Vertical Si Pillar Fabricated by ECR Plasma Etching with Precise Control of O_2 Flow Rate in Cl_2/O_2 Mixtures

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Abstract

This paper shows the vertical Si pillar which is the body of Surrounding Gate Transistor (SGT)[1] could be fabricated by using Electron Cyclotron Resonance (ECR) plasma etching with precise control of O_2 flow rate in Cl_2/O_2 mixtures.

Introduction

ECR plasma source can generate higher density plasma with a lower sheath voltage and are expected to achieve a free damage with higher selectivity. However in etching of (100)-oriented silicon wafer for a pure Cl_2 plasma, it is difficult to control the etched profile and to form the vertical Si pillar. We investigated the effects of O_2 added on the etched profile.

Process

We used (100)-oriented p-type silicon wafer. To etch the silicon surface using plasma, we used the ECR plasma apparatus. The ECR plasma was continuously generated for 5 min at 0.5 mTorr with the supplied microwave (2.45GHz) power of 250W and transported with applying RF bias (13.56MHz) power 100W. O_2 percentage in Cl_2/O_2 plasmas at a total gas pressure of Po = 0.5 mTorr was varied in this experiment.

Results

Fig.1 are cross sections of the Si pillar (O_2 percentage:3.8%, 10.1%, 13.3%).This figure shows "subtrench" is observed at 3.8%, the vertical Si pillar at 10.1% and "grass" at 13.3%. This shows that O_2 decrease the subtrench and promote the grass generation. Si pillar with subtrench or grass has undesirable electronic properties.

Subtrench depth and Si pillar height were measured as shown in Fig.2. Fig.3 is Etch rate and subtrench depth/Si pillar height as a function of O_2 percentage in Cl_2/O_2 plasmas at a total gas pressure of Po = 0.5 mTorr. The major results of this experiment are summarized as follows;

1) As the O_2 percentage is increased, subtrench depth/Si pillar height decreases gradually and becomes zero above 10.1%.

2) As the O_2 percentage is increased, etch rate is maintained almost constant from 0% to 10.1%, and falls off above 10.1% O_2 added.

There is the best O_2 percentage condition for Si pillar formation and the condition in this experiment is that O_2 percentage is 10.1%. These results are shown schematically in illustration of Fig.3.

conclusion

We demonstrated that the best O_2 percentage condition for Si pillar formation exists and the vertical Si pillar can be fabricated by ECR Plasma Etching with precise control of O_2 flow rate in Cl_2/O_2 Mixtures.

Acknowledgement

The Device was fabricated in super clean room of Laboratory for Electronic Intelligent Systems, Research Institute of Electrical Communication, TOHOKU University.

Reference

[1] H. Takato et al, IEEE ED38 No.3 Mar 1991 p573-578

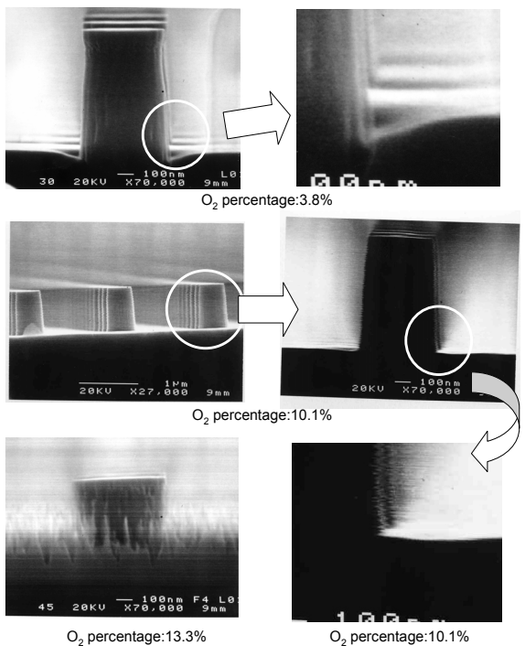

Fig.1: Cross sections of the Si pillar at O_2 percentage: 3.8%, 10.1%, 13.3%, respectively (SEM photograph).

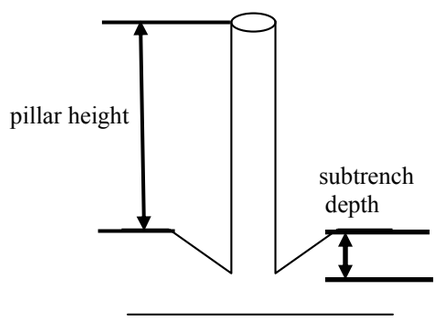

Fig.2:Cross section of the Si pillar(SEM photograph)

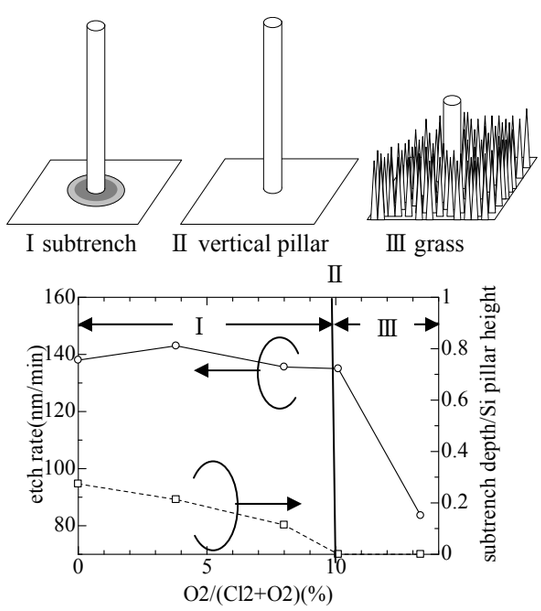

Fig.3: Etch rate and subtrench depth/Si pillar height as a function of O_2 percentage in Cl_2/O_2 plasmas. Solid line and circles are etch rates. Dashed line and quadrangles are subtrench depth/Si pillar height.