Role of Hydrogen at the Si/SiO2 Interface on MOS CV Characteristics

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Abstract- In this study an attempt has been made to investigate the effect of intentional doping of hydrogen near the Si/SiO_2 interface by ion implantation. MOS capacitors were fabricated with a composite stacked dielectric of thermally grown SiO_2 and LPCVD nitride with and without H-implantation. Poly gate capacitors fabricated on both N and P type silicon wafers showed no significant change with hydrogen implant. Effect of hydrogen was distinct in aluminum gate structures.

1. INTRODUCTION

There is an increasing evidence that hydrogen in various forms plays a very important role in almost all aspects of Si/SiO_2 interface structures. In particular, it is believed that atomic hydrogen at the interface attaches itself to the silicon dangling bonds thereby making them electrically neutral and therefore reducing the interface trap density [1]. It is also discussed in literature that excess hydrogen may form silanol (SiOH) and hydroxyl (OH) groups in the oxide giving rise to additional charges in the oxide [2]. In the present study, an effort has been done to investigate the effect of intentional doping of hydrogen near the Si/SiO2 interface by ion implantation in MOS structures.

2. DEVICE FABRICATION

MOS capacitors were fabricated with composite stacked dielectric. First, 455A of gate oxide was thermally grown at 1100C for 7 minutes in dry O_2. Subsequently, a layer of silicon nitride was deposited by low pressure chemical vapor deposition at 800C using SiH_4 and NH_3. The thickness obtained was 1150A. Triatomic hydrogen (H_3^+) was implanted at an energy of 90KeV. The implant doses of $5e14/cm^2$ and $1e15/cm^2$ were chosen. Energy of the implant was determined using TRIM [3] to place the peak just below the Si/SiO_2 interface.

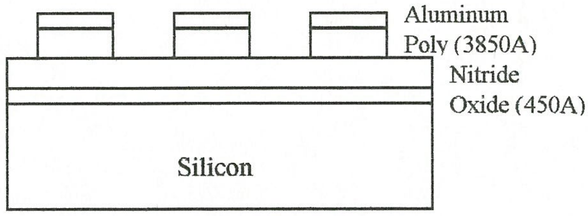

Figure 2: Capacitor structure as fabricated.

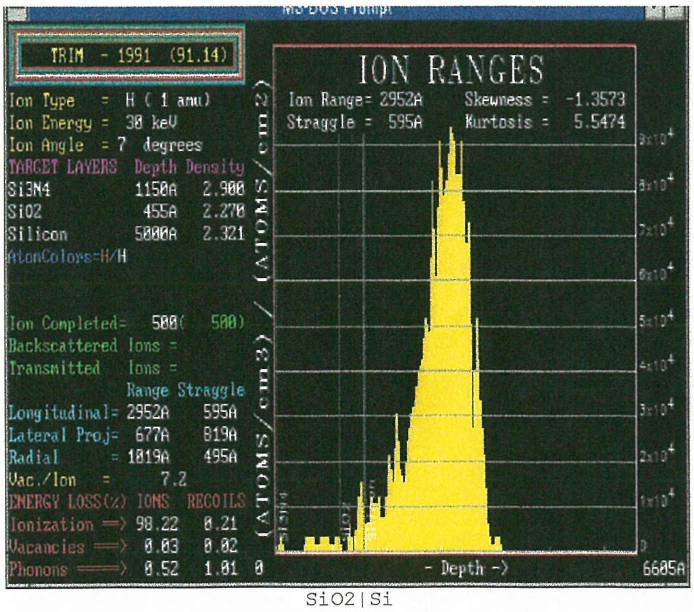

Figure 1: Hydrogen Implantation Profile Simulated by TRIM (TRansport of Ions in Matter).

Wafer	Gate	Threshold Voltage (volts)	Flat Band Voltage (volts)	Total effective charge (cm^{-2})	Interface Trap density at midgap ($cm^{-3}\ eV^{-1}$)
N1	n+ poly	-1.17	-0.4	2E10	1E12
N4	Al	-1.95	-1.1	1.58E11	5E11
N5	Al	-2.55	-1.7	2.75E11	1.2E11

Table 1: Extracted parameters from CV curves for different capacitors.

A layer of 3850A of n+ polysilicon gate was then deposited using LPCVD at 610C. Polysilicon was doped with a spin-on N250 arsenic source. Diffusion was carried out at 900C for 30 minutes. This step also acted as the implant damage anneal for hydrogen. Aluminum electrode was then deposited using vacuum evaporation, on top of polysilicon. The gate region was defined by wet etching aluminum followed by dry etching poly in the Reactive Ion Etcher (SF_6+O_2, power=20W, pressure=200mT). The final capacitor structure is shown in figure 2.

3. C-V ANALYSIS

The capacitors were studied for their CV behavior using Keithley Model 82-DOS Simultaneous CV System. The poly gate capacitors fabricated on both N and P type silicon wafers showed practically no change with the hydrogen implant upto the dose of 1e15/cm2 (figure 3,4).

