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主 論 文 の 要 旨

論文題目　**Eye Surgery Training Simulator Having 3D Microchannels**
(3次元微細構造を有する眼科手術訓練シミュレータ)

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論 文 内 容 の 要 旨

The ability to produce artificial organ/tissue, that mimics the real organ/tissue in its physical properties, with an effective, rapid, easy, inexpensive, and reproducible techniques, is significant in a number of medical applications such as surgical training, surgical planning, evaluation of robotics systems, and tissue engineering.

Synthetic models are functional tools for training novice surgeons and for assessment of medical equipment or surgical assistant robotics systems. Currently, a plethora of surgical simulation systems, which can be used for training apprentices or evaluation of medical devices, exist. For successful and workable simulator model however, it is necessary to: 1) the simulator imitates the target human organ or tissue in its anatomical and mechanical characteristics, 2) the simulator should exhibit properties such as reproducibility, durability and the fabrication methods of the simulator should be inexpensive and easy to use, as much as possible, and 3) the models do not have ethical concerns.

This dissertation aims, firstly, to introduce two fabrication methods, photolithography and femtosecond laser and mask hybrid exposure (FMEx), for fabrication of three dimensional (3D) microchannel that allow for a close simulation of the natural structure of small diameter of human microvessels (≤15 μm) that can be used as surgical simulator, for different types of surgeries such as eye surgeries, or other biomedical applications. The first method, photolithography with the aid of 3D printing models, enables us from creation of 3D microchannel, with rectangular cross section, over irregular surface with different depths and a large model size. Second method, FMEx, made it possible to fabricate microchannel, having circular cross section, with part of the millimeter-scale structure with a submicrometer resolution in 3D. Both methods made it possible to fabricate a millimetre-scale 3D structure with a submicrometric resolution and achieve an easy injection of solution. This is because it was possible to fabricate typical microfluidic channels used for model inlet and outlet ports. Furthermore, in the FMEx method, we employed an acid-diffusion effect using a chemically amplified resist to form a circular channel cross-section. The acid-diffusion effect made it realizable to fabricate a smooth surface independent of the laser scanning line width. Finally, the microvessel model made from materials with controllable mechanical characteristics that can be tuned to make them close to the mechanical properties of human microvessel.

Secondly, by using a simple fabrication techniques, we successfully developed an eye model, which consists of sclera with clear cornea and 3D microchannel, which simulate human micro tube named Schlemm's canal (SC), and thin membrane, which represents the trabecular meshwork (TM), cover the microchannel, as an eye surgical simulator for glaucoma surgery. The eye model was fabricated by soft materials with controllable mechanical demeanor to make it similar to actual target tissues. The proposed eye surgery model can be used as a simulator for training unexperienced surgeons on glaucoma surgery. Additionally, to emulate the surgery with constraints similar to those in a real operation, the eye model was installed on a skull platform. A preliminary assessment by eye doctors showed that the model can help novice eye doctors to develop the basic skills of the surgery. We foresee a number of applications for the proposed eye model, besides simulation and training for the surgery, including medical device testing and surgical planning.

In conclusion, two fabrication methods of 3D microchannel, which mimics human microvessel, were developed. Moreover, an eye surgery training simulator, which consists of 3D microchannel that represents human microvessel, sclera, and trabecular meshwork tissues, introduced as surgical simulator for glaucoma surgery.