Extended Abstracts of the 1993 International Conference on Solid State Devices and Materials, Makuhari, 1993, pp. 955-957

IG Mechanism of Iron in Semiconductor Silicon

L.Fabry*, B.Hackl#, K.-J.Range#
*Wacker-Chemitronic GmbH, W-8263, Burghausen
#Inst.of Inorg.Chem., Univ.of Regensburg, W-8400 Regensburg, Germany

Introduction

Heavy metals degrade the performance of microchips. Iron is a particularly effective minority carrier lifetime killer [1]. Nevertheless, neither silicon wafers nor devices can be manufactured without processing equipment (e.g. wafering, ion implanting) and consumables (photoresist) that are inexhaustible sources of iron [2]. In order to reduce yield losses due to iron, it ought to be either completely absent in the fab environment and in construction, auxiliary and consumable materials or it must be rendered harmless by means of defect engineering applying internal gettering (IG).

IG is based on tailored precipitation of O_i yielding $SiO_{x\leq 2}$ in single crystalline silicon. Varying the initial values of O_i with a subtle thermal treatment we studied the gettering capacity in B-doped CZ-silicon. We have found a detrimental impact of iron on the O_i-nucleation and on the growth of these nuclei.

Experimental

Materials: As-polished, RCA-cleaned ($Fe<1.3\ 10^{10}$ at.cm^{-2}, silicon wafers (150 mm/diameter, 675 µm/thickness, damage-free back side), B-doped (7-22 Ωcm), $5.75\ 10^{17}$ at.cm$^{-3}<[O_i]<8.75\ 10^{17}$ at.cm^{-3} CZ [100] and $[O_i]<6\ 10^{16}$ at.cm^{-3} FZ [100] reference. The wafers were spiked with $Fe(Cl_3)$ by spin-coating [3] at different stages of thermal treatment:

Sample A: before BMD cycle
Sample B: after Step I
Sample C: after Step II and additional drive-in $1000^{o}C/6$ h/100% O_2

Thermal treatment, BMD cycle:

Step I $780^{o}C/3$ h/100% dry O_2 - nucleation
Step II $1000^{o}C/16$h/100% dry O_2 - growth

Analyses: FTIR, EDAX (Mg-K_α) and DLTS (drive-in at ($1100^{o}C/10$min)

Results

Fig.1 Fe contamination thwarts precipitation of [O_i] (sample C).

Fig.2 Varying [Fe_i] before nucleation (A) we found a critical threshold level of iron (sample A). Below this level the precipitation has occured as anticipated.

Fig.3 Introducing Fe after the nucleation (sample B, C) did not hinder gettering: IG efficiency > 50%.

Fig.4 EDAX spectrum of a spot (<10 nm, sample A, [Fe_i] > 10^{11} at.cm^{-3}) with SiO_x nuclei. Fe signal was not detected in every precipitation spots after the BMD cycle.

Discussion

The formation of thermally unstable $FeSi_2$ can compete with the nucleation process of O_i. All the iron cannot be gettered in stable fayalite ($2FeO.SiO_2$) modification because $FeSi_2$ is stable below 800 ^oC and it is masking the SiO_x nuclei. At temperatures around 1000 ^oC $FeSi_2$ decomposes and the Fe can be redissolved in silicon (Fig.5). At this temperature the diffusion of Fe is faster than its reaction rate with the SiO_x particles [4].

The Fe_i is forming mainly an FeB complex. Both species are effective deep level traps. Generally, an equilibrium manifold has to be considered in order to interpret the influences of heavy metals on nucleation and gettering (Fig.6). The precipitation can be affected through the competitive reaction of interstitials (Si_i) with the migrating metal species. The major reaction path is a basic function of the temperature and of the relative concentrations of the active species.

Fig.6 Chemical equilibrium manifold of heavy metals in B-doped silicon (M: heavy metal, M_{fac}: surface enrichment, k: rate const)

Fig.5 Competitive reaction paths of iron in CZ silicon during gettering

References

[1] R. Takizawa, T. Nakanishi, A. Ohsawa, J.Appl.Phys, 62(12), 4933 (1987)
[2] Metallic Contamination in Mega Processes, Nikkei Microdevices, pp.54-62, May 1990
[3] M. Hourai, T. Naridomi, Y. Oka, K. Murakami, S. Sumita, N. Fujino, T. Shiraiwa, Jpn.J.Appl.Phys, 27(12), 2361 (1988)
[4] B. Hackl, K.-J. Range, H.J. Gores, L. Fabry, P. Stallhofer, J.Electrochem.Soc., 139(11), 3250 (1992)

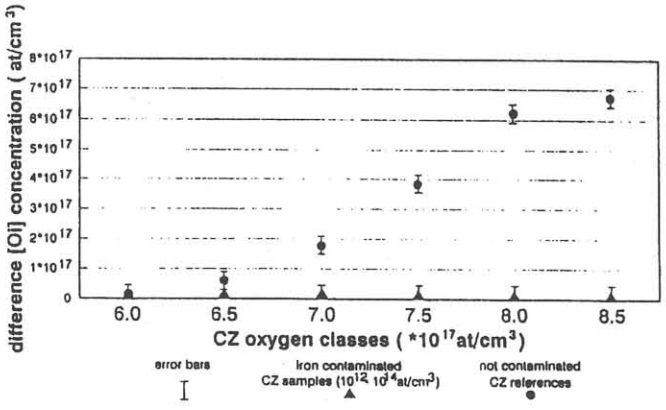

Fig.1 Fe contamination thwarts precipitation of [O_i] (sample C).

