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Switchable and flexible underwater acoustic metasurface based on phase-change materials

Min Li[1], Haoyu Guo[2], Guangyuan Su[3], Yongquan Liu[4], Tongqing Lu[5]

[1] Xi'an Jiaotong University, China. 3121106038@stu.xjtu.edu.cn
[2] Southern University of Science and Technology, China. guohy@sustech.edu.cn
[3] Southwest Jiaotong University, China. sugy2024@swjtu.edu.cn
[4] Xi'an Jiaotong University, China. liuy2018@xjtu.edu.cn
[5] Xi'an Jiaotong University, China. tongqinglu@mail.xjtu.edu.cn

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Extended Abstract

Abstract

The manipulation of underwater sound is fundamental to various scenarios on sonar design, ocean geologic mapping, and seabed resource exploration. Flexible and switchable metasurfaces may revolutionize the design of multi-functional underwater structures, but remain underexplored. In this study, we present a flexible and actively switchable acoustic metasurface capable of efficiently manipulating underwater ultrasonic waves. The metasurface is constructed by embedding periodic channels filled with the phase-change material ethylene carbonate (EC) into a polydimethylsiloxane matrix. Leveraging the supercooling-induced reversible transition of EC between a porous solid and a transparent liquid within the seawater temperature range, we introduce a unique mechanism for underwater acoustic modulation. Based on this mechanism, we systematically optimize the channel dimensions and supercell configurations, achieving a significant enhancement in modulation efficiency. Combined experiments and simulations confirm that the optimized supercell design enhances viscous loss in porous solid EC via structural coupling. As a result, the metasurface achieves reversible switching between acoustic transmission and isolation over a broadband frequency range from 50 kHz to 120 kHz and under a large incidence angle between ±60°. Moreover, the flexible matrix allows the metasurface to freely deform into curved and even closed configurations while maintaining stable acoustic modulation capabilities. This study presents a pioneering approach on underwater noise control and signal processing in a compact and switchable way.

Keywords:

Underwater acoustics Metasurface Structural optimization Phase-change material Transmission Supercell