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Cell Stretcher Based on Single-crystal Bimorph Piezoelectric Actuators

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Biomechanical studies of stretched cells are important for understanding of mechanisms and reactions driving muscle contraction, migration of cells, processes in cytoskeleton etc. Several methods for stretching cells are available today. The simplest of them consists in a uniaxial expansion of a flexible substrate with a cell culture by a stepper motor. More complex methods include incubating cells with protein-coated superparamagnetic beads with subsequent use of a needle-shaped core of an electromagnet and utilizing substrates with stress-sensitive fluorescent markers [1, 2]. These methods allow stretching an entire cell culture, thus working with isolated cells is difficult. There is also a tool on the market produced by IonOptix, USA which can be utilized for stretching single cardiac myocytes [3], however, this equipment is expensive and not always appropriate for use with complex systems such as scanning ion conductance microscopes (SICM).

In this paper we present a concept of a stretcher of isolated cells with actuators based on $LiNbO_3$ bidomain single crystals. Bidomain crystals are ferroelectrics which contains only two bulk domains with oppositely directed vectors of spontaneous polarization. Application of a voltage or mechanical deformation to the bidomain plates leads to a bimorph-like behavior which allows to design new mechano-electric devices such as precise sensors, actuators and waste energy harvesters [4–7]. The main feature of actuators made of bidomain crystals is a linear dependence of the position on the applied voltage in the entire range of deformation of a piezoelectric material. Another advantage is the availability of the bidomain crystals: $LiNbO_3$ is a lead-free commercially manufactured material having a consistent quality and a relatively low price.

The stretcher is designed to be installed on the SICM based on an inverted optical microscope with a 3-axis probe positioning stage. Two 3D stages provided by ThorLabs, USA implement coarse positioning of the bidomain piezoelectric actuators fastened from both sides. Each of the actuators is equipped with a rigid rod having a thin tip with a diameter of ca. 20 μm (Fig. 1).

The micrometer screws of the positioning stages allow a careful selection of a goal cell into a Ø 50 mm Petri dish. After the cell being selected, the tips of the rods are attached to it by a biocompatible adhesive. Then the cell can be stretched or compressed by the piezoelectric actuators. The deflection limit of each of the actuators is 100 μm, the positioning accuracy is less than 10 nm. The absence of stepper motors and the linearity of the actuators with respect to the applied voltage allow researchers to stretch the cell in a controlled and careful manner. The use of commercially available parts and materials reduces the cost of the device and simplifies the repair and upgrade of the stretcher.

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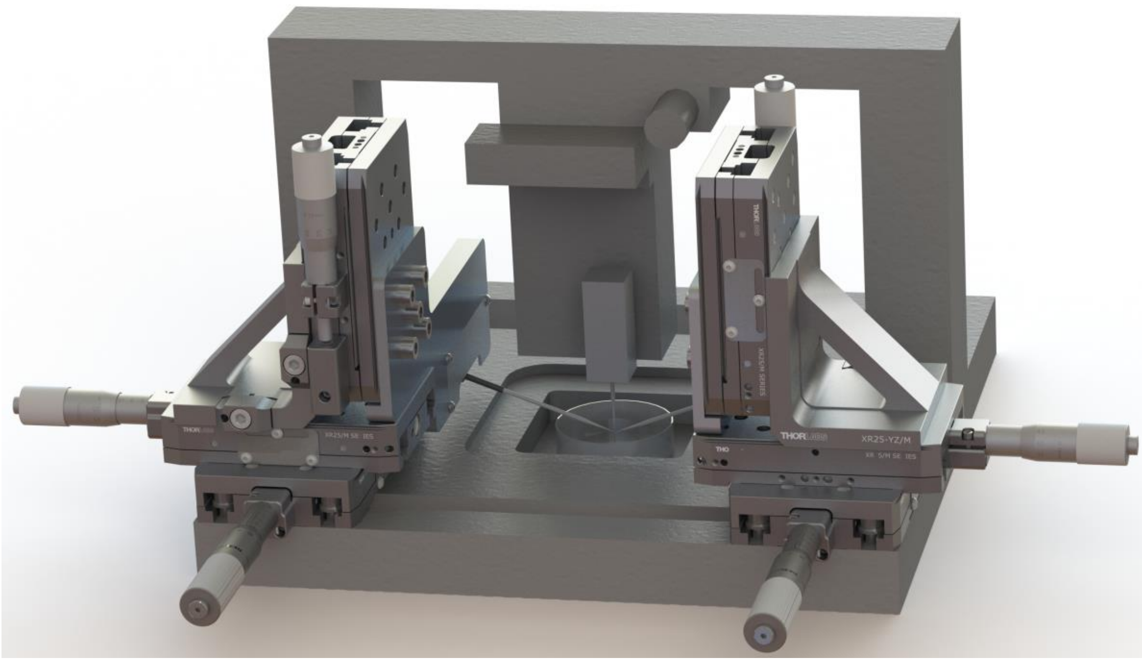

Figure 1. Visualization of the cell stretcher

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