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Flexible cell culture device made of membrane-type silicone composites for simulating human body

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ABSTRACT

Human tissues are exposed to various mechanical stimuli, and the types and magnitudes of the mechanical stimuli acting on cells and tissues are important factors in controlling the development pathway of cells and tissues. Therefore, giving repetitive mechanical stimuli to culturing cells may provide beneficial effects, such as differentiating target cells or accelerating cell development, by controlling the type of stimulus and its magnitude. Electroactive polymers (EAPs) respond to electrical voltage with significant changes in shape or size and can transfer appropriate (1–20%) mechanical stimuli to cells. In this study, we designed a new type of flexible cell culture device made of silicone (composite) film, and evaluated the actuating strain of the driving portion of the cell culture device according to the pre-stretching condition and the clay nanoparticle (i.e., organically modified montmorillonite, or OMMT) content. The effect of OMMT particles on the electro-mechanical performance of the silicone (composite) film actuators was investigated by adding 0–5% OMMT particles to silicone elastomer using the solvent-assisted mixing method. The effects of these two major variables on actuation strain were quantitatively investigated, and the most appropriate conditions for the driving part of a cell culture device were determined.

1. Introduction

Electroactive polymers (EAPs) are materials that respond to electrical stimuli with significantly large deformation. Since EAPs have many advantages, such as fast response speed, high energy density, large deformation, and good flexibility, these materials are drawing the attention of researchers in the field of actuators. The aforementioned properties complement the shortcomings of existing sensor/actuator materials (e.g., ceramics and shape-memory alloys). Hence, EAPs are actively being studied for sensors and actuators in several applications [1–5]. EAP actuators can generate various deformation patterns through control of the frame shape, pre-stretching conditions, and so on. Electronic EAPs, which are driven by electronic polarization, require a high driving voltage but have a fast response speed, large deformation, and high energy density. In addition, they maintain their deformed state under DC voltage, so electronic EAPs are more suitable than ionic EAPs as ordinary actuators.

Dielectric elastomers, which belong to the electronic EAP category, are strong candidates for biomimetic actuators because of their ability to undergo large deformations, their excellent durability, and their high energy density [6,7]. Although acrylic elastomers show very large electrically induced strains (with a maximum of 380%), they have some critical drawbacks, such as high viscosity, hysteresis, and frequency-dependent behavior. On the other hand, silicone elastomers exhibit temperature stability and fast response speed, but their activation strain is relatively low. Such characteristics have made the silicone elastomer a suitable material for dielectric elastomer actuators (DEAs) [8]. In addition, EAPs are known as 'artificial muscles', because their driving mechanism and properties are similar to biological muscles [9]. This means the human body environment can be easily provided by these materials.

Generally, human tissues are exposed to complex *in vivo* conditions related to mechanical stimuli. The types and magnitudes of these stimuli are important because they may affect the differentiation and development pathways of cells and tissues. Mechanical stimuli have been utilized to regenerate human tissues and cells by replicating this mechanism [10]. In particular, the cells related to the musculoskeletal system are significantly affected by the mechanical environment [11–13]. Thus, in the field of bone tissue engineering, dynamic cell culturing has been actively studied for effective healing of damaged bones [14,15]. Although it is difficult

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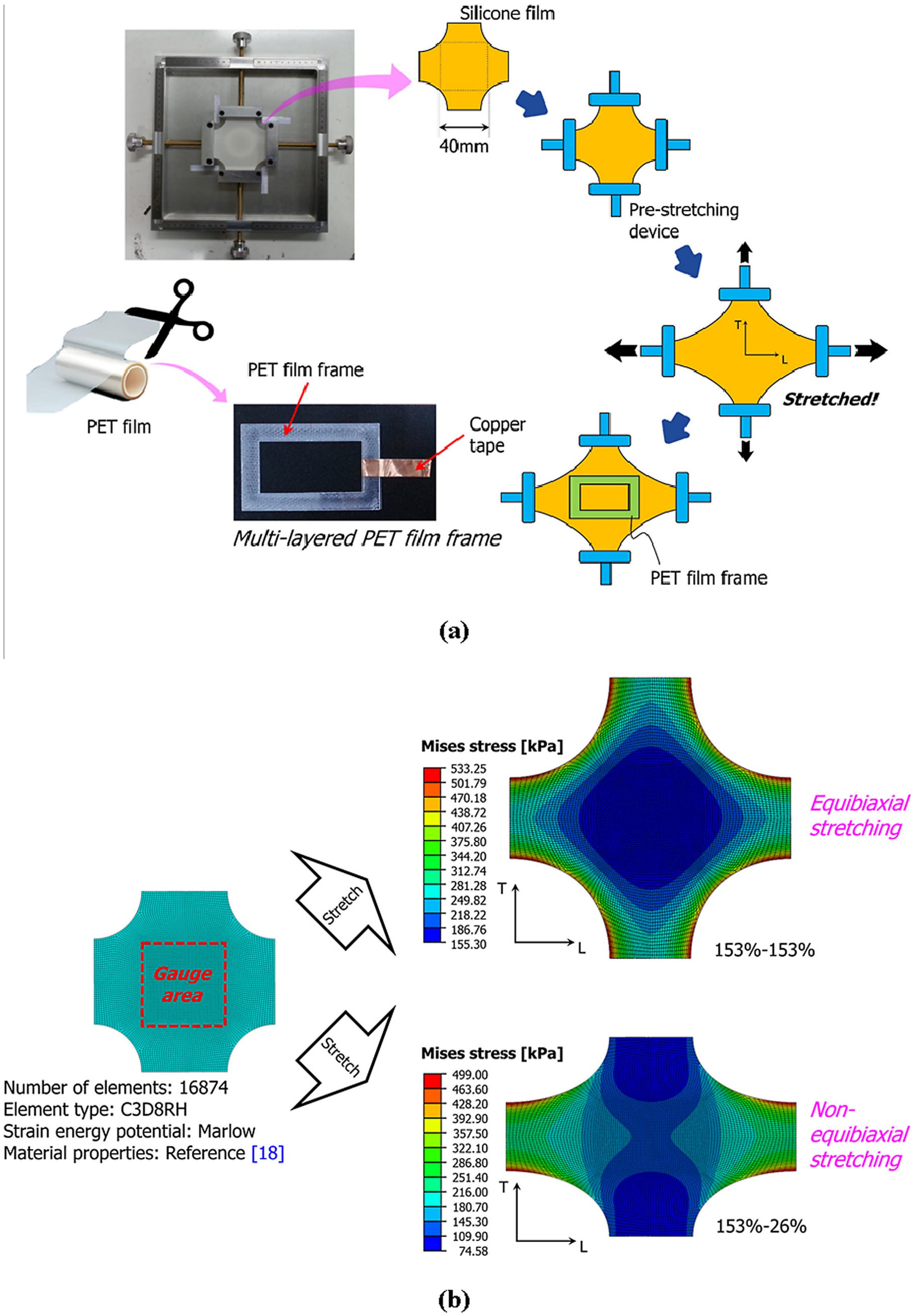

Fig. 1. Specimen preparation; (a) configurations of pre-stretching process, and (b) stress distributions under equibiaxial and non-equibiaxial stretching conditions.