Fast macropore etching via large current and high HF concentration on p-type silicon

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As an important porous material, more and more attention has been paid for porous silicon produced by electrochemical etching due to its wide applications [1]. As we known, the limitation of etching rate is one of the most important factors that would affect the yield of porous silicon for application. Several researches on fast pore etching on n-type silicon have been reported in the past few years [2]. However, here are few reports drawing attention on the fast pore etching on p-type silicon. Vyatkin [3] obtained macropores with etching rate no more than 100 μm/h using electrolytes composed of dimethylformamide (DMF) and HF on p-type silicon of resistivity of 10 Ωcm.

Here we demonstrate a fast macropore etching on p-type silicon. The effects of HF concentration and current densities on the macropore etching rate on p-type silicon have been investigated. Under optimized conditions, macropore etching rate up to 1900 μm/h was achieved in our work.

Lowly-doped p-type wafers (40 Ωcm, 500 μm-thick, [100] -oriented and polished) were used in our experiments. The ohmic contact was achieved by sputtering an 800 nm-thick Al film on the backside of samples. The electrolytes used for anodization contained 48 wt.% aqueous HF and DMF. Galvanostatic current densities of 10-800 $mAcm^{-2}$ were applied from an Agilent power source with a tolerance up to 60 V.

First, for the same electrolytes (HF: DMF = 3:7), a set of anodizing experiments were performed at different applied current densities (30, 150, 300 $mAcm^{-2}$), in order to investigate the dependence of pore quality and etching rate on the applied etching current densities. Increasing the current density, the pore growing speed increased while the pore size and pore-wall roughness decreased (Fig. 1). From Fig. 1a to 1c, the current density increases from 30 to 300 $mAcm^{-2}$, and the etching rates increase from 1.3 to 13.3 μm/min.

In order to further investigate the dependence of macropore etching rates on the applied current densities and HF concentrations, two sets of anodizing experiments were carried out at different applied current densities (10-300 $mAcm^{-2}$), of which the HF concentration was 30% and 43% respectively. The results are shown in Fig. 1d. It indicates that the macropore growth rate increases linearly with the increasing current densities, and the HF concentration increasing also leads to increase of the pore growth speed.

In our experiment, the pore etching rate can reach 1900 μm/h (approx 32 μm/min) by anodization of p-type silicon at 800 mA/cm^2 in solution containing 15 ml HF and 20 ml DMF. The macropores are rather straight and smooth with depth up to 48 μm and diameters of 1.8 μm, which are shown in Fig. 2.

References

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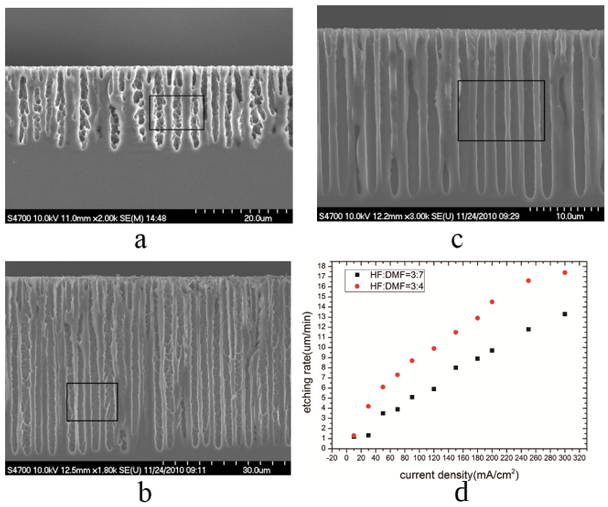

Figure.1 (a, b, c) Cross section SEM micrographs of macropores formed on different current densities: (a) 30 mA/cm^2, 15 min; (b) 150 mA/cm^2, 5 min; (c) 300 mA/cm^2, 1.5 min. All samples were anodized in electrolyte composed of 30% HF (HF: DMF=3:7). (d) Current densities and HF concentration dependence of macropore etching rate obtained by anodization of p-type silicon in the solution containing HF and DMF.

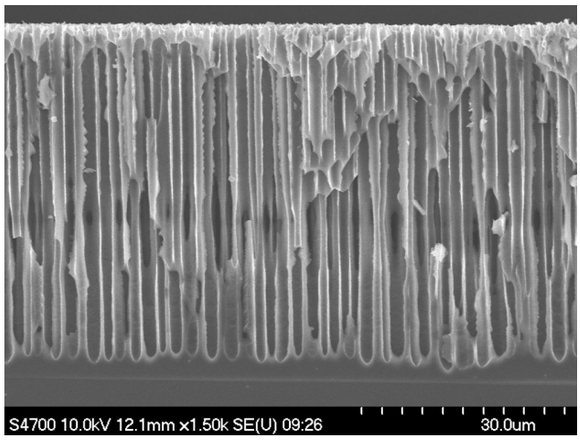

Figure.2 Cross section SEM micrograph of macropore obtained on p-type silicon: 43% HF (HF: DMF=3:4), 800 mA/cm^2, 1.5 min, depth up to 48 μm.