectric composites will distort easily when heated or mechanical impacted. Modified 1–3 piezoelectric composite (1-3-2 composite) consists of 1–3 piezoelectric composite and ceramic plate, which not only has the characters as 1–3 piezoelectric composite but also is more stable than it [2].

In the paper, 1-3-2 composites were fabricated, and a cylinder transducer array made of the composites was developed.

2. The Structure and Fabrication of 1-3-2 Piezoelectric Composite

Figure 1 illustrates the structure of 1-3-2 piezoelectric composite, which is composed of piezoelectric ceramic plate and 1–3 piezoelectric composite. The rods array on the ceramic plate and connected each other with polymer as a whole. Hard PZT supports the epoxy at

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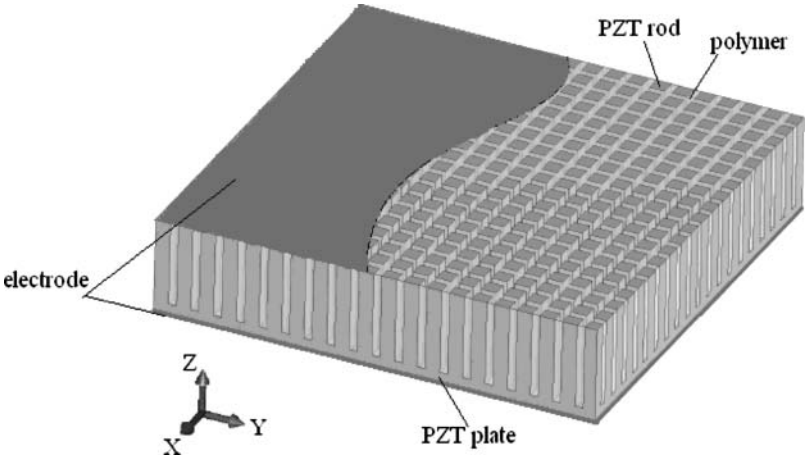

Figure 1. The structure of 1-3-2 piezocomposite.

both transverse and longitudinal directions in 1-3-2 composite, which makes the structure more stable than 1–3 composite.

1-3-2 PZT/epoxy composite was fabricated by dice-fill technology. PZT-5A plates were produced by Institute of Acoustics, Chinese Academy of Sciences, and have been polarized. The ceramic framework formed by dicing PZT-5A along mutually perpendicular two directions on the surface with Automatic Dicing/Cutting Saws (DAC321, Disco company, Japan). Epoxy (WRS618), produced by the resin factory of WuXi, China, was mixed with solidifying reagent (ethylenediamine) and DBP with the proportion of 10:1:1. The mixed epoxy was oscillated by ultrasonic in 3 minutes, vacuumed in 25 minutes to extract air-bubble, and then was filled into the grooves of the PZT framework. After the epoxy had solidified, roughcasts were formed. Shaping roughcasts, we got the 1-3-2 composite plates and plated them with silver. Finally, the properties of composites were measured.

A 1-3-2 PZT/epoxy piezocomposite (40 mm $\times$ 20 mm $\times$ 10 mm) was fabricated by the aforementioned technique. The width of ceramic rod and epoxy was respectively 0.9 mm and 0.45 mm. The thickness of ceramic substrate was 1mm. The piezocomposite plate was diced into 24 pieces of 10 mm $\times$ 6.5 mm $\times$ 10 mm. Among them 18 pieces with uniform performance were selected as array elements of transducer. The thickness resonance performances of each piece listed on Table 1.

3. The Structure and Facture of Transducer

3.1 The Structure of Transducer

Figure 2 showed the structure of the cylinder transducer array.

As Fig. 2 shown, 1-3-2 composite transducer array consists of piezocomposite element, brass backing, brass bracket and cover board.

The 18 elements were coated electrode and arrayed in a circle. The epoxy resin adhered and fixed the elements in the groove of brass backing which enhanced the resonance displacement of piezocomposite elements. The decoupling material was filled into the gap among them in order to obstruct the acoustic coupling between elements. Cathodes of elements were welded with the down-lead to become parallel connection. The down-lead

Table 1
The resonance performance of 1-3-2 piezocomposite plate element

No.	f_t/kHz	Δf/kHz	No.	f_t/kHz	Δf/kHz
$1^{\#}$	120.6	2.8	$10^{\#}$	120.6	2.9
$2^{\#}$	119.1	3.5	$11^{\#}$	120.6	3.7
$3^{\#}$	120.6	3.8	$12^{\#}$	120.6	2.7
$4^{\#}$	120.6	2.8	$13^{\#}$	120.6	5.4
$5^{\#}$	120.6	3.7	$14^{\#}$	120.6	3.0
$6^{\#}$	120.6	4.9	$15^{\#}$	120.6	3.7
$7^{\#}$	120.6	2.7	$16^{\#}$	120.6	5.2
$8^{\#}$	120.6	3.5	$17^{\#}$	120.6	3.6
$9^{\#}$	119.3	3.3	$18^{\#}$	120.6	3.0

was elicited from the hole of backing respectively and jointed with the cable. The cable was wrapped using water joint and fixed on the array. The polyurethane enwrapped the array to be waterproof.

