

論文 / 著書情報
Article / Book Information

Title	Piezoelectric-based compact ultrasound transducer for cavitation assisted transdermal drug delivery
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Citation	International workshop on piezoelectric materials and applications in actuators 2022, 13002
Pub. date	2022, 10

Piezoelectric-based Compact Ultrasound Transducer for Cavitation Assisted Transdermal Drug Delivery

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Background: Needleless drug administration has been pursued to eliminate the fear and pain of needle puncture and the risk of infection due to misusing needles. Transdermal drug delivery is a potential alternative to needle injection, absorbing drug molecules across the skin. However, hydrophobic or large weight molecules cannot pass through the outer layer of skin [1]. To overcome this, low-frequency ultrasound (US) cavitation has been employed as mechanical stimuli, which temporarily and locally destroy the outer layer of the skin and form passages for the poor permeable molecules [2]. This is due to a liquid jet formation by a cavitation bubble collapse, as illustrated in Fig. 1(A).

Motivation and Objective: However, a compact and low-frequency US transducer has not been commercially available because downsizing US transducers has still been a technical challenge. Furthermore, it is necessary to generate cavitation by weak ultrasound so that the sound wave do not damage healthy tissue. In this study, we aim to develop a compact, low-frequency and damage-less US transducer suitable for cavitation yield on skin surfaces. To this end, we propose a novel vibration structure which amplifies the sound pressure above the skin, attenuating in tissue under the skin surface.

Materials and Methods: Fig. 1(B) describes the key mechanism of our transducer prototype. A concave-shaped US radiator filled with a liquid is driven by the radial vibration of a circular piezoelectric actuator. This compact structure allows us to amplify the sound pressure in the liquid phase, generating and driving cavitation bubbles onto the skin surface. Moreover, the sound wave does not penetrate further into the skin because the acoustic resonance is localized inside the radiator due to geometric attenuation of the sound wave field. The total height of this transducer is 10 mm as seen in Fig. 1(C).

Results: The two lowest resonance frequencies of this transducer are 69 and 124 kHz. These are suitable for the low-frequency US treatment. We can generate ultrasound cavitation onto a skin mimicking phantom at the resonance frequencies. Moreover, it is found from direct pressure measurements that the enhanced pressure field is confined in the concave structure and is attenuated outside the radiator aperture.

Conclusion: Our compact transducer design enhances ultrasound cavitation yield on a compliant solid surface like human skin under a non-invasive moderate ultrasound irradiation.

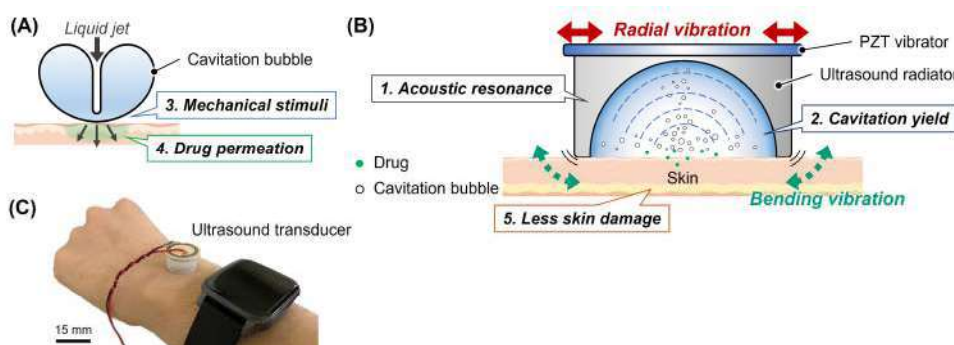


Figure 1 Schematics of (A) a liquid jet formation by a cavitation bubble collapse and (B) a piezoelectric-based compact ultrasound transducer. (C) Photograph of our prototype US transducer.

Reference

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