Development of Microneedles Fabricated by Synchrotron Radiation Lithography for Bio-medical Applications

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In this thesis, development of microneedles fabricated by synchrotron radiation deep x-ray lithography with PCT (plane-pattern to cross-section transfer) technique is summarized. In Chapter 1, a review of previous reports on the fabrication of microneedles for a painless use based on the nervous system of human skin and the future developing trend are presented. The introduction to the research carried out in this thesis is included in this chapter. The design concepts of three configurations of the PMMA microneedles; single-tip, quadruplets, and hollow types are addressed in Chapter 2. Fabrication process of the three types of microneedle array of 1024 microneedles with 100 μm- diameter and 300 μm-length in a chip of 1 cm^2 is described in Chapter 3 including the requirements of facilities, apparatuses, materials and the x-ray mask. The difficulties in preparation of the fabrication process are also discussed. In Chapter 4, the fabrication results of the microneedles developed in this study including that of the improved process are exhibited. Chapter 5 focused on the quadruplets-microneedle which was designed to be used for a blood extraction by capillary phenomena. Mathematical models of the capillary rises and related functional characteristic of the quadruplets-microneedle structure were developed to confirm the use of this type. In Chapter 6, the experiments for evaluation uses of the microneedle were carried out. The experiments were; a penetration test for observation of flaring skin by a single-tip microneedle array, a liquid-extraction test by a quadruplets-microneedle array, a capillary rising test by microgrooves whose cross section was identical to that of the quadruplets-microneedles and the strength test by a hollow microneedle array. The results of first three tests are illustrated by images of, skin flaring after a penetration, the extracted liquid remained inside the groove of quadruplets-microneedles, the blood raised by capillary force along the microgrooves up to 8.6 mm and for the latter test, a compressed load plot shows that a hollow microneedle could endure a load of 0.4 N before breaking down. Chapter 7 described the application of each microneedle type in this study. The bio-medical applications such as the drug delivery and the blood extraction were examined. The hollow microneedle was selected to be integrated with portable system designed for blood electrolyte analysis as a recommended application for the future work. In Chapter 8, the entire results of microneedle fabrications and evaluations are summarized including the cost list of manufacturing the microneedles.