SRP and SIMS

For spreading resistance profiling (SRP), the semiconductor sample is angle lapped and then a pair of closely spaced probes, having ultra-small contact areas, are stepped down the bevel. A small voltage (0.005v) is applied and the resistance is recorded. With calibration standards and a lot of mathematics, the resistivity-depth and the carrier concentration-depth can be determined.

For Secondary ion mass spectrometry (SIMS), the sample is placed in a relatively high vacuum and then sputter-etched using oxygen or cesium ions. Some of the volatized material is collected by a mass spectrometer, separated into mass-to-charge ratios and counted. Using calibration standards, the counts can be converted to atoms/cubic centimeter.

SRP is most useful for silicon and germanium whereas SIMS can depth-profile almost any solid.

SRP determines resistivity-depth and carrier concentration-depth. These profiles have a rather direct relationship to the final semiconductor product's performance. Atomic concentration determined by SIMS is also important but seems to be a step further removed from the final objective.

Many of our customers view the two techniques as complementary and request profiles by both methods. (Solecon does not perform SIMS analysis but we will be happy to out-source it if requested.)

SRP has sensitivity to about 8 decades of resistivity (and concentration) where it is generally thought that SIMS is usually limited to 3 decades. (Recently, we have seen a few SIMS results indicating 4 decades of dynamic range.)

SRP is generally considered less costly than SIMS. The equipment for both techniques is high maintenance but SRP is less complicated by not having an ultra-high vacuum requirement.

SIMS has the edge in ultra-shallow profiles but it cannot distinguish between electrically active and inactive impurities. SRP senses electrically active species almost exclusively.

For deeper profiles, SRP has the edge. For evaluation of epitaxial layers, SRP is accepted almost universally as the preferred method.

SIMS can identify the dopant species. SRP can only identify if the dopant is n- or p-type.

Carrier concentration (determined by SRP) and atomic concentration (determined by SIMS) usually have a one-to-one relationship except in the case of junctions, surfaces, and implants not fully activated. The carrier concentration relates closer to the electrical performance of the device.

In many cases, spreading resistance results can be verified by four-point probe measurements. To our knowledge, no similar verification is available for SIMS.

Because SRA determines resistivity, the reported carrier concentration in poly is often under-reported, due to the carrier mobility in poly being lower than in single crystal. With SIMS the atomic concentration should be correct but you don't how much of it is activated nor what the resistivity is.

Areas that SRP is particularly useful:

1. Epi profiles: We believe SRP is the best way to determine epi thickness, resistivity, and any autodoping present.
2. Troubleshooting: A rather large region can be beveled and stained. Interesting regions can be identified and then profiled.
3. Sensitivity to very low dopant contamination problems.
4. All tools have problems with ultra-high resistivity (say greater than 1000 ohm-cm and certainly >5000 ohm-cm.) Although not as reliable as one would prefer, SRP is probably the best method in nearly all circumstances. (The sheet resistance determined by four-point probe is another good method IF the necessary conditions are met-large area, top layer only, uniform resistivity with depth through the entire top layer, with an insulator or electrical junction underneath.)
5. SRP is the best way to profile VERY deep structures. Greater than 500 microns can be done.