Advanced Ultra-Shallow Junctions (USJ) Formation via Co-implantation for Nano-CMOS Devices

S.H. Yeong[1], M.P. Srinivasan[1], C.J. Liu[1], A.T.S. Wee[1], A. Ramam[2], B. Colombeau[3] , K.R.C. Mok[3], F. Benistant[3], L. Chan[3]

[1]Department of Chemical and Biomolecular Engineering, Depearment of Physics, National University of Singapore (NUS)
[2]Institute of Material Research and Engineering (IMRE) *[3]Chartered Semiconductor Manufacturing Ltd (CSM)*

Introduction

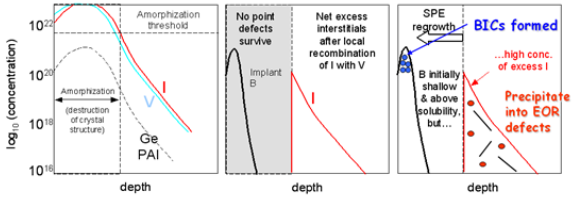
As CMOS devices evolve into sub-nanometer, formation of ultra-shallow junction (USJ) in the source/drain (S/D) extension poses one of the major challenges. The S/D extension regions are generally formed by introducing dopants using ion-implantation and electrically activated by annealing process. Unfortunately, during the annealing, dopants exhibit anomalous transient enhanced diffusion (TED) which increases the dimension of devices. In addition, dopant clustering induced by implant damages/defects will degrade device electrical performances.

Aims

- **Study the impact of Carbon(C) / Fluorine(F) co-implantation on the USJ formation.**
- **Demonstrate USJ optimization in devices coupled with novel co-implant process, based on physical understanding, modeling and simulation.**

Results and Discussion

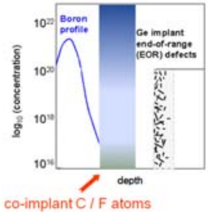
Experiments and Physical Understanding



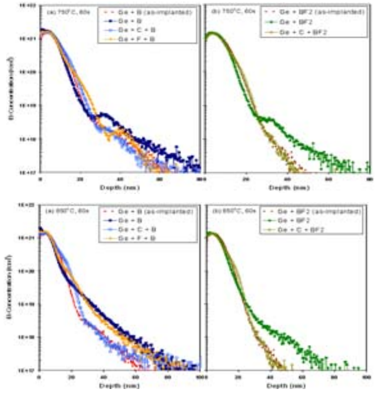
Colombeau et al., EMRS 2005

Schematic illustration of the underlying physics for dopant diffusion and defect evolution in the crystalline phase silicon.

Range/location of co-implant species

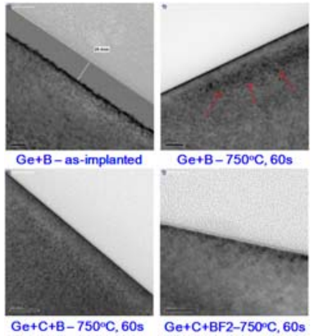


SIMS profiles (right) clearly reveal the impact of C/F co-implantation on dopant diffusion and trapping at EOR .

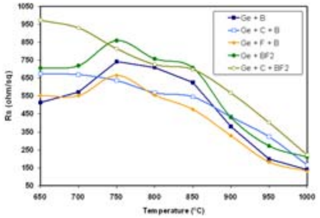


Ge+B: significant TED & trapping
Ge+F+B: TED + significant trapping
Ge+C+B: no TED + small trapping

Ge+BF_2: significant TED + small trapping
Ge+C+BF_2: no TED + no trapping

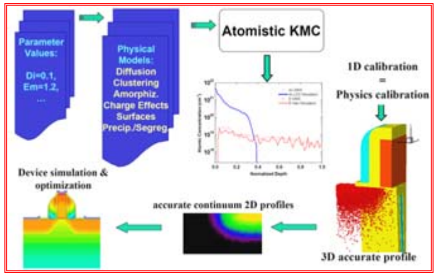


*Co-implantation affects the defect evolution. **C co-implantation reduces residual EOR defects after annealing.***

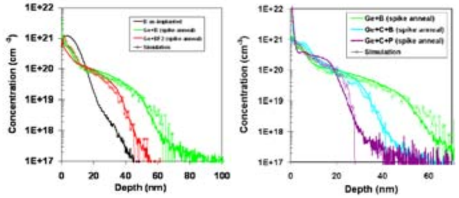


*Rs as a function of isochronal annealing temperature. **Dopant de-activation can be suppressed to a certain extent with respect to the co-implant condition.***

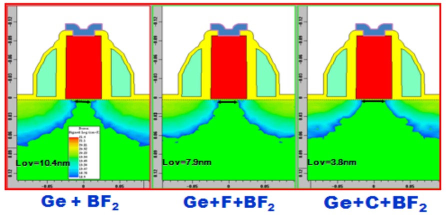
Modeling and Simulation



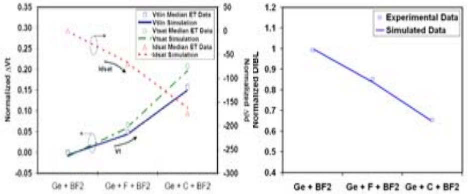
Methodology in device simulation** coupled with **atomistic simulator** which embedded with **diffusion, activation and defect evolution mechanisms.



Diffusion parameter calibration with SIMS profiles.



*2D doping profiles of 65nm PMOS using different co-implant schemes. **C_{ov} decreases with co-implant.***



***Good agreement between experimental and predicted co-implant impact** on 65nm PMOS electrical characteristics with different schemes.*

Conclusions

➲ **Co-implant scheme has great potential for USJ formation in nano-CMOS. (Suppression of TED and dopant de-activation)**

➲ **Better understanding has been gained on the interactions of implant damages/defects with dopants coupled with C/F co-implantation.**

➲ **USJ optimization with novel co-implant process can be achieved via simulation to improve the device performance.**

NUS National University of Singapore

Institute of Materials Research and Engineering A*STAR

Chartered semiconductor manufacturing

January 2008