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A New Ultrafine Si Trench Etching Technique Using Multi-Step Processing

T. Shibata and M. Oda

NTT Electrical Communication Laboratories
Atsugi, Kanagawa 243-01, Japan

A new approach to an ultrafine silicon trench etching using plasma oxidized side wall protection and multi-step processing is described.

There has been much interest in silicon trench etching techniques for application to high density VLSIs. Reactive ion etching (RIE) has been widely used for such purposes. However, as the trench opening width shrinks and the aspect ratio (depth/ width) becomes larger, some problems arise. In particular, undercutting due to ion scattering at sloped mask edges is a serious problem.

In this work, we sought to achieve highly directional etching by forming a plasma oxidized film to eliminate undercutting. A conventional reactive ion etching (RIE) apparatus has been used both to etch and oxidize silicon.

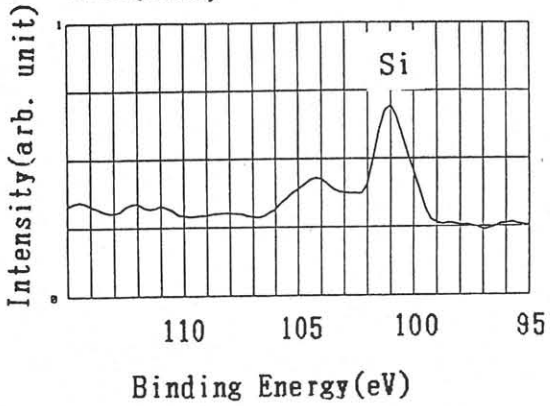
Fig. 1 shows XPS Si 2p spectra of silicon surfaces (a) after RIE using chroline as an etching gas and (b) after the same RIE followed by short oxygen plasma treatment. Thus, by short oxygen plasma treatment, silicon dioxide layer is found to be formed on a silicon surface etched by chroline RIE.

Fig. 2 shows the Multi-Step Trench (MST) etching method process sequence. First, a short period chroline RIE is performed, in which the etched depth is shallow enough for the side wall of the etched trench to be vertical , and undercutting is negligible, as shown in Fig. 2(a). Then, a short oxygen plasma treatment is performed by changing the gas in the same chamber. By this treatment, a thin oxide film layer is easily formed on the trench inner wall. And then, chroline is substituted for oxygen, and etching is continued. In this step, the etching proceeds vertically as shown in Fig. 2(c). This is because the oxide layer formed on the trench bottom is removed by ion bombardment during the etching step, whereas the side wall covered with the oxide layer cannot be attacked. Thus, directionality results. A deeper trench is easily obtained by repeating these etching and plasma oxidation steps.

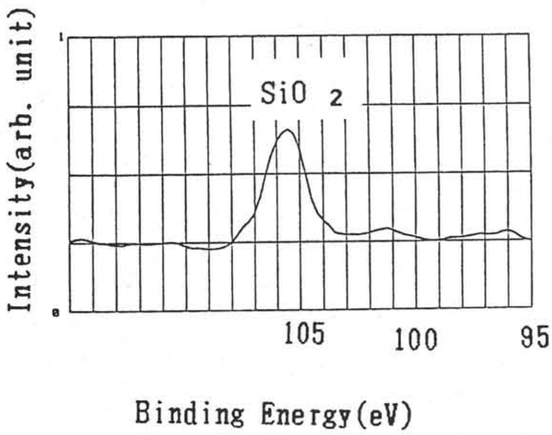
Fig. 3 shows an SEM photograph of the cross section of silicon etched by the MST method(a), compared with that of the trench pattern obtained by conventional RIE(b). The undercutting is found to be reduced by the MST method to a negligible level for an ultrafine trench with widths even in regions as narrow as 100 nm.

In conclusion, by adding short plasma oxidation to etching steps, ultrafine trenches with vertical side walls are obtained.

References
(1) S. Ohki, M. Oda, and T. Shibata, Proc. of 7th Symp. on Dry Process, 108(1985)
(2) D. Chin, S. H. Dhong, and G. J. Long, J. Electrochem. Soc. vol. 132, No. 7, 1705(1985)

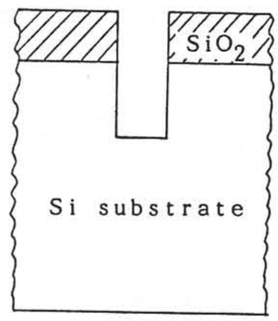


(a) after chroline RIE

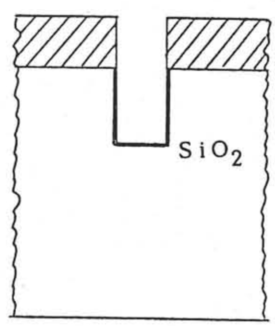


(b) after chroline RIE followed by oxygen plasma treatment

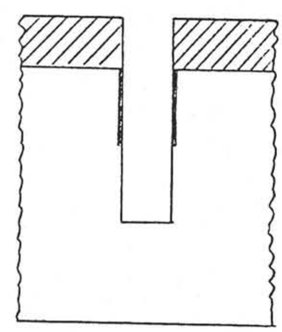
Fig. 1 XPS Si 2p spctra of etched Si surfaces



(a) 1st chroline RIE

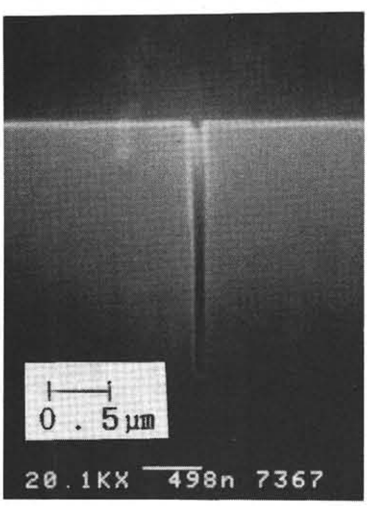


(b) oxygen plasma treatment

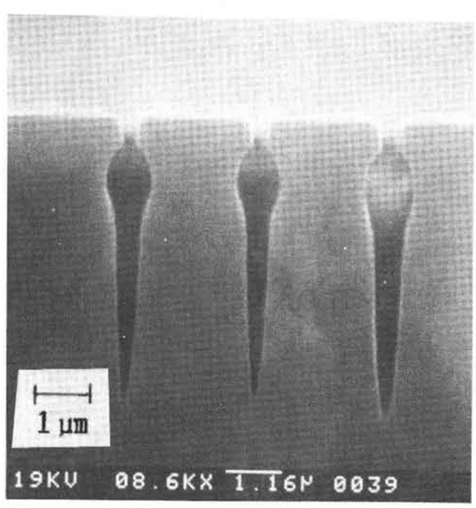


(c) 2nd chroline RIE

Fig. 2 MST method process sequence



(a) by MST method



(b) by conventional RIE

Fig. 3 SEM photographs of etched Si trenches