Pore Distribution of Porous Silicon layer by Anodization Process

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Abstract

The purpose of this study is to investigate the effect of process conditions on pore distribution in porous silicon layer prepared by electrochemical reaction. Porous silicon layers formed on p-type silicon wafer show the network structure of fine pores whose diameters are less than 100Å. In n-type porous silicon, selective growth was found on the pore surface by wet etching process after PR patterning. And numerical method showed high current density on the pore tip. With this result we confirmed that pore formation has two steps. First step is the initial attack on the surface and second step is the directional growth on the pore tip.

Keywords

Porous silicon; anodization; chemical etching.

Introduction

Porous silicon was discovered in 1950's by Tuner and Uhlir[1,2] during the electropolishing silicon wafer in HF solution. Although porous silicon can find its possibility of application in diverse area, it has not been used commercially since the pore formation mechanism and the properties of porous silicon are not completely understood and the process technology is not mature. The possible applications of porous silicon are capacitor to increase the capacitance for highly integrated device, photodevice semiconductor formation, measuring device in semiconductor and so on. For these applications, there are two issues. The first is the development of new process to fabricate the porous silicon layer which has suitable structure for such applications. Second is the optimization of process conditions in such processes. To solve these problems, it is necessary to investigate mechanism of pore formation and find process variables which control pore depth and distribution. In this study, effects of the major variables that affect the pore formation, reaction characteristics in surface, and distributions of current and electric potential in boundary of solution have been studied to control the size and distribution of pores in porous silicon layer.

Porous silicon was prepared by the anodic reaction of silicon wafers in mixed solution of HF and ethanol in teflon reactor. Its structure and pore size were examined by SEM photographs.

Experiment

The silicon samples were p-type 6-inch (100) with resistivity of 10-20 Ωcm and n-type 4-inch (100) with resistivity of 2-5 Ωcm single-crystal silicon wafers. The back side of the wafer was coated with a layer of 0.2μm Al in p-type and 0.7μm Al in n-type for the Ohmic contact between a silicon wafer and a

copper strip. Porous silicons were formed anodically using silicon wafers as anode and platinum as cathode in teflon reactor. The silicon sample area exposed to electrolyte for anodization was 4.13cm^2. To investigate the pore formation, wet etching in the mixed solution of HF, water, and HNO_3 (1:5:1) after patterning was performed at n-type silicon wafer. And we constructed the mathematical model of pore growth and obtained the solution numerically. The pore structure was observed by SEM, and then thickness of porous layer, pore size, and distance between pores were roughly measured.

Results and Discussion

Fig.1 shows the structure of porous silicon formed on p-type silicon wafer. It shows the network structure of fine pores of which diameters are less than 100Å. Fig.2 illustrates the relation of anodization time and pore growth. It shows that the thickness of p-type porous silicon layer has limit point at the time of about 10 min in the solution of HF:etannol=1:1 and at this time the pore depth is 1μm.

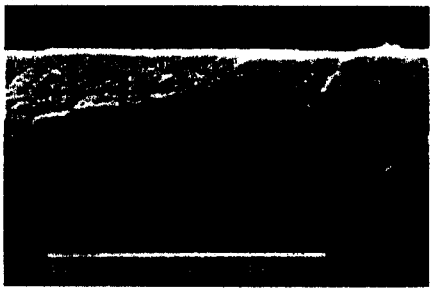

Fig.1 SEM picture of p-type porous silicon sample
(HF:ethanol = 5:1 40mA)

Fig.3 shows the effects of HF concentration and ethanol concentration on the thickness of p-type porous silicon layer. In previous work[3] When the porous silicons were prepared in HF aqueous solution without ethyl alcohol, the thickness of porous layers was less than that of other samples made in HF-ethanol solution. It is explained by ethanol's effect of reduceing the size of hydrogen bubbles which disturb the pore formation.

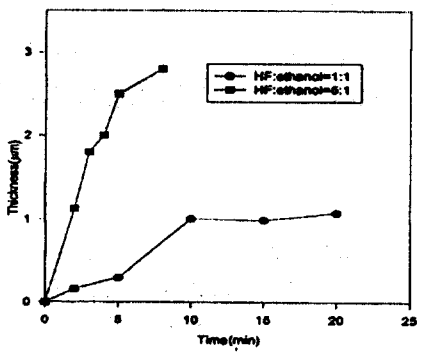

Fig.2 Plot of thickness of p-type porous silicon layer vs reaction time

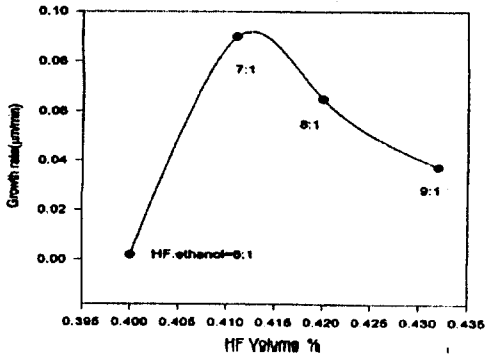

Fig.3 Plot of thickness of p-type silicon layer vs HF concentration.

Fig.4 Pore distribution after wet etching of patterned wafer
(current=40mA, reactio time=4min, HF:ethanol=1:1)

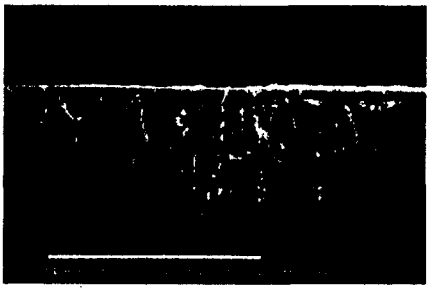

Fig.5 Cross section of Fig.4

Our results showed that this effect have maximum in HF solution with 13 volume % of ethanol.(HF solution:ethanol=7:1)

Fig.4 show pore distribution after wet etching of patterned layer, the width of patterned line is 20μm. Fig.5 is the the cross section of the layer. Pore formation is concentrated near the patterned line. It is because the pore growth started at the defect point of surface. The wet etching process enforced the roughness of the wafer, therefore the pore size and depth are enlarged.

Fig.6 shows the electric field in the pore wall in n-type silicon. the high current density at the pore tip explains partially the directional growth of pore.

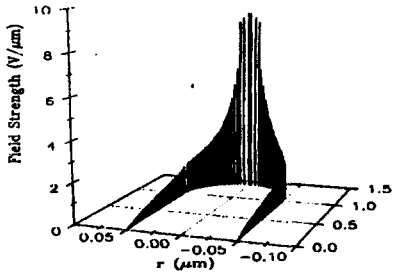

Fig.6 Electric filed at the pore wall

Conclusion

Porous layer formed on p-type silicon has the network structure and the pore size is less than 100Å. The growth rate of porous layer has a maximum value at 13 volume % ethanol solution. and has a limit point at 10 min. Selective growth can be performed by the control of surface roughness. Directional growth of pores can be explained by the high current density in the pore ends.

References

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