3.2 The Resonance Shape of Transducer

The thickness vibration of 1-3-2 piezocomposite element was using to implement the transition between electrical and mechanical energy of the transducer. Figure 3 showed the resonance shape of one element obtained by simulation in ANSYS. The conductance-frequency curve of the piezocomposite array transducer under water measured by Precise Impedance Analyzer was shown in Fig. 4.

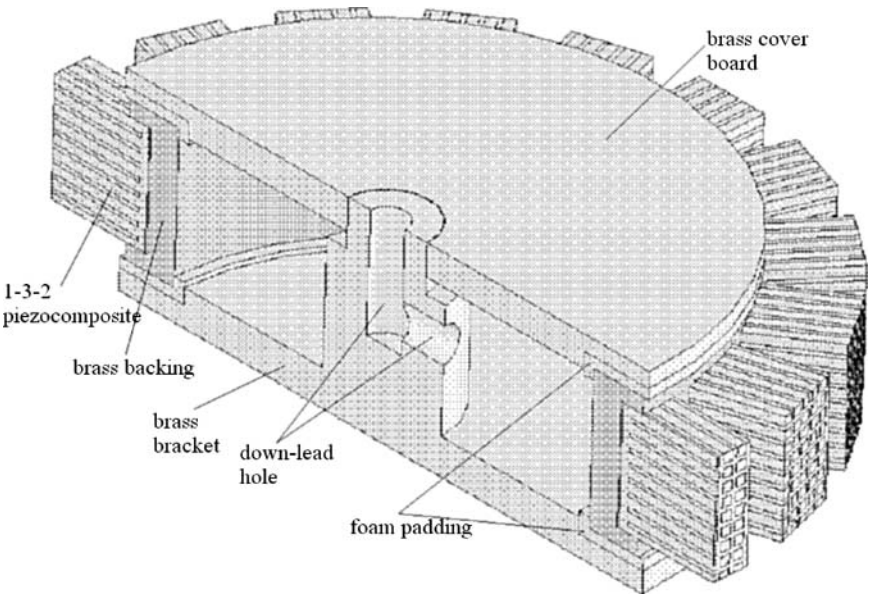

Figure 2. The structure of 1-3-2 piezocomposite transducer array.

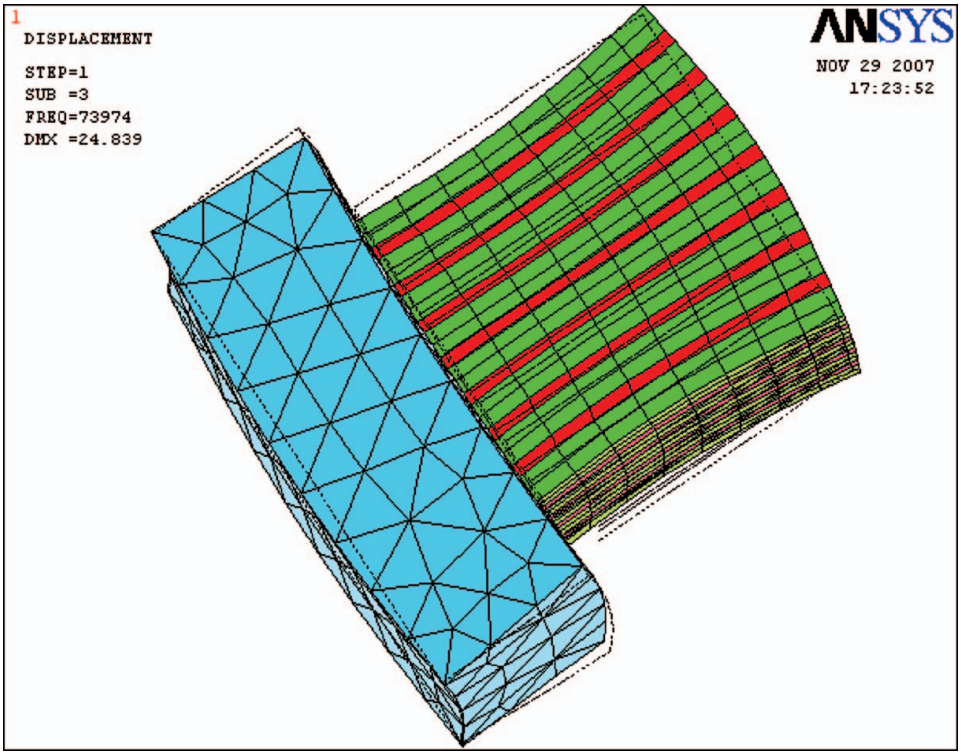

Figure 3. The resonance shape of an element in transducer array by ANSYS. (See Color Plate XVI)

