SB^{3}C2016
Summer Biomechanics, Bioengineering and Biotransport Conference
June 29 –July 2, National Harbor, MD, USA

PERFORMANCE EVALUATION OF A DEVELOPED ACOUSTIC IMPEDANCE DEVICE IN TUMOR SCREENING

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INTRODUCTION

Piezoceramic transducers (PZTs) have been widely used in industry to evaluate mechanical impedance of materials.[1] Imposing a constant voltage on a PZT exerts a constant force on the transducer, and it causes a PZT to vibrate when the PZT is connected to an alternating electric field. On the contrary, a vibrating PZT can produce output voltage signals; when these signals are analyzed by an I/O electronic circuit board, the impedance of the transducer can then be calculated based on the measured voltage and current. When the PZT is bonded with a testing material specimen, the impedance measured reflects the structural features of the specimen. In industry this is often used as a non-destructive evaluation (NDE) method for defect detection. Compared to other NDE techniques such as ultrasound, acoustic emission, x-ray, and thermography, PZTs have been considered cost-effective and user-friendly because of its simplicity and effectiveness in those applications.

In a previous study,[2] we have developed a low cost acoustic impedance device coupled with an I/O electronic circuit board and software to excite a PZT and record the generated electric signals. This device has been tested in fiberglass epoxy composites, wooden samples, and polymer specimen with an embedded crack. It has been shown that the device can detect the presence, shape and approximate dimension of the defect area.

In this study we test the performance of this device on detecting tumors embedded in agarose gels. Our hypothesis is that the structural and composition difference between the tumor and the gel would sufficiently result in variation in the measured acoustic impedance, and consequently can be used to detect the presence of the tumor located below the gel surface. The surface contour of the normalized impedance is mapped by scanning the device on the surface. The results are compared to the actual locations of the embedded tumors.

METHODS

Figure 1 shows the inner components of the transducer, consisting of: (1) a PZT disk of 10.2 mm in diameter and 2.0 mm in thickness (PZT-5A, American Piezo Ceramics, Mackeyville, PA), (2) a flexible copper clad laminate, (3) a frame manufactured by 3D printing, and (4) coaxial cables connected to an impedance evaluation board (AD5933 board, Analog Device Corporation, Norwood, MA). The board serves as both the actuator and the recorder of the electric signals. The experimental setup is shown in Figure 2.

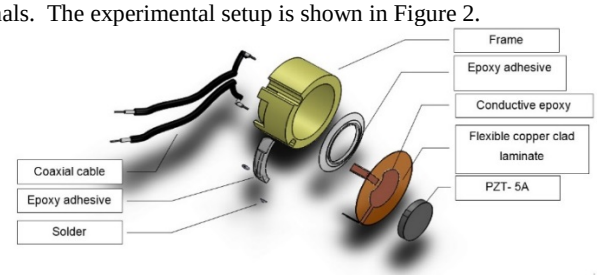

Figure 1: Exploded view of PZT transducer

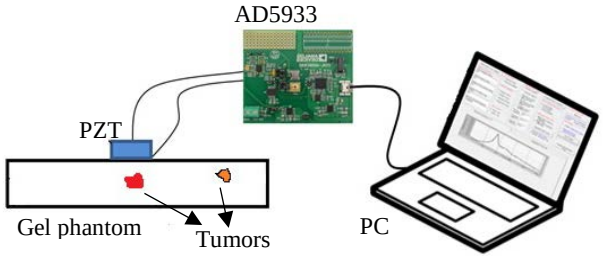

Figure 2: The experiment setup

Typically, the measured impedance is strongly affected by the frequency of the imposed alternating voltage. As shown in Figure 3, a plot of the impedance can be constructed via activating the transducer and recording the responses over a range of the frequency of the voltage. Among all frequencies, there is a peak impedance occurring at the resonance frequency of f_{res}. The impedance at the resonance frequency of the transducer bonded with a specimen (ΔZ in Figure 3) is compared to that of the transducer unloaded, i.e., in air (ΔZ_0 in Figure 3). The bonded specimen will influence the ratio $\Delta Z/\Delta Z_0$, therefore, a surface contour of the ratio can be plotted to show structural variation of a specimen for defect screening.

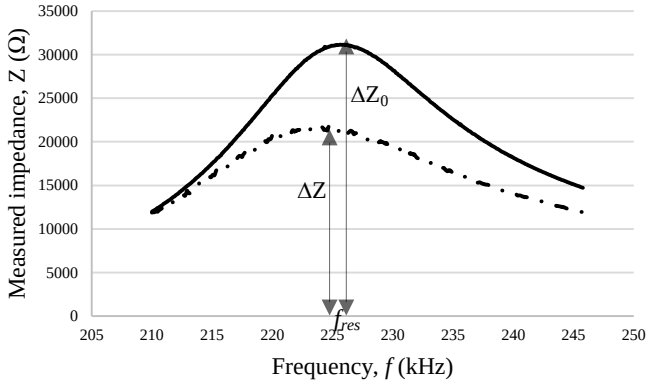

Figure 3: Impedance versus frequency for a loaded (ΔZ) and unloaded transducer (ΔZ_0)

