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Optimization of silver-assisted nano-pillar etching process in silicon

Abstract

In this study, a respond surface methodology (RSM) model is developed using three-level Box-Behnken experimental design (BBD) technique. This model is developed to investigate the influence of metal-assisted chemical etching (MACE) process variables on the nanopillars profiles created in single crystalline silicon (Si) substrate. Design-Expert® software (version 7.1) is employed in formulating the RSM model based on five critical process variables: (A) concentration of silver (Ag), (B) concentration of hydrofluoric acid (HF), (C) concentration of hydrogen peroxide (H2O2), (D) deposition time, and (E) etching time. This model is supported by data from 46 experimental configurations. Etched profiles as a function of lateral etching rate, vertical etching rate, height, size and separation between the Si trenches and etching uniformity are characterized using field emission scanning electron microscope (FE-SEM). A quadratic regression model is developed to correlate critical process variables and is validated using the analysis of variance (ANOVA) methodology. The model exhibits near-linear dependence of lateral and vertical etching rates on both the H2O2 concentration and etching time. The predicted model is in good agreement with the experimental data where R 2 is equal to 0.80 and 0.67 for the etching rate and lateral etching respectively. The optimized result shows minimum lateral etching with the average pore size of about 69nm while the maximum etching rate is estimated at around 360nm/min. The model demonstrates that the etching process uniformity is not influenced by either the etchant concentration or the etching time. This lack of uniformity could be attributed to the surface condition of the wafer. Optimization of the process parameters show adequate accuracy of the model with acceptable percentage errors of 6%, 59%, 1.8%, 38% and 61% for determination of the height, separation, size, the pore size and the etching rate respectively.

Keywords

Box-Behnken design; Metal assisted chemical etching; Nano-texturing; Response surface methodology; Si nanostructures