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A High-Sensitivity Co-Oscillating Electrochemical Vector Hydrophone Based on Micron-Scale Controllable Microelectrodes

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Summary:
This paper reports a novel co-oscillating electrochemical vector hydrophone with ~5 times higher sensitivity than that of current best levels (peak sensitivity -166.36dB vs. -180.10dB REF 0dB=1V/μPa) within 1Hz~ 1000Hz. This considerable improvement was due to the novel MEMS microelectrodes which featured with a micron-scale controllable spacing between the anode and cathode and larger cathode area.

Keywords: MEMS, electrochemical, co-oscillating vector hydrophone, microelectrodes, micron-scale controllable.

Background, Motivation an Objective

Vector hydrophones act as important parts in underwater acoustic detections and target reignitions. With the development of shock absorption and noise reduction technologies, the radiation noise of underwater targets has been reduced. However, very low-frequency noise (such as blade frequency and shaft frequency) cannot be eliminated. Current hydrophones still have limitations in low-frequency sensitivity [1]. Although we have accumulated some technical expertise [2-3], there remains room for improvement in this field.

Description of the New Method or System

Figure 1 shows the new type vector hydrophones based on co-oscillating electrochemical principles. This sensor composes of protective shell, electrolyte, and proposed micron-scale controllable microelectrodes. In operation, the external underwater sound distributions change the active ion concentrations around the two cathodes, and then unbalance the REDOX reactions ($3I^- - 2e^- = I_3^-$ and $I_3^- + 2e^- = 3I^-$) occurred on microelectrodes. Finally, the differential voltage is output.

Figure 2 (a) shows proposed novel micron-scale controllable microelectrodes. Smaller spacing between anode and cathode and lager cathode area are definitively conducive to improve sensitivity. In this paper, a micron-scale controllable insulation ring structure is designed to realize smaller distance between anode and cathode. Meanwhile, the area of the anode and cathode spacing on the surface is reduced, which is conducive to the distribution of more vias, so as to have a larger cathode area on the sidewall of vias. The micron-scale controllable insulation ring structure is achieved by using aluminum as sacrifice layer for lift-off. Figure 2 (b) shows the MEMS process flow of the microelectrodes. Before etching vias, the circular aluminum sacrificial layer for lift-off was made as the anode and cathode spacing. After deep reactive ion etching the vias and depositing electrode metal Ti/ Pt by sputtering, selectively removing aluminum sacrificial layer in 85 wt% phosphoric acid.

Results

The watertight encapsulated co-oscillating electrochemical vector hydrophone was tested with a vibration table and a standing-wave tube. Figure 3 (a) shows its sensitivity curve. Its peak sensitivity reaches -166.36dB @ 20Hz (REF 0dB=1V/μPa). Figure 3 (b) shows the noise level, with a lower level than shallow sea state zero between 1-200Hz. Figure 3 (c) shows its directivity curve @ 200Hz, with a smooth and symmetrical shape of “8”, and the pit depth reached -47.6dB. Compared with the existing devices, the results are shown in Table 1. The vector hydrophone described in this paper has higher sensitivity and deeper pit point. The above good performance shows excellent application prospect of proposed vector hydrophone in very low-frequency.

Figures

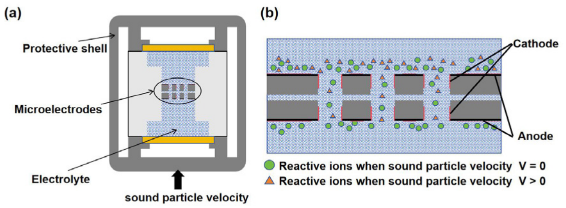

Fig. 1. *Schematic diagram of MEMS co-oscillating electrochemical vector hydrophone (a) Structure diagram (b) Working principle*

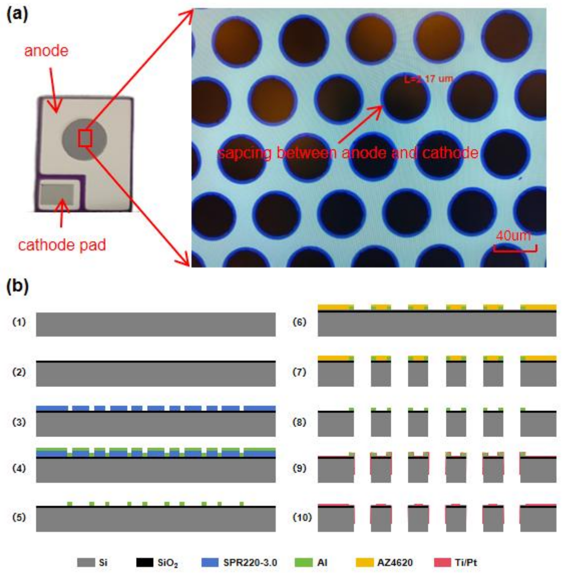

Fig. 2. (a) *Proposed microelectrodes image* (b) *MEMS process flow chart*

Tables

Tab.1: *Performance comparison of different devices*

"dB" of sensitivity REF 0dB=1V/μPa;

"dB" of pit depth is relative amplitude.

Device	Peak sensitivity	Pit depth
[2]	-188.86dB	/
[3]	-180.10dB	-40.8dB
This study	-166.36dB	-47.6dB

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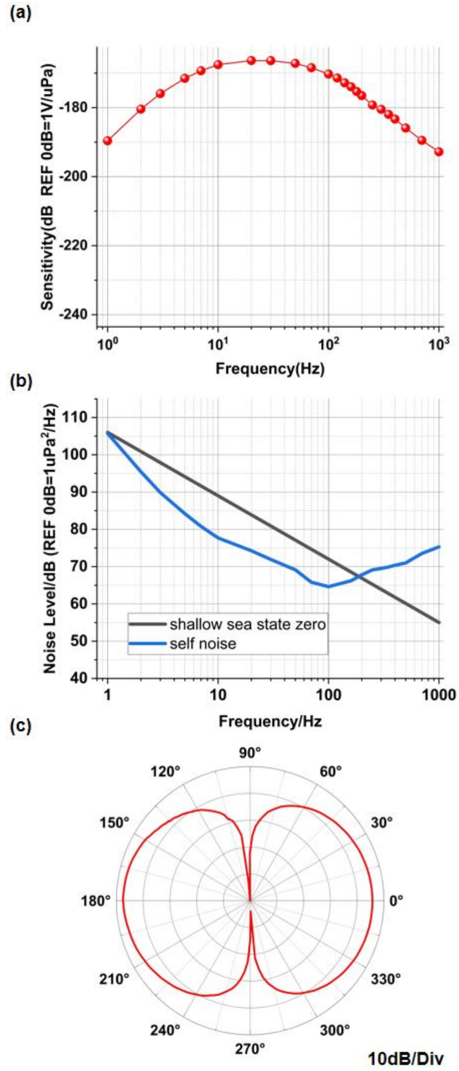

Fig. 3. *Experimental results (a) Sensitivity curve (b) Noise level (c) Directivity curve @200Hz*

Reference

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