A phantom gel (1% m/m) is prepared by dispersing agarose powder (Sigma-Aldrich, Saint-Louis, MO) in a 10% buffer solution (Tris-Borate EDTA, Gibco BRL, Rockville, MD).[3] The mixture is then heated until the agarose is completely dissolved. After being cooled at room temperature to 60°C, the solution is loaded into a container and cooled further to room temperature (25°C) until solidification. Four prostatic tumors are placed inside the container before the pouring in order to ensure that no bubbles or air gaps are formed in the gel. Tumors 2 - 4 are approximately 10 mm in diameter and tumor 1 is 20 mm in length and 10 mm in width. Tumor 1 is embedded 2 mm beneath the gel surface, tumors 2 and 3 are located deeper in the phantom gel (10 mm), and tumor 4 is the most deeply located in the group (20 mm from the surface). The total surface area to be scanned by the PZT device is 220 mm by 220 mm, gridded in 10×10 mm squares. Note that the actual surface area is much bigger, and we only scan the middle region of the surface to avoid the edge effect. A weight of 50 g is placed on the top of the transducer in order to ensure good and consistent contact between the transducer and the gel surface. The acoustic impedance at the resonance frequency is determined at each gridded square, resulting in a matrix of 22×22 of $\Delta Z/\Delta Z_0$ to cover the gel surface.

RESULTS

Figure 3 also gives the actual experimental recordings of the dependence of the impedance on the imposed frequency. The resonant frequency without loading is identified as 225 kHz. Although the resonant frequency may be affected by the structure of the specimen, the value of f_{res} with the specimen varies slightly in this study (222 kHz – 230 Hz). The impedance magnitude vs frequency curves with or without specimen attachment suggest that the deviation of the ratio of $\Delta Z/\Delta Z_0$ from unity is most evident at the resonant frequency. The ratio at this specific gridded square is 0.7.

The contour of the ratio $\Delta Z/\Delta Z_0$ mapped on the gel surface is presented in Figure 4. $\Delta Z/\Delta Z_0$ varies from approximately 0.70 to 0.86. The ratio at the location without tumor is very uniform, varying slightly as 0.850±0.007, implying repeatability of the sensor. The sensor fails to detect tumor 4; however, it could accurately locate the other three tumors. The gridded squares close to tumor 1 show the lowest ratio of 0.7 - 0.75, while presence of tumors 2 and 3 results in a relatively higher $\Delta Z/\Delta Z_0$ of 0.79, which is still below that of the normal gel of 0.85. The red circles in Figure 4 represent the actual tumor locations and shape. Tumor 4 is not detected because of its depth. Tumor 1 is the most evident; this may be due to the fact that it is located closer to the gel surface and has the largest size in the group.

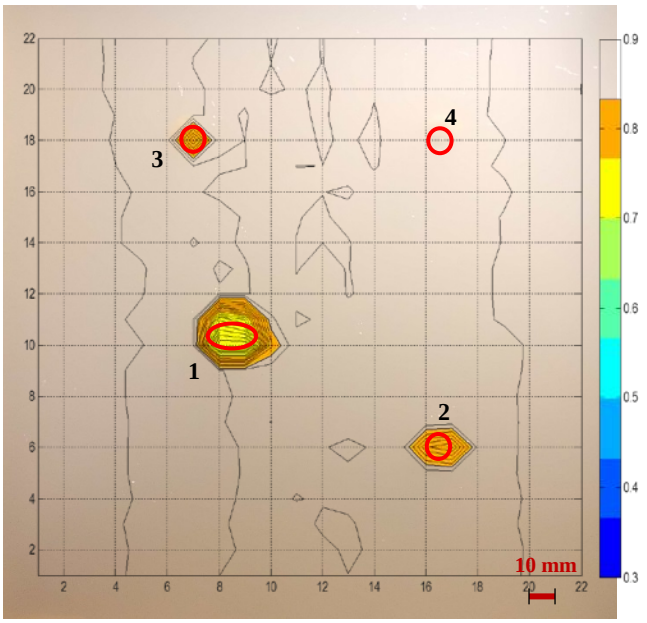

Figure 4: Superimposition of the tumors (red circles) and the contour plot of $\Delta Z/\Delta Z_0$ on the phantom surface.

CONCLUSIONS

In summary, we have developed and prototyped a PZT device for defect screening. The PZT device is tested to evaluate its potential for screening tumors in biomedical applications. In this preliminary study, we could correctly identify three of the four tumors embedded in a gel specimen. The detection fails when the tumor is located more than 10 mm below the gel surface. The results suggest that structural difference between prostatic tumors and normal gels is sufficiently large to generate detectable impedance variation, and demonstrate the feasibility of this approach when the tumor is located close to the surface and/or the tumor is big. Future studies are planned to further improve the device and assess its performance in detecting tumors embedded in actual tissue.

ACKNOWLEDGEMENTS

This study was supported by UMBC.

REFERENCES

[1] Anamdas and Soh, *J Intelligent Material Systems and Structures*, 21:41-59, 2010.

[2] Mohammadabadi A, MS thesis, University of Michigan – Shanghai Jiao Tong University Joint Institute, 2014.

[3] Salloum M, R Ma, D Weeks, and Zhu L, *International Journal of Hyperthermia*, 24(4):337-345, 2008.