

A PIEZOELECTRICALLY-ACTUATED CELL STRETCHING DEVICE

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INTRODUCTION

A number of systems have been designed to subject cells to mechanical loading in the laboratory and thereby simulate the micromechanical environment seen by many different types of cells (Schaffer, et. al., 1994). In most systems the cells are adhered to an elastic membrane that is deformed mechanically, thereby transferring the deformation to the cells.

The current methods commonly used for cell deformation primarily utilize vacuum actuation on the membrane or cam and follower mechanisms that load the membrane. Producing repeatable strains at levels below 1% can be impractical with these devices. A recent study by Tanaka (1999) presented a piezoelectric device for mechanically stimulating cells. The actuator was a piezoelectric bimorph which was attached to a collagen block containing cells. Achievable strains of 0.02% to 4% were reported, although only strains of 2% were verified.

The objective of this project was to design a new cell stretching mechanism that can produce repeatable membrane strains of less than 1%, at frequencies ranging from 0.5 to 5 Hz. A piezoelectric actuator was chosen to be the prime mover in the mechanism, because its displacement and force range is ideally suited to this application. In addition, one can easily achieve a wide

range of position vs. time functions from the piezoelectric actuator.

DESIGN OF THE DEVICE

A schematic of the cell stretching device is shown in Fig. 1. Two silicone membranes (7.6 cm x 2.5 cm) are supported in a polystyrene frame. One end of each membrane is fixed to the frame, while the other end is attached to a linkage that is free to rotate, thus stretching the membranes. The cell culture will adhere to the membranes, so that mechanical strain imparted to the membranes will be transferred to the cells. The frame is housed in a 20.3 cm diameter petri dish which contains growth media. The linkage is driven by a piezoelectric Thunder actuator (model TH-7R, Face International Corporation). Since the toxicity of the actuator materials are unknown, the actuator is separated from the media with a lever arm.

A Thunder actuator is a thin (~0.6 mm) curved piezoelectric transducer consisting of a stainless steel backing and a piezoceramic wafer bonded together by a polyimide. The piezoceramic has electrodes on the top and bottom (across its thin dimension). When a voltage is applied, the piezoelectric effect causes the ceramic to contract or expand along its length. Because the ceramic is bonded to and constrained by the stainless steel, these very small strains are amplified by relatively large changes in actuator

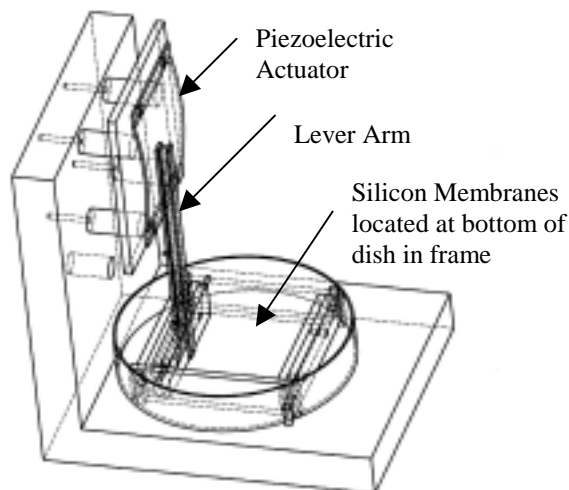


Figure 1: Schematic of piezoelectrically actuated cell stretching mechanism.

curvature or dome height. This dome motion is imparted to the lever arm, and therefore to the membrane.

RESULTS

The Thunder actuator used in this design is capable of producing motions of approximately 1 mm under static loading of the membrane in the mechanism. At a frequency of 5 Hz, the peak-to-peak displacement is reduced to approximately 0.75 mm. These deflections are for a 180 V excitation applied to the actuator. If applied directly to the membrane, these deflections correspond to strains of 1.3% and 1%, respectively. By moving the actuator further away from the fulcrum of the lever, the displacement ratio is reduced by as much as six times. So, at its farthest location, the same actuator deflections correspond to strains of 0.22% and 0.16%. Of course, the excitation can be reduced for even lower strain in the membrane.

Actual strain in the membrane was measured for a series of static deflections of the lever arm to ensure that the device was imparting the expected strain levels. Strain was

determined optically by tracking the separation of markers placed on the membrane. An example of strain data is shown in Fig. 2 for two sets of markers placed 1 mm apart in the center of the membrane. Sets A & B are 20 and 40 mm, respectively, from the fixed end. Measured and expected strains are plotted, where expected strain is calculated from the deflections imparted to the lever arm by a dial caliper. Since the resolution of the optical system is very coarse for this application (strain resolution was limited to only ~0.35% corresponding to one pixel of motion), the data only serves to show that the correct trend is followed as the membrane elongation is increased.

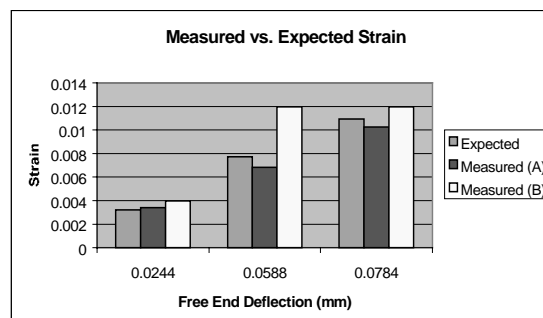


Figure 2. Strain in membrane for known lever arm deflections.

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