In situ Langmuir probe diagnostics of poly-Si/SiO_2 etching: plasma parameters and end-point detection

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Experiments on etch process monitoring by *in situ* Langmuir probe diagnostics of plasma parameters in ICP etcher have been performed. Processing plasma of SF_6/O_2 was applied to anisotropic poly-Si etching. It was revealed that plasma parameters abruptly changes when: 1) wafer was placed into empty chamber, and 2) when polysilicon layer was completely removed. The investigations show these facts could be used for end-point detection of etching at poly-Si/SiO_2 interface with relatively simple probe technique.

Introduction

Real time plasma diagnostics is convenient non-intrusive technique for monitoring of plasma processing in ICs microfabrication. For instance, emission spectroscopy of chemically active neutrals in plasma is widely used [1] for end-point detection due to change of surface reactions and plasma chemistry at interfaces of layers. It is obviously the change of neutral species content should be followed by alterations in charged particles – positive and negative ions, electron density and, quite possible, in the EEDF. This effect should be more pronounced in low pressure HDP etchers when flows of by-products from surface into plasma are comparable with flows of feeding reactive gases. Langmuir probe diagnostics is comprehensive method for analysis of charged species, but correct measurements in reactive plasmas can be provided with careful stabilization of probe surface to avoid non-conductive films [2]. In current investigation probe measurements was applied to real time monitoring of plasma parameters during etch process of polySi/SiO_2/Si structures.

Experimental

The etching of polysilicon on SiO_2 layer has been performed in ICP (13.56 MHz) etcher by SF_6/O_2 plasma in wide range of process settings: P_{RF} = 400 – 800 Watt, P_{bias}= 50-150 Watt, p = 2.5 – 6 mTorr, fl = 50 – 160 sccm. Monitoring of plasma properties *in situ* was made by platinum probe arranged near outer wafer edge at the periphery of chamber. Probe data were processed in real-time mode and were analyzed after etching termination additionally. Optical spectroscopy of fluorine emission at 703.7 nm was used for independent end-point detection at poly-Si/SiO_2 and SiO_2/Si interfaces. The details of these experiments are published in [3].

Results and discussion

It has been revealed that positive ion density, electron density, electron temperature (T_e) and EEDF, plasma and floating potentials in processing plasma differs noticeably in empty chamber and chamber with wafer. The changes in plasma parameters were observed also when plasma was in contact with etched polysilicon or SiO_2 layer. Due to these variations the ion saturation current and electron current at plasma potential measured by probe could be used as end-point detector sygnal at poly-Si/SiO_2 and SiO_2/Si interfaces. Another suitable parameter for this purpose is floating potential of probe. The real time T_e measurement is less convenient from the signal/noise reason. EEDF in plasma was very sensitive both to process settings and to etched materials, and deviates from Maxwellian distribution significantly. Effective T_e and hot tails of EEDF measured by *in situ* Langmuir probe diagnostics are the subjects for optimization of charging effects on the surface of etched structures.

References

[1] I. P. Herman, Ann. Rev. Phys. Chem., **54**, p. 277 (2003).
[2] A. V. Miakonkikh *et al.*, Proc. SPIE, **6260**, p. 6260-0A (2006).
[3] K. V. Rudenko *et al.*, Russ. Microelectron., **36**, issue 3, *in press* (2007).

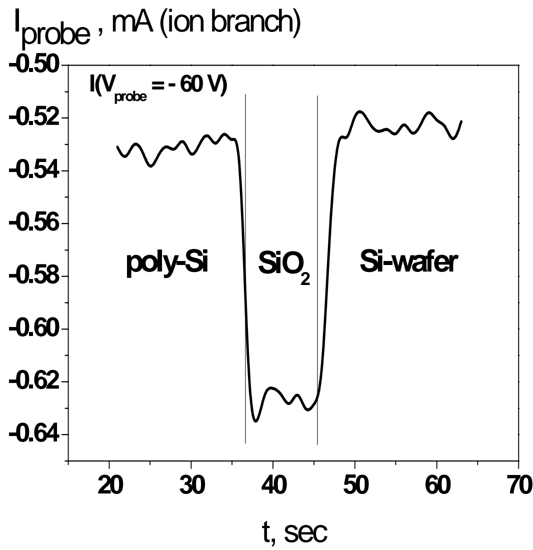

Fig. 1. Ion saturation current on probe measured *in situ* in etch process of poly-Si/SiO_2/Si structure.

