Toward Ultrasonic Hydrogel Devices: A Protocol for Stimulus-Dependent Bulk Wave Characterization

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Abstract. Hydrogels are increasingly being applied towards sensing, actuation, and acoustic and ultrasonic devices. Development of such devices requires characterization of hydrogels in their intended operational frequency range. To this end, we have developed a test protocol for measuring the bulk acoustic wave transmission spectra of different gels. We also report the effect of different stimuli on the transmission spectra of agarose gel recorded using this protocol.

Possible Sessions

29. Ultrasonic devices, 16. Novel Experimental Techniques, 4. Biomaterials & Biomechanics

Introduction

Hydrogels are 3-dimensional hydrophilic polymer networks. These networks are typically imbued with water and formed through covalent interactions, physical entanglement, and/or hydrogen bonding between polymer chains [1]. Most often, these materials have been developed for and applied to the biomedical field for 3D cell culture and tissue engineering [1]. In recent years, there has been increased interest in hydrogels for biocompatible sensing and actuation [2], [3], wearable technology [4], electronic devices [5], and applications in damping or energy dissipation [6]. Given the intended applications, these hydrogel-based devices are often focused in the acoustic and ultrasonic regimes [7], [8]. It is common for mechanical properties such as stiffness, storage moduli, and loss moduli to be reported when hydrogels are used for structural or biomedical applications. In contrast, transmission spectra for hydrogels are not often reported within publications on sensing and ultrasonic devices.

To this end, we have developed a test protocol for measuring the bulk acoustic wave (BAW) transmission of different gels. This protocol adapts apparatus previously developed for cell patterning [9] to instead measure transmission of gels across a wide range of frequencies (from kHz to MHz). The aim of developing this protocol was to enable testing hydrogel response to external stimuli, such as temperature, humidity, electromagnetic field, and pressure, by assessing change in the transmission spectra as a function of these variables. To this end, we present both the test protocol and preliminary results of transmission spectra recorded of agarose gel under different stimuli. Based the measured stimuli response and transmission spectra, this protocol and adapted apparatus will be applied towards developing hydrogel-based ultrasonic devices.

Experimental Methods

Hydrogel Preparation. Agarose gels were prepared in concentrations ranging from 0.5 to 3 wt% by dissolving the required amount of agarose powder in deionised water. The solution was then autoclaved at 120°C for 20 minutes and then cooled until a gelation occurred at room temperature. For casting, the gels were microwaved in 20s increments until liquified, then poured into 3D printed microwells (fig. 1b). Each sample was left for 10 minutes until gelled before recording a measurement.

Test Protocol and Apparatus. The apparatus consists of laser cut acrylic base adhered to an acetate backing plate using cyanoacrylate glue. Small piezoelectric ceramic slabs are glued to the acrylic (fig.1c). Wires were soldered to the wrap-around electrodes on the piezos to enable electrical contact. A function generator was used to supply a sinusoid sweep or standing wave in the range of interest to the TX piezo. High impedance oscilloscope probes were connected to a picoscope 2405a digital oscilloscope to record the TX and RX piezoelectric signals. The 3D printed microwell was manufactured to fit flush within the acrylic base and was used to house the samples.

Results

Bulk acoustic wave transmission of agarose gel was recorded while varying gel concentration, pressure, and temperature. To enable these measurements, the apparatus (fig. 1) was used to first assess frequency range of interest and the influence of several variables on the precision of each measurement. Fig. 2a shows the effect of time and evaporation on BAW transmission (fig. 2a), where peaks at 3.6, 3.7, and 4.0 kHz increase during gelation. The 3.7 and 4.0 kHz peaks increase sharply after gelation, suggesting a small time window for measurements to be precise. Similarly, fig. 2b shows the effect of varying mass during sample fabrication, where differences of only 100 µL of sample volume were shown to significantly alter the transmission spectra.

