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Optical and acoustic characterization of freeze-thawed polyvinyl alcohol phantoms

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Introduction

- Preclinical validation of non-invasive photoacoustic imaging of carotid artery atherosclerosis requires vessel phantoms that imitate optical, acoustic and mechanical properties of vascular tissue.
- In this study, we investigated the relation between acoustic scatterers and optical absorbers to quantify optical and acoustic properties of the polyvinyl alcohol (PVA) phantoms.

Material and Methods

The PVA gel was molded in cylindrical vessel molds to get vessel shaped samples with a wall thickness of 1 mm. After each freeze-thaw (F-T) cycle, pieces of vessel wall were taken out to fit inside 96-well plate slots as seen in Figure 1. The absorbance measurements of the samples were performed using a plate reader with 3 nm increment from 400 nm to 990 nm.

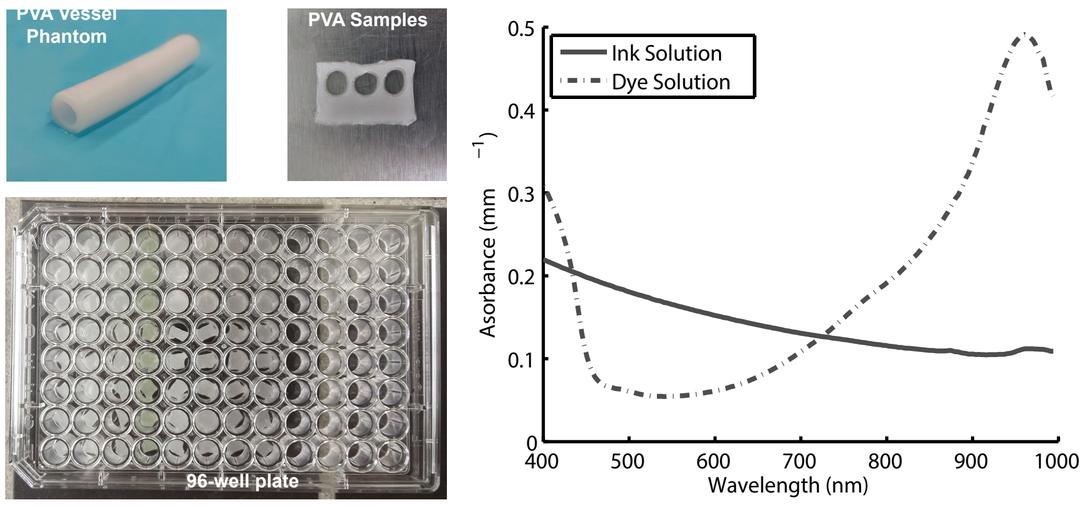
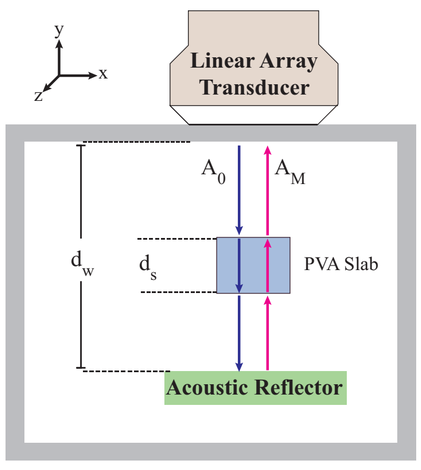


Figure 1: The optical characterization setup

Planewave ultrasond system is used to measure the speed of sound and the attenuation. The demineralized water was used as a reference as in Eqn. (1). The attenuation of acoustic energy through the sample was calculated based on the amplitude change in the wave reflected from the acoustic reflector as in Eqn. (2) and Eqn. (3).



$$(1)\quad \frac{1}{c_s} = \frac{1}{c_w} - \frac{\Delta t}{2d_s}$$

$$(2)\quad \alpha_s = \frac{1}{d_s}\ln\sqrt{\frac{A_M}{A'_M}} + \frac{2}{d_s}\ln\left(1 - R_{PVA}\right) + \alpha_w$$