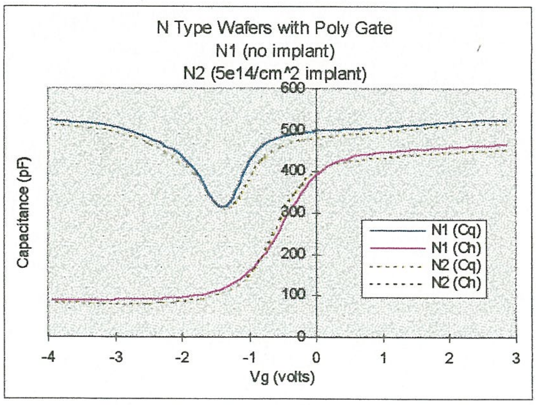

Figure 3: C-V Analysis of H-implanted N Type Wafers with Poly Gate.

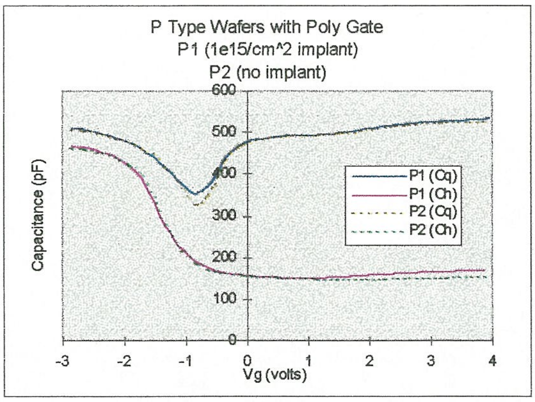

Figure 4: C-V Analysis of H-implanted P Type Wafers with Poly Gate.

The parameters e.g. threshold voltage V_T, flat band voltage V_{FB}, Q_{eff} and $D_{it\ (midgap)}$ were extracted from the high-low frequency CV curves. It was inferred that the interface non idealities were extremely large even in unimplanted capacitors to resolve any changes due to hydrogen incorporation. A process step such as polysilicon etch (done by RIE) might have caused this effect. Thereafter, devices were fabricated with aluminum gate. Figure 5 shows the effect of hydrogen implant quite distinctly in aluminum gate structures. The H-incorporation by implantation has certainly deteriorated the devices with excessive interface trap density. However, there is an indication of overall reduction in effective oxide charge as observed from the flat band voltage shift of +0.6volts. Perhaps lower doses of implants are needed to exploit the advantages of hydrogen in saturating the dangling bonds. Besides, it is necessary to know the actual hydrogen profile to explain the results.

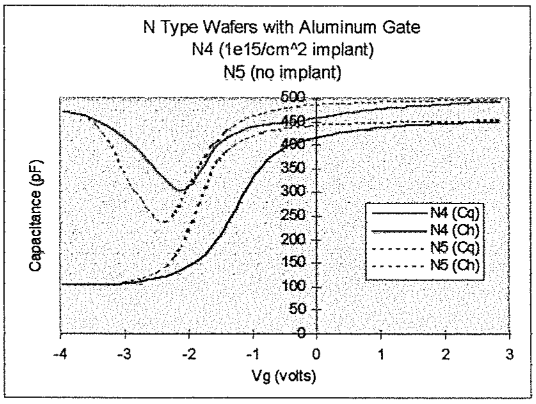

Figure 5: Effect of H-implant on the CV curve of N Type Wafers with Aluminum Gate.

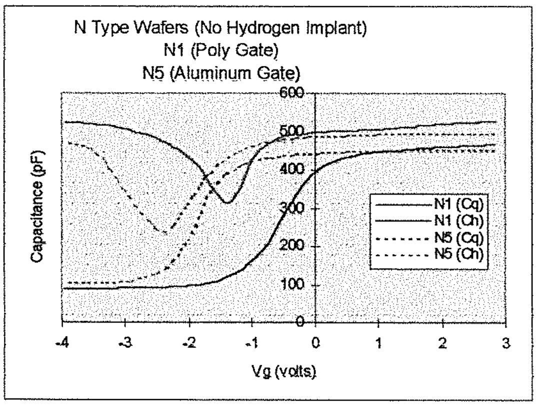

Figure 6: Effect of Gate Material on the CV curve of N Type Wafers with no implant.

An important side result obtained from this study indicates that excessive interface trap charges may result during the poly gate formation by RIE in MOS capacitors (figure 6). This is not of a great concern since in actual processing anneals are performed after the gate etching. It is also observed that poly gate capacitors have a less negative flat band voltage, therefore smaller effective oxide charge density.

4. CONCLUSIONS

There was no significant change seen in C-V curves due to H-implant in poly gate capacitors. Deterioration was observed in C-V curves due to H-implant in Aluminum gate capacitors. There was an increase in interface trap density (D_{it}). Poly gate formation influenced C-V curves. Annealing while poly doping shifted flatband voltage towards positive and reduced effective oxide charge. Reactive ion etching of poly could have increased interface trap density in poly gate capacitors.

REFERENCES

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