Point Defect Engineering and Its Application on Ultra-shallow Junction Formation*

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Point Defect Engineering (PDE) is a method to inject vacancies near the surface region. This can be realized by high energy ion bombardment with excessive interstitials created near the end of the projected range and leaving a region rich in vacancies close to the surface. Reduction of the transient diffusion of B in silicon by co-implantation with MeV Si ions has been reported by Raineri *et al,* [1] although they explained it as being due to the secondary defects, formed by MeV implantation, acting as efficient sinks for Si interstitial. Using a buried SiO_2 Layer in a silicon-on-insulator wafer to isolate the effect from MeV implantation induced defects, Holland *et al.* [2] and Venezia *et al.* [3] have demonstrated that such reduction is due to the surface vacancy rich region by MeV Si implantation.

We demonstrated that ultra-shallow junction formation of sub-10 nm junctions can be realized by the technique of point defect engineering [4-7]. Effects of MeV Si ion implantation on the transient enhanced diffusion, oxygen enhanced diffusion and boride enhanced diffusion were systematically studied. Boron superlattices grown by molecular-beam-epitaxy have also been used to get depth dependent boron diffusivity. Those results provide clear evidences that high energy implant provide a effective method to suppress boron diffusion at the surface region. Such suppression has a strong relation with implant dose and annealing temperature. Our preliminary results further indicate the following advantages by PDE:

1) increasing stability of high doped junction formed by spike annealing or molecular-beam-epitaxy growth with suppression of transient enhanced diffusion and boride enhanced diffusion;
2) retarding boron diffusion to a rate much less than normal diffusion, essential for forming ultra-shallow profiles, with vacancy concentration governing the extent of diffusion retardation;
3) tailoring the dopant profile sharper with lower sheet resistance than an ordinary drive-in diffusion profile, which usually results in a complementary error function;
4) increasing dopant concentration beyond the solid solubility limit (our preliminary result indicated an enhancement of boron activation by a factor of four).

We have identified two key parameters for PDE: 1)implantation energy that determines the spatial separation between interstitials and vacancies, and 2)implantation dosage that determines the vacancy and interstitial concentrations. With purpose to find optimal conditions for shallow junction formation, some fundamental issues in point defect engineering at various annealing conditions are presented and discussed.

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* Research supported in part by the state of Texas through the Texas Center for Superconductivity at the University of Houston, and by International SEMATECH.

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