$$(3)\quad R_{PVA} = R_{Steel}\frac{A_{PVA}}{A_{Steel}}$$

Figure 2: The acoustic characterization setup

Results

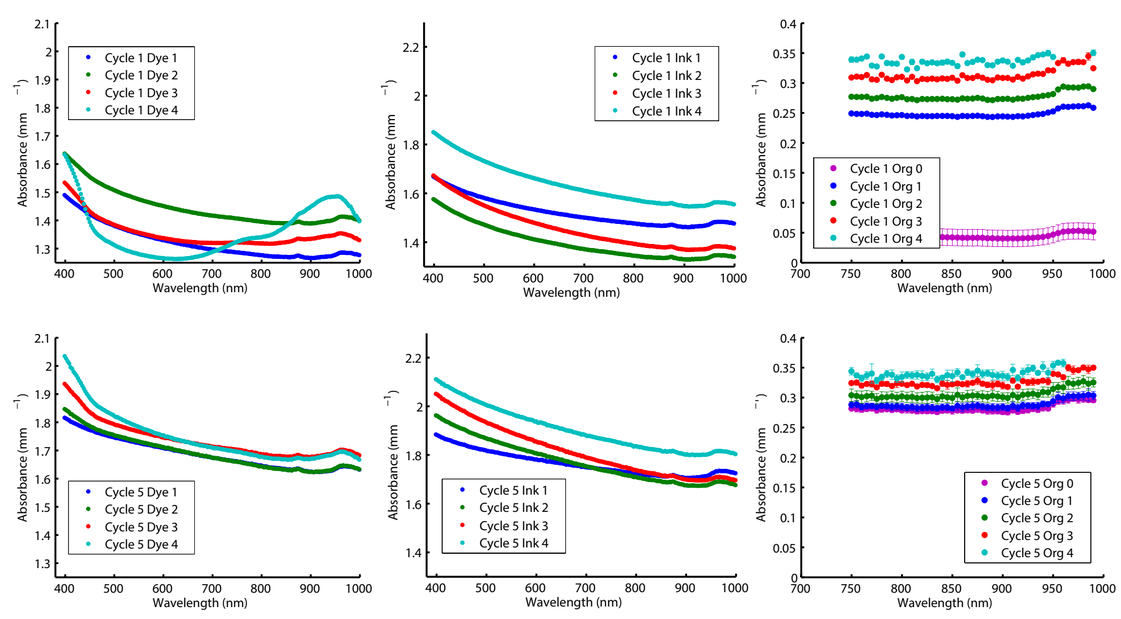


Figure 3: The highest concentration of dye resembles the spectral behavior of pure dye after the first F-T cycle. However, after the fifth cycle scattering becomes more dominant and the difference between four samples diminishes. On the other hand, overall absorbance increases by 30% from the first cycle to the fifth cycle.

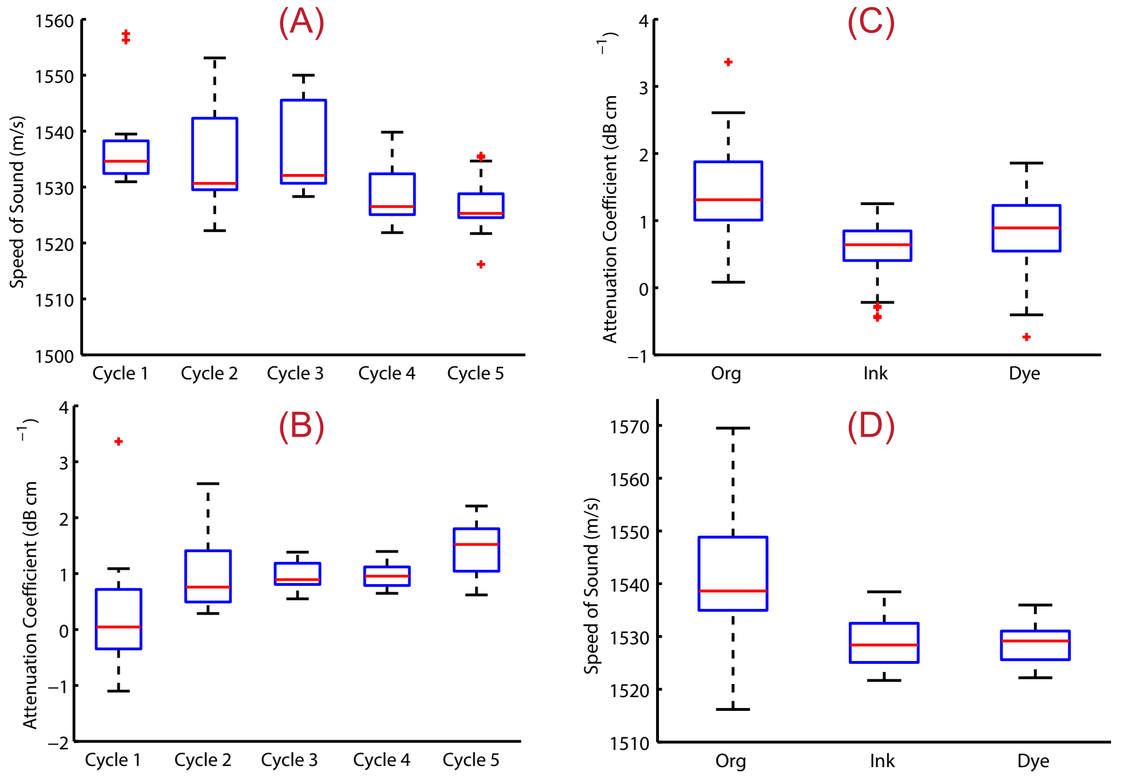


Figure 4: (A)The speed of sound values vary in the range of 1528 - 1535 m/sn and (B) attenuation increases from 0.1 to 1.4 dB/cm with F-T cycles. (C, D) Orgasol alters acoustic properties significantly; however, optical absorbers does not.

Discussion

- Freezing and thawing targets to imitate stiffness of the soft tissue; however, it introduces acoustic and optical scattering.
- Multi-layer vessel phantoms with different inclusions, photoacoustici analysis of phantoms is planned for in future work.

Acknowledgement

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/Department of Biomedical Engineering

Reference:
Arabul, M.U. et al., doi: 10.1109/ULTSYM.2014.060