Dopant Activation Evaluation in Si:P by Scanning Spreading Resistance Microscopy (SSRM) and Differential Hall Effect Metrology (DHEM)

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Introduction:

- Introduction of ultra high concentration of P into Si and formation of Si:P helps reducing the S/D ohmic contact resistivity and induces the needed strain into the channel.
- For contact resistivity reduction, the dopant activation level is more important than the high dopant amount. Accurate and complete carrier profile feedback is necessary to engineer process to achieve low contact-resistivity for next generation nodes.
- Measuring the mobility distribution, comparing the measured mobility and carrier distribution with the mobility curve for undamaged and unstrained materials can enable the development of processes that result in minimal generation of defects.
- Here we compare DHEM and SSRM carrier profiles for highly doped SiP epi materials.

Results and Discussion:

- In-situ phosphorus (P) doped Si epi-layers were grown over two p-type 300mm diameter wafers.
- In the data presented below, sample D02 represents the wafer with the as-deposited Si:P epi layer, which was about 45nm thick. Sample D03, with about 53nm thick epi-layer, was the wafer subjected to the annealing process.
- Table 1 Provides the measured 4PP and DHEM sheet resistance values. It also gives the sheet resistance value calculated from the ALPro™ 100 DHEM carrier profiles.
- Figure 1 Provides the SIMS total dopant, and SSRM and ALPro™ 100 DHEM carrier concentration depth profiles for the samples.

SAMPLE No	Measured R_s (Ω/□) 4PP	Measured R_s (Ω/□) DHEM	Calculated R_s (Ω/□) from DHEM profile	Calculated R_s (Ω/□) from SSRM profile
D02	136	138.3	139	330.9
D03	62	63.5	65.1	346.4

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

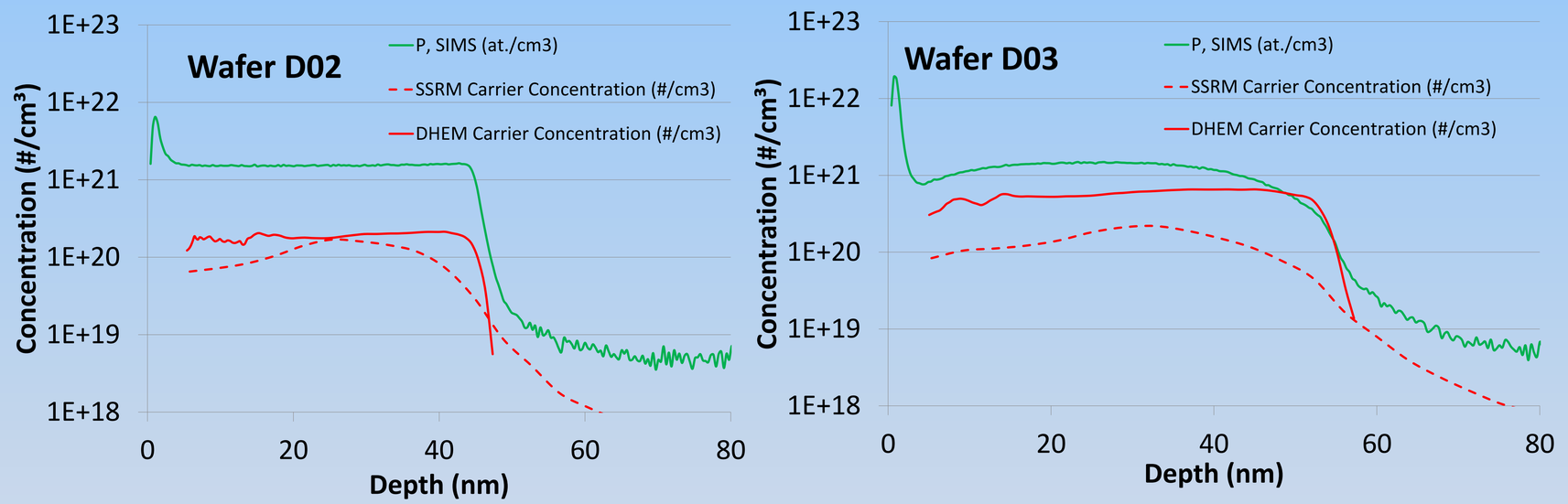

FIGURE 1. SIMS total dopant, and SSRM and ALPro™ 100 DHEM carrier concentration depth profiles for samples D02 and D03.

Conclusion:

- 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 process steps.
- To better understand the appreciable differences observed in the carrier concentration depth profiles provided by DHEM and SSRM techniques we calculated the bulk R_s values for the two samples. As can be seen from this data the bulk Rs measurements from 4PP and DHEM system agree very well. One can conclude that SSRM underestimated the carrier concentration values in these doped epi layers. DHEM measurements provided consistent results.

ALPro™ 100 is the most advanced DHEM system in the world.

Provides *complete electrical property depth profiles* (mobility, carrier concentration, resistivity) through semiconductor layers at nm-level depth resolutions.

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