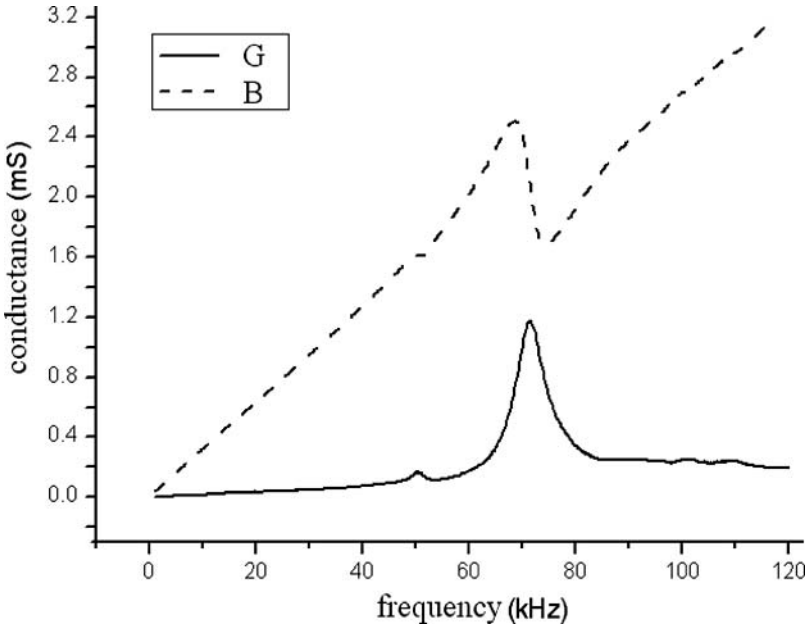

Figure 4. The conductance-frequency curve of the transducer under water.

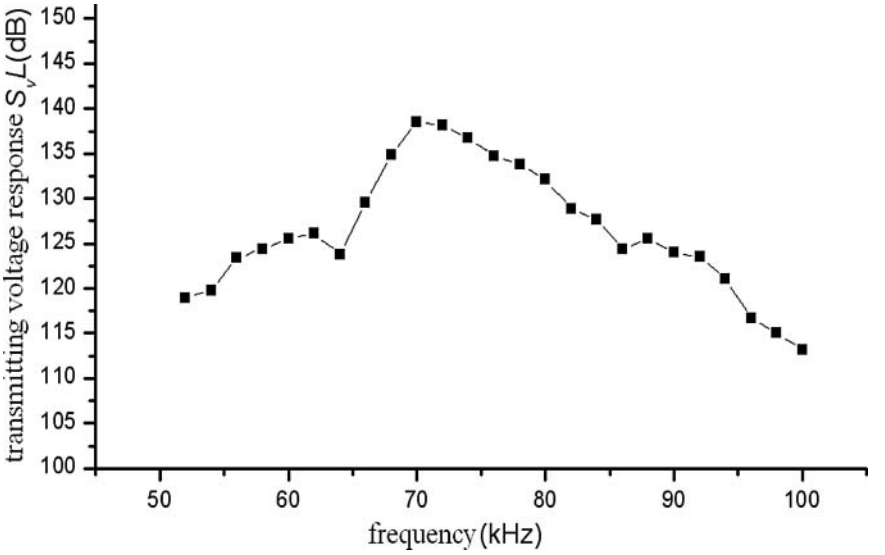

Figure 5. The transmitting voltage response of 1-3-2 piezocomposite transducer array.

4. The Performance of Transducer

4.1 The Transmitting Voltage Response

The transducer was tested using the pulse technique in the frequency range of 50 kHz to 100 kHz [3]. It was accomplished in anechoic water tank at Beijing GreatWall Wireless Factory, China.

