Ultra-shallow Junction Formation Using Ion Implantation and Conventional Spike Anneal in a Hot-wall RTP system.

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Introduction

In recent years, conventional ion implantation and rapid thermal annealing (RTA) have been used in manufacturing to form ultra-shallow junctions at 130nm. In an attempt to scale devices to meet the ITRS requirements, manufacturers have been challenged to develop manufacturable solutions at 100nm and beyond. This work will address several of the challenges of developing robust and manufacturable ultra-shallow junctions in a production environment. First, we examine the critical process parameters for RTP spike-annealing (peak temperature, thermal budget, and annealing ambient), and second, we examine the influence of implant parameters (dose, energy, species, pre-amorphization) on the sheet resistance (R_s) and junction depth (X_j). The RTP system used for annealing studies is the Axcelis Summit 300XT, a “hot-wall” RTP system. The ultra-low energy implants were investigated with the Axcelis GSD-ULTRA high current implanter.

Process Control for RTP

With device sizes shrinking, there is an increasing demand on device engineering to find a manufacturable process using Ion Implantation and RTP to form ultra-shallow junctions. Ultimately, the manufacturability of these devices, will require tight control of RTP process parameters. In order to quantify the level of control required for RTP, we performed a sensitivity analysis of junction depth on three main parameters: Peak wafer temperature (T_p), thermal budget (TB : total time above T_p –50 ^oC), and O_2 concentration. The implant is B^+ 500eV 5e14cm^{-2}, and the nominal RTP conditions are T_p = 1050 ºC and O_2 concentration = 1000ppm. The results of the sensitivity analysis are shown in Table 1. Also shown are the current capabilities of the Summit hot-wall RTP system with respect to control of each parameter, and the relative junction depth variation one might expect from the associated process parameter variations.

The main conclusion from the analysis is that the wafer-to-wafer peak-temperature repeatability and within-wafer peak temperature uniformity are the most critical parameters for maintaining stable Rs-Xj performance (an order of magnitude greater than TB and O_2 concentration). The hot wall RTP system used for these experiments has inherent advantages for controlling these critical parameters [1]: 1) This RTP system is operated in “quasi-thermal equilibrium” with the wafer, and the wafer is heated from all directions, 2) The heat delivery system consists of a vertical furnace and elevator, both inherently simple and stable sub-systems and 3) The heating environment is non-reflective, which simplifies pyrometric temperature measurement and facilitates modeling for temperature control. The simple and stable nature of the heat delivery system, combined with state-of the-art temperature measurement and control system, allow tight control wafer-to-wafer peak temperature. The quasi-thermal equilibrium nature of the heating source and multi-directional heating lead to uniform heating of the wafer, including mitigation of pattern effects. These issues will be investigated in detail using experimental methods and numerical simulations

Parametric Study of Implant Parameters

In the second part of the paper, we review results of an ongoing investigation of the effect of implantation conditions on R_s, X_j and abruptness. The work focuses on forming a typical PMOS extension, since this is the most challenging roadmap requirement. The implant conditions parameters investigated are:

1) Implant energy, focusing on the minimum required implant energy
2) Implant species, B^+ vs. BF_2^+
3) Effect of Ge pre-amorphization, with an effort to understand the effect of PAI dose and energy, and also, understand the mechanism for the effects (e.g., chemical effects vs. disorder effects)
4) Effect of F co-implantation to suppress transient enhanced diffusion (TED)

References

[1] J. Willis and J. Hebb, “Cutting Edge Temperature Measurement and Control Over a Wide Range of Process Temperatures in a 300mm RTP System,” Proceedings of the 202nd Electrochemical Society Meeting, Philadelphia, PA (2002).

RTP Param.	Xj senstvy	Variation in Summit	Xj variation
Tp Rpt	1% / ºC	1 ºC	1%
Tp Uniform	1% / ºC	3 ºC	3%
TB (T-50)	0.4% / %	0.5 %	0.2%
O2 Conc.	0.1% / %	10%	0.1%

Table 1: Junction depth sensitivity analysis for B^+ 500eV 5e14 cm-2 with nominal RTP conditions: T_p =1050 ^oC, 1000 ppm O_2