Accepted Manuscript

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PII: S0093-6413(17)30219-7
DOI: http://dx.doi.org/doi:10.1016/j.mechrescom.2017.08.005
Reference: MRC 3206

To appear in:

Received date: 28-4-2017
Revised date: 20-7-2017
Accepted date: 15-8-2017

Please cite this article as: Yotam Ziser, Gal Shmuel, Experimental slowing of flexural waves in dielectric elastomer films by voltage, *<![CDATA[Mechanics Research Communications]]>* (2017), http://dx.doi.org/10.1016/j.mechrescom.2017.08.005

Experimental slowing of flexural waves in dielectric elastomer films by voltage

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Abstract

Shape and physical properties of dielectric elastomers are changeable by voltage. Theoretical works show that these changes can be harnessed to tune the propagation of superposed elastic waves. We experimentally demonstrate this concept by manipulating waves in a dielectric elastomer film, focusing on the flexural mode at low frequencies. To this end, we design an experimental apparatus to pre-stretch, actuate, excite waves at low frequencies in a VHB™ 4910 film, and measure the velocity of the fundamental flexural mode. Our results show that the excited wave velocity is slowed down by the applied voltage, and provide experimental proof of concept for the application of deformable dielectrics as tunable waveguides.

In the presence of electric fields, dielectric elastomers can experience large strains accompanied with a change in their physical properties [1, 2]. The standard actuation mechanism is established by coating the surfaces perpendicular to the thickness of an elastomeric film with deformable electrodes, and connecting them to a voltage source; ensuing Coulomb forces between accumulated charge cause deformation and change the electromechanical response [3]. Various applications were realized based on this electrostatic actuation, such as tunable valves [4], noise filters [5, 6], and soft robotics [7], to name just a few. (For more applications, see the book by [8].)

Recently, the potential of dielectric elastomers as tunable waveguides has been extensively explored using theory [9–18]. Corresponding experimental work—the focus of this paper—has yet to be realized, where experiments on the dynamics of soft elastomers are limited to the study of inflation [19–22] and in-plane deformation [23] of membranes, radial motions of tubes [24], and to particular actuators [25–27]. Herein, we explore the tunability of plate or *Lamb* waves [28] in a dielectric elastomer film [29]. We focus on the fundamental anti-symmetric wave—the only flexural mode in the low frequency regime. We show that the mode is slowed down by the applied voltage, as theoretically suggested by [29].

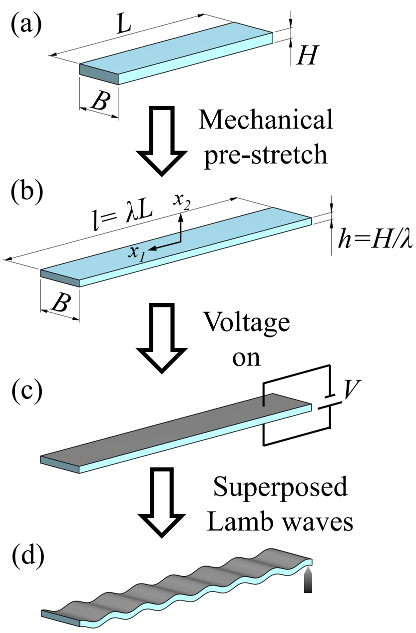

Figure 1: An elastomeric film coated with compliant electrodes (a) in the reference configuration; (b) clamped after pre-stretched, (c) subjected to a voltage V; (d) when Lamb waves are excited on top of its actuated state.

Theory and analytical model. We begin by concisely revisiting the governing equations and analytical model; for