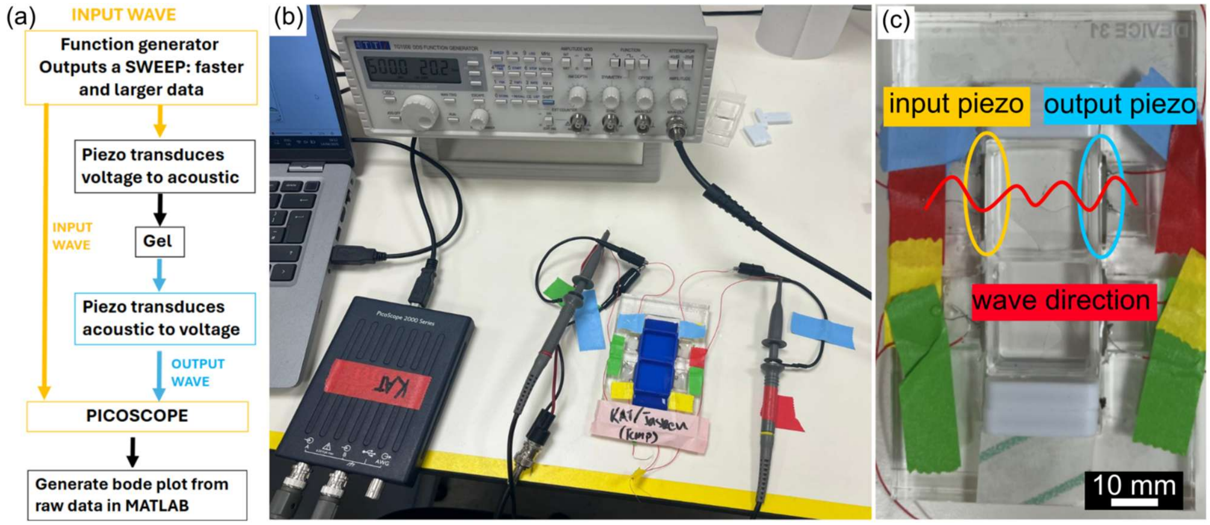

Figure 1: (a) flow map depicting process for data collection and processing. (b) System used to record bulk acoustic wave transmission of hydrogels, including function generator and picoscope. The blue 3D printed microwell is shown placed inside the acrylic base (c) close up of the acrylic base, highlighting input and output piezoelectric transducers and the wave propagation direction through the medium.

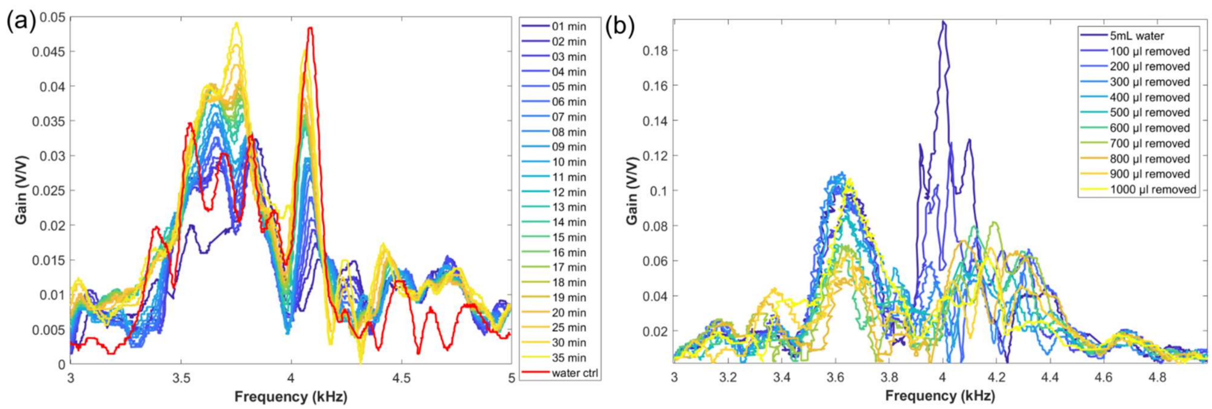

Figure 2: (a) transmission spectra recorded beginning immediately after agarose solution was poured into microwell. The legend indicates minute since sample was cast. Gelation occurred at approximately minute 9. (b) transmission spectra recorded for water, where 100 µL were removed each scan.

Conclusion

We have developed a test protocol for measuring the bulk acoustic wave transmission spectra of different gels and report the preliminary results for agarose recorded using this protocol. First, we assess the effect of variables influencing sample precision on the quality of the measurement possible with our apparatus. We then report the effect of different stimuli on the transmission spectra of agarose gel.

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