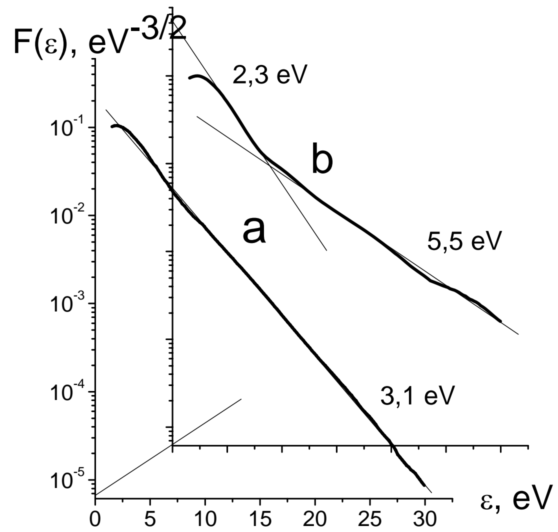

Fig. 3. Plasma EEDF in empty etcher chamber at W_{RF} = 600 Watt, p = 5 mTorr: a) Ar plasma; b) SF_6/O_2/Ar plasma.

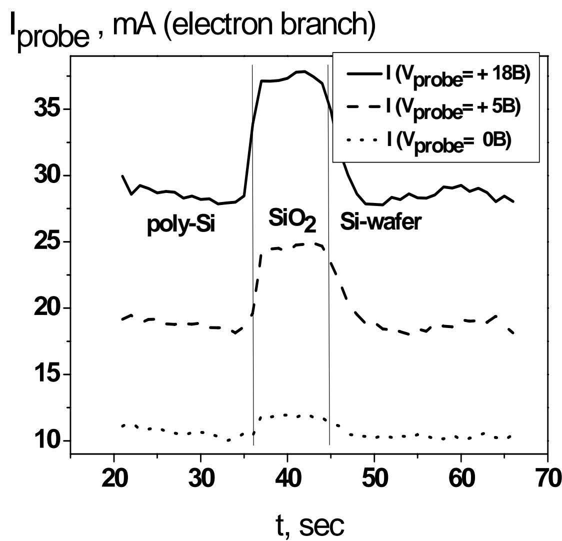

Fig. 2. Probe current in electron branch of I-V curve measured *in situ* in etch process of poly-Si/SiO_2/Si structure.

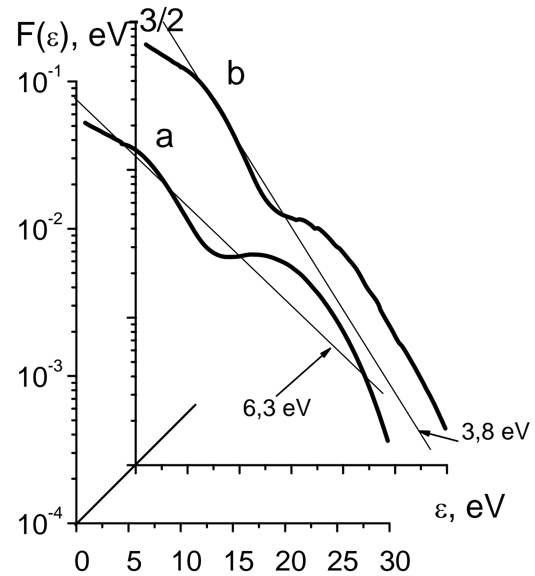

Fig. 4. Plasma EEDF in chamber during etch process at W_{RF} = 600 Watt, p = 5 mTorr, SF_6/O_2/Ar plasma: a) etching of poly-Si; b) etching of SiO_2.