How Big a Pattern Do We Need for Spreading Resistance Analysis?

The following discussion, presented in a question and answer format, deals with some of the difficulties encountered when profiling small areas. Generally speaking, profiles run on patterned surfaces tend to be inferior to those on test (unpatterned) wafers and the smaller the size the greater the compromise. As the size decreases, care in beveling must increase. Frequent inspections are necessary and each inspection increases the risk of scratches.

Q) Aren't you overstating it a bit saying that profiles run on patterned wafers are inferior to those run on unpatterned?

A) I can think of lots of disadvantages and only two advantages:

1) Patterned wafers do give you the opportunity to profile several different structures on a common bevel if the patterns are large and arranged in an order. (Please see the technical note "The Desirability of Dedicated Spreading Resistance Test Patterns".)
2) Profiling patterned wafers means that you can pluck your samples from an honest-to-goodness production run.

Disadvantages (particularly if the pattern size is small) include:

1) Cutting the sample out adequately aligned to the pattern. Sometimes they break right in the middle of the area you are trying to profile.
2) Choosing a bevel angle that makes it possible to profile down to the maximum depth of interest while maintaining some resolution.
3) Interrupting the beveling process to see if you have gone far enough (or too far.)
4) Going too far, especially on one-of-a-kind patterns.
5) The need for multiple inspections during the beveling process risking scratches or a change in angle (and not being able to do a darn thing about it).
6) Coping with the tension in the back of the neck and the general bad humor generated by the above mentioned items.

Q) Are you saying that inspections during beveling are bad?

A) Well, at least risky. Every time you place the beveling jig back onto the beveling wheel, there is the possibility that part of the debris collected under the leading edge of the sample will move to the sample surface or the beveling wheel AND CAUSE SCRATCHES. If you have a nice wide pattern, you can sometimes dodge a scratch or two when probing. Also, upon repositioning of the jig to the beveling wheel, the sample may start beveling at a new angle. If the pattern is long enough (and the new bevel angle isn't too weird), you can just continue to bevel until the new bevel angle has completely replaced the old one. Our people are pretty skilled at minimizing these risks but they haven't been able to eliminate them.

Q) How wide a pattern do you need?

A) At the very minimum both probes need to be within the pattern. With judicious shaping of the probe tips, you can get the minimum spacing down to about 20 microns. With much effort, the separation can be made smaller, but it drastically reduces the life expectancy of the probe tips and thus compromises the reliability of the measurements. Good form suggests that minimum distance from the probe to the edge of the structure should be about half the probe separation to avoid distorting the current lines. (Fig. 1) If probe separation is 20 microns, and half that width is added to each side, we now have a width of 40 microns. Add another 10 microns for slop and the desired pattern width is 50 microns.

Q) Then 50 microns is always wide enough?

A) No, not always. Sometimes epi shift causes us to miss buried layer patterns. We have observed the silicon step indicating the location of the buried layer pattern to be shifted laterally a distance equal to epi thickness in some cases. In samples with thick epi and epi shift, a minimum width of 100 microns would be appreciated. Significant lateral diffusions intruding into the pattern to be measured should also be considered.

Q) How long?

A) There are a number of considerations. Please bear with me. The probe tips are made of a tungsten carbide. The contact area is deliberately made small—about 10 billionths of a square centimeter.

Even at very light loads, the pressure is tremendous—on the order of a million pounds per square inch. Silicon is fractured immediately under the probe tip and