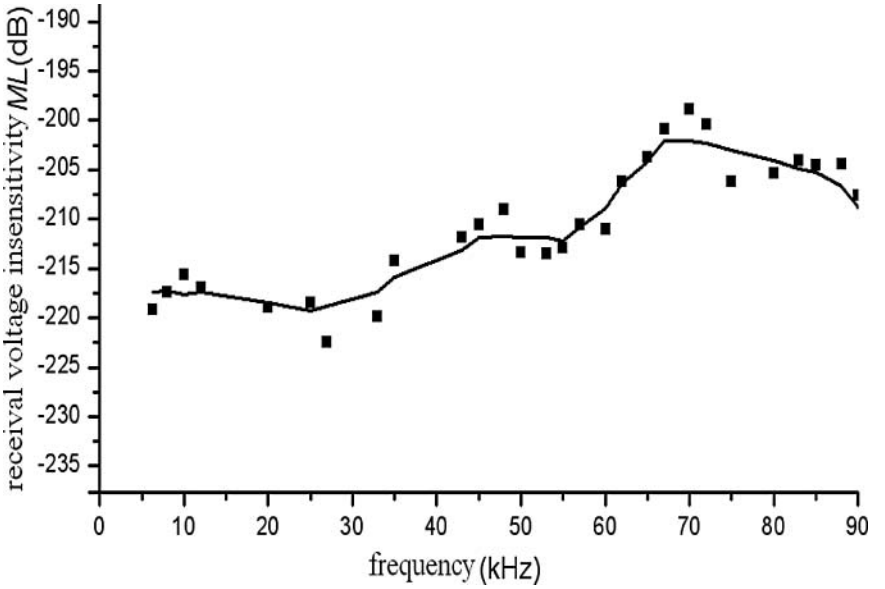

Figure 6. The voltage insensitivity of 1-3-2 piezocomposite transducer array. (a) horizontal directivity response pattern (b) vertical directivity response pattern.

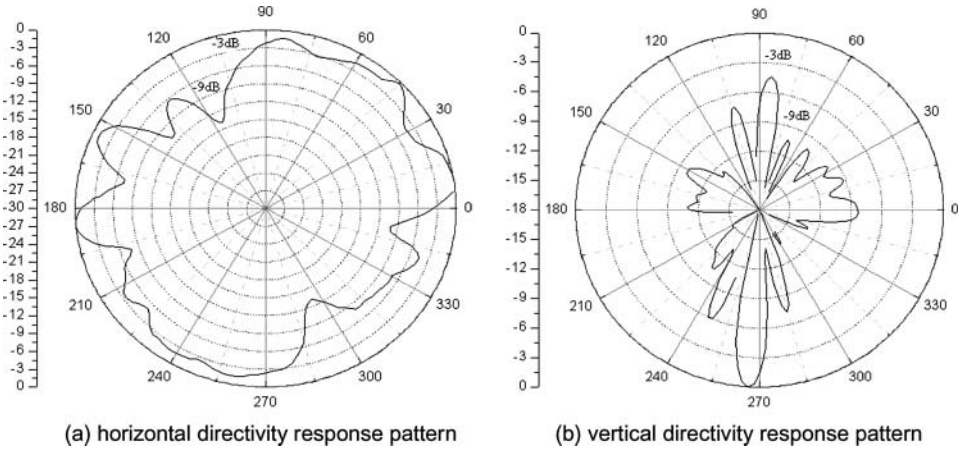

Figure 7. The transmitting directivity response pattern of 1-3-2 piezocomposite transducer array.

The transmitting voltage response of 1-3-2 piezocomposite transducer array was measured and plotted in Fig. 5. It showed that the operating frequency of transducer was 72 kHz. The voltage response was more than 139dB and the bandwidth (3dB) at the frequency of 72 kHz was 7 kHz.

4.2 The Voltage Sensitivity

The voltage sensitivity was measured by comparing the output of the transducer with that of the standard receiver [4].

The measurement result of the sensitivities of transducer varied with the frequency was shown in Fig. 6. The voltage sensitivities of transducer was -212 ± 4dB in the range of 20 kHz to 60 kHz from Fig. 6.

4.3 Directivity Response of Transducer

The vertical and horizontal directivity responses were measured and the results were shown in Fig. 7. The horizontal directivity responses of the transducer array undulate with value of -4 dB at the range of 360°. The beam width of -3dB was 12° in the vertical directivity response pattern.

5. Conclusion

1-3-2 piezocomposite was good material for underwater transducer applications. It was prepared by dice-fill technology. The cylinder array transducer was fabricated by arraying 18 pieces of 1-3-2 composite plates in a circle. The performance of array transducer was measured, and the transmitting frequency, bandwidth (3dB) and receiving voltage sensitivity of the transducer is respectively 72 kHz, 7 kHz and -212 ± 4dB in the range of 20 kHz to 60 kHz. The horizontal directivity responses of the transducer array undulate with value of -4 dB at the range of 360°. The beam width of -3dB was 12° in the vertical directivity response pattern.

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