Comparison of Dopant Activation in Si as Characterized by Spreading Resistance Profiling (SRP) and Differential Hall Effect Metrology (DHEM)

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Introduction:

➢ Advanced devices employ ever shrinking source/drain (S/D) junction depths, which bring along high parasitic resistance challenges.

➢ Therefore, doping/annealing/activation processes are being developed to reduce contact resistivity.

➢ Prediction of contact resistivity and device performance require a knowledge of the exact location and activation of dopant species in the junction area of such structures.

➢ As a result, the need for techniques that offer high depth resolution and accuracy for profiling carriers through ultra-thin layers has been increasing.

➢ Here we compare DHEM and SRP carrier profiles for B and As implanted Si.

Results and Discussion:

➢ Two sets of samples were prepared for characterization. For one set, an n-type Si substrate (2-7 Ω-cm) was implanted with 11BF2+ species with energy ~ 10keV, dose ~2E15 #/cm2, tilt ~7° and twist ~22° using a Varian EHP-500 system. The second set employed a p-type Si substrate (15-25 Ω-cm) that received 75As+ implantation under similar conditions.

➢ The B implanted samples were subjected to an RTA process at 950 °C in a nitrogen atmosphere for 30 seconds. The As implanted samples received a CO_2 laser anneal step in air, at a power level of 130W (0.72 J/cm2).

➢ Table 1 Provides a comparison between the measured 4PP, and sheet resistance values obtained by integrating DHEM and SRP carrier profiles.

➢ Figure 1 Provides the SIMS total dopant, and SRP and DHEM carrier concentration depth profiles for the samples.

Sample	R_s bulk measured By Van der Pauw	R_s calculated by Integrating DHEM data	R_s calculated by integrating SRP data
B doped + RTA	362.8	368.8	840.5
As doped + laser anneal	198.4	207.9	355.2

TABLE 1. Measured and calculated bulk values of sheet resistance for the two samples characterized.
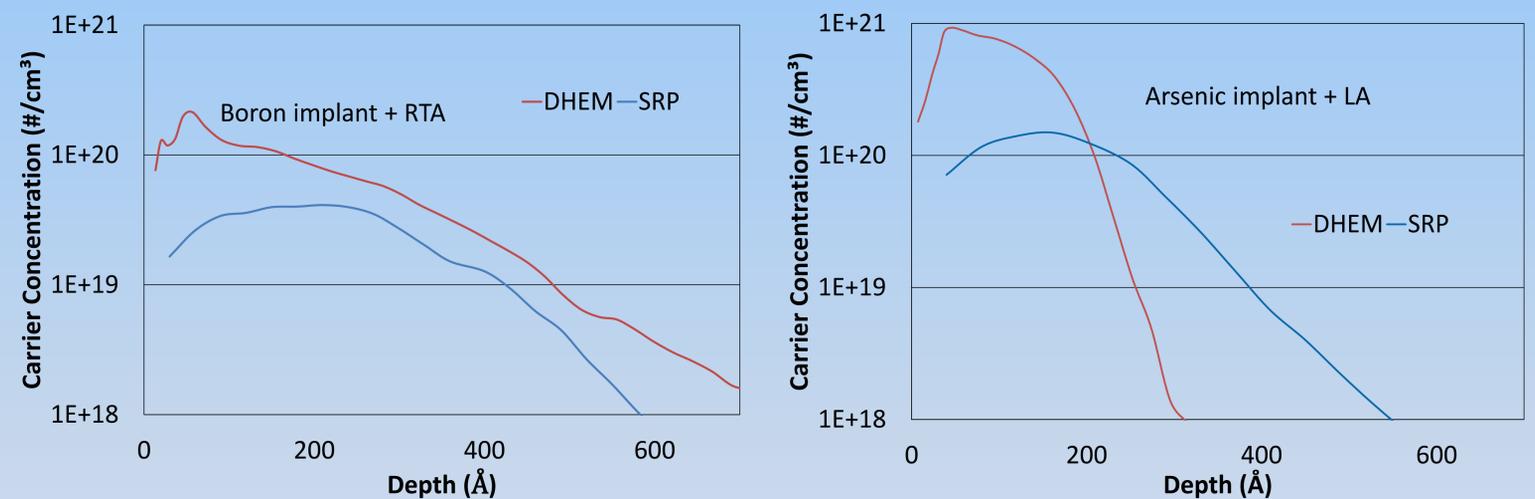

FIGURE 1. Carrier concentration depth profiles obtained from the B implanted and RTA annealed sample (left) and As implanted and laser annealed sample (right) using SRP and DHEM techniques.

Conclusion:

➢ In SRP, the sample is polished and beveled at low angle (<0.5° for very shallow junctions) to expose the junction. The two probes are then stepped along the beveled surface and the collected data is interpreted to find the spreading resistance values. These are then translated into resistivity using relationships established through calibration. Finally, carrier concentrations are calculated using models providing resistivity-carrier concentration relationships

➢ DHEM provides depth profiles of mobility, resistivity and carrier concentration through a semiconductor layer by making successive sheet resistance (Rs) and Hall voltage measurements using Hall effect/Van der Pauw techniques, as the electrically active thickness of the layer is reduced through successive oxidation steps.

➢ As can be seen from Table 1, the bulk Rs values measured for both samples agree well with the values obtained from integrating the DHEM profile data. Rs calculations for the SRP data employed the resistivity depth profiles corresponding to the SRP data plotted in Fig. 1. Integration yielded values that were much higher than the measured bulk values for both samples. This is a clear indication that SRP greatly underestimated the activation levels of the shallow and ultra-shallow structures used in this study.

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