# Doping Type Determination

The spreading resistance probe is basically a glorified ohmmeter which does not sense doping type per se. Whether a profile gets plotted with "n" or "p" doping type is solely determined by the operator's input to the data reduction computer. The operators have a number of ways to determine type:

- We can rely on information supplied with the sample. If you tell us you have a boron implant into a p-type substrate, we may not check further unless we suspect something different based on the appearance of the measured resistance data. This has, on occasion, caused us to provide inaccurate results. Many times what we actually find is very different from what our customers have told us to expect. This is especially true when the samples are for R&D. Therefore, this method is our least favorite.

- Minor flat location, though not absolutely reliable for smaller wafers, and not even available on larger wafers, will tell us substrate type. As we learned in the old school, with reference to the major flat:

  - If the minor flat is 180 degrees from the major flat the wafer is N-type <100>.
  - If the minor flat is 90 degrees to the left or right the wafer is P-type <100>.
  - If the minor flat is 45 degrees up on the left or right the wafer is N-type <111>.
  - If there are no minor flats the wafer is P-type <111>.

  Since junctions are relatively easy to spot in the raw data (they cause a cusp in the profile), we can count junctions up from the substrate to get an indication of type for any portion of a profile. Unfortunately the industry is moving towards larger and larger wafers and putting flats on them is thought to consume too much surface area or to cause a severe wobble when spun. This has led to the introduction of the notch. Wafers with notches do not have substrate type and orientation indicators.

- The most commonly used method is the hot probe. We have equipped our instruments with auxiliary circuitry which allows us to switch to a mode where one of the two probe tips is heated several degrees centigrade above ambient – hence "hot-probe" (Figure 1). We then run a second profile on the sample where we measure the open circuit voltage rather than the resistance between the probes. The polarity of the voltage, determined by the Seebeck Effect, tells us the conductivity type. The method is reliable, except on very thin layers – particularly when they are sandwiched between high concentration regions such as emitters and collectors. The sampling volume is several times larger than that for resistance measurement. When the heated probe touches the silicon, heat is transferred to the sample. If there are both N and P regions in close proximity, sometimes the one that has the higher concentration will dominate the signal. Our technicians learn to recognize the shape and amplitude of the measurement and can intuitively determine the correct type. This method can also be uncertain in very high resistivity material. When hot probing samples in the $10^4$ ohm-cm and higher resistivities, the N-type mobility being higher than P-type mobility can lead to false N-type signals. Quite often when probing high resistivity we will do two hot-probe scans – the second being in reverse polarity. If the resistivity is too high, the reverse polarity hot probe will not swap to the type opposite that indicated by the normal polarity hot probe.

- Chemical stains are often used, but are notorious for being misleading. They do provide supporting information though, and are used to confirm junction location. This is handy when we are suspicious that we may have fallen out of a pattern, but that's a topic for another technical note. The Philtec Safe-t-Stain that we use can be handled without chemically resistant gloves and does not have a shelf life. It comes in five concentrations for staining lightly to heavily doped silicon. It will normally stain N-type material and leave P-type unstained. However we have seen it stain the P-type and not the N-type. Sometimes it even stains both!
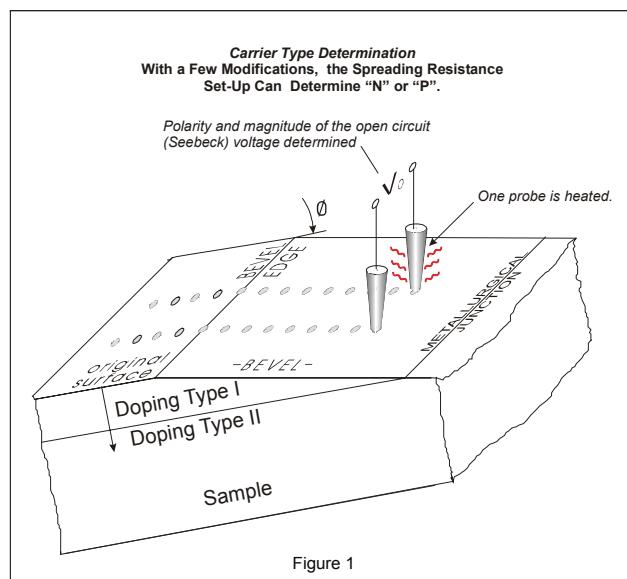


Figure 1