Evaluating the Shape of a Nonlinear Deformed PVDF Wearable Pressure Sensors by Analyzing the Acoustic Travelling Wave Speed

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Abstract. Rolling, folding, and stretching a pressure sensor can change the initial geometry during its performance. This deformation can be nonlinear but is measurable by acoustic methods. For example, the form of a flexible piezoelectric strip can considerably affect the time of flight (ToF) of an acoustic wave traveling alongside a strip. Different ToFs can describe the effect of curvature in the flexible strips, which can predict the geometrical shape of the strips performing as a flexible actuator or sensor.

Introduction

Utilizing flexible piezoelectric pressure sensors has been extensively studied in recent papers. The importance of their application in blood vessels [1, 2], cardiovascular monitoring [3], and biomedical [4] are discussed in many types of research. The shape of a flexible piezoelectric sensor can change due to its performance due to the movement of the parts when they bend, turn, stretch, or roll; thus, the stretchable strips should form and return their original shape during a periodic performance. The effect of the stretches on the final body of the strip is not linear but can be practical on the ToF; consequently, how the geometry has been shaped based on the final measured data is the main idea of this paper. The thickness and depth of the strip are assumed to be constant; thus, the cross-section area is also constant during a vessel's deformation. This sectional area deforms like an ellipse where the area does not change during the deformation.

Results and Discussion

The 2D model geometry is created for numerical simulation. The material is Polyvinylidene Fluoride (PVDF)

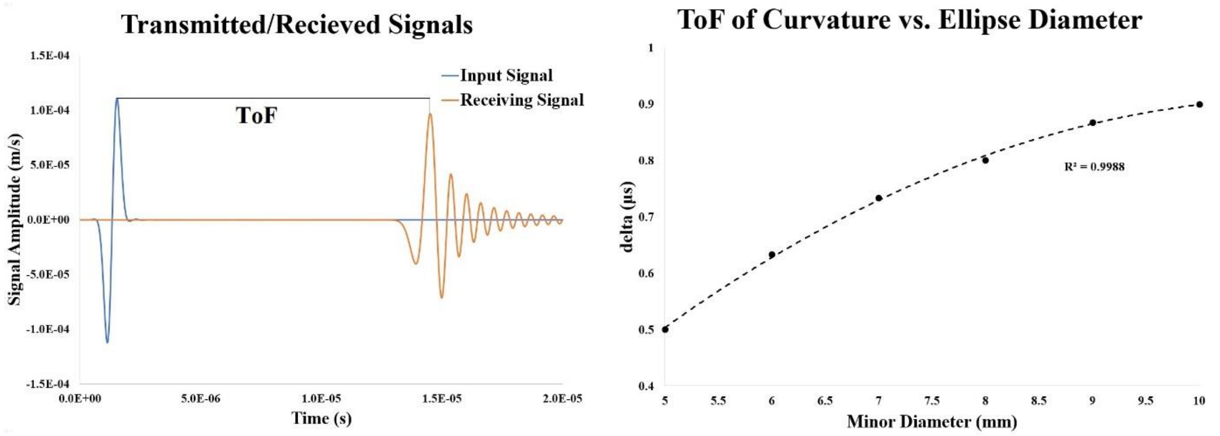

Figure 1. The results show that the effect of the curvature can be measured by ToF

which is anisotropic and has different mechanical characteristics based on the coordinate orientation. The strip thickness is 0.2 mm, and a 2D geometry in COMSOL is utilized. "Elastic Wave" and "Time Explicit" modules are chosen for the simulation. For simplicity, we used the source signal as a bulk acoustic wave. Figure 1 displays the method used to measure the ToF in different cross-sectional areas. In different values of the diameters ("a" in Figure 1), the ToF changes due to the effect of curvature. The trendline is a second-order polynomial with a correlation factor R2=0.9988. Thus, when the ellipse's minimum diameter grows and gets closer to a circular shape (a=10 mm), the ToF of the curvature is at the maximum. Thus, the ratio of the ToF of curvature can identify the magnitude of the load on a circular flexible piezoelectric layer around a vessel. The same procedure is practical for other shapes and parameters with different anisotropic materials. The effect of the curvature in ToF can be measured effectively; thus, this idea introduces a new generation of pressure sensors. The following parts of the paper will discuss the experimental prototypes and their results consistent with the final numerical data.

References

[1] Li, C., Wu, P. M., Lee, S., Gorton, A., Schulz, M. J., & Ahn, C. H. (2008). Flexible dome and bump shape piezoelectric tactile sensors using PVDF-TrFE copolymer. *J. Microelectromechanical Systems* 17(2): 334-341.

[2] Sharma, T., Aroom, K., Naik, S., Gill, B., & Zhang, J. X. (2013). Flexible thin-film PVDF-TrFE based pressure sensor for smart catheter applications. *Annals of biomedical engineering* 41(4): 744-751.

[3] Chang, Y. M., Lee, J. S., & Kim, K. J. (2007). Heartbeat monitoring technique based on corona-poled PVDF film sensor for smart apparel application. In *Solid State Phenomena Trans Tech Publications Ltd.* 124: 299-302.

[4] Johar, M. A., Waseem, A., Hassan, M. A., Bagal, I. V., Abdullah, A., Ha, J. S., & Ryu, S. W. (2020). Highly durable piezoelectric nanogenerator by heteroepitaxy of GaN nanowires on Cu foil for enhanced output using ambient actuation sources. *Advanced Energy Materials* 10(47): 2002608.