A Porous Polymer Microneedle Array for Interstitial Fluid Monitoring

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Transdermal monitoring of interstitial fluid offers an exciting alternative to blood based monitoring as the interstitial fluid contains most of the analytes present in blood. However, as the stratum corneum, the outermost layer of the skin, has evolved into an efficient barrier to outward migration of body fluids, a suitable technique is required to extract sufficient quantity of interstitial fluid for analysis. A microneedle array, a two-dimensional array of submillimeter needles, penetrates skin without stimulating the nerves located deeper in the skin and therefore eliminates pain and discomfort. Microneedle arrays can bypass the skin barrier for drug delivery [1] and monitoring of biomarkers or glucose. Although there are reports on hollow microneedles that can extract sufficient interstitial fluid from the skin [2], these hollow microneedles are made of either silicon or glass that easily break and remain in the skin to cause a problem. Here, we fabricated a novel porous polymer microneedle array with continuous micropores that enables fast fluid extraction.

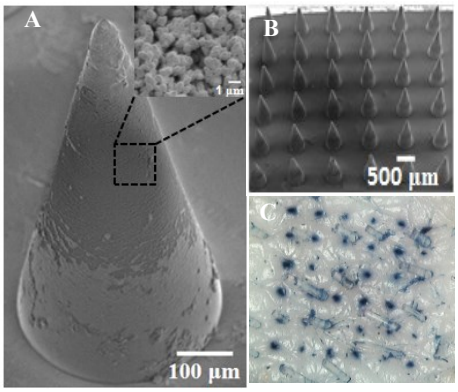

Fig 1. A. SEM image of a single microneedle; B. SEM image of the microneedles array; C. a photo of a pig skin stained by trypan blue after penetrating by the porous microneedles

A mixture of a methacrylate monomer, crosslinkers, a porogen polymer, a photoinitiator, and solvent was poured into a mold, and polymerized by UV irradiation for 1 hour. The polymerized microneedle array was peeled off and put into methanol/water to dissolve the porogen. Scanning electron microscopy images (Fig 1. A) show that the diameter of pores in the microneedles is about 1 µm. Skin penetration with the fabricated microneedle array followed by staining with trypan blue (Fig 1C) showed that the insertion rate of the fabricated microneedles is >80%. Speed of water absorption of the microneedle array was tested by inserting into a colored agarose gel. The porous microneedle array allowed water to go through the microneedle in 7 minutes, whereas a microneedle array fabricated without a porogen did not let water to permeate more than one hour, which indicates continuously porous structures in the microneedle are essential for the fast water absorption. In summary, we successfully fabricated the porous microneedles that can penetrate the skin and absorb water quickly, which will open up possibilities for monitoring interstitial fluid.

Reference

[1] Prausnitz, Mark R. Advanced drug delivery reviews 56.5 (2004): 581-587.
[2] Mukerjee, E. V., et al., Sensors and Actuators A: Physical 114.2 (2004): 267-275.