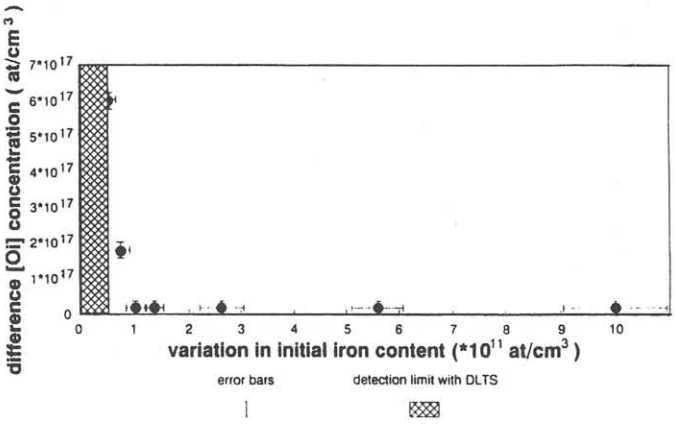

Fig.2 Varying [Fe_i] before nucleation (A) we found a critical threshold level of iron (sample A). Below this level the precipitation has occured as anticipated.

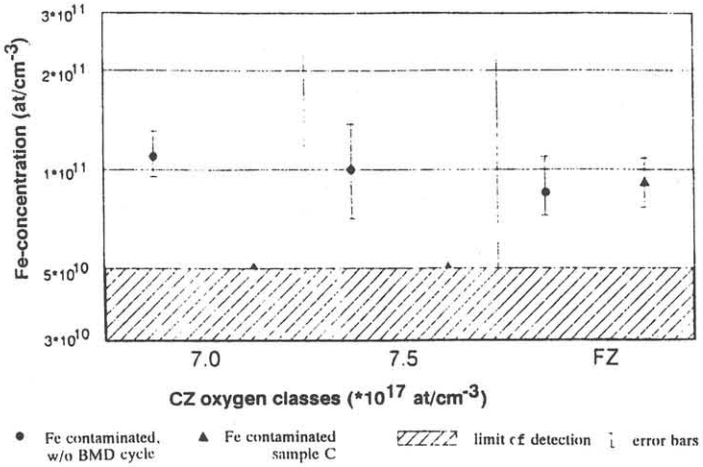

Fig.3 Introducing Fe after the nucleation (sample B, C) did not hinder gettering: IG efficiency > 50%.

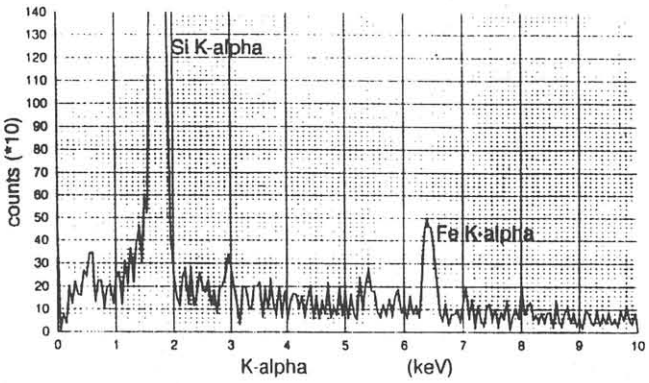

Fig.4 EDAX spectrum of a spot (<10 nm, sample A, [Fe_i] > 10^{11} at.cm^{-3}) with SiO_x nuclei. Fe signal was not detected in every precipitation spots after the BMD cycle.

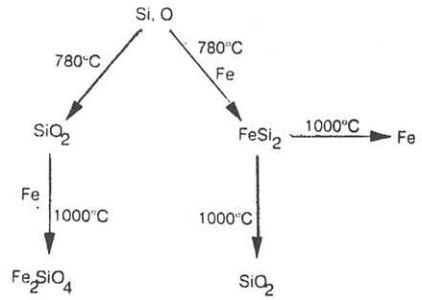

Fig.5 Competitive reaction paths of iron in CZ silicon during gettering

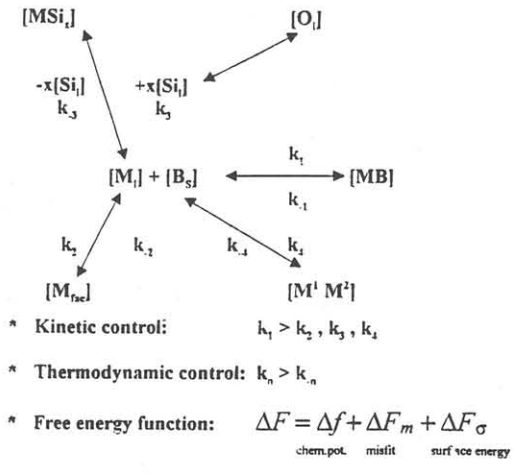

Fig.6 Chemical equilibrium manifold of heavy metals in B-doped silicon (M: heavy metal, M_{fac}: surface enrichment, k: rate const)