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## Photomask Patterning for Slope-Form Deep Etching Using Deep-Reactive-Ion Etching and Gradation Exposure

Masaki Yamaguchi\* and Yuki Nakayama

Graduate School of Engineering, Iwate University, 4-3-5 Ueda, Morioka 020-8551, Japan

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The purpose of this research is to demonstrate a methodology for etching silicon to particular required depths that can be used when designing structures to manufacture microneedles. A photolithography technique was demonstrated using gradation exposure and deep-reactive-ion etching (DRIE). The entire photolithography process was carried out in two steps: (i) a photoresist pattern was transferred onto silicon dioxide using a layout mask, and (ii) a silicon mold was formed using exposure through the use of a gradation mask and DRIE. A digital gradation mask design that included 16 scales was proposed. The exposure time and thickness of the photoresist were optimized experimentally under 102 different conditions. The aspect ratio of the resist reached 19:1 and the maximum etched depth was 285  $\mu$ m under conditions of 6 s exposure time and 3  $\mu$ m thickness of the photoresist. It was demonstrated that the slopes formed by deep etching ranged between 0–285  $\mu$ m, which is needed for microneedles to be realised by DRIE and grey-scale technology.

\*Corresponding author: e-mail: masakiy@iwate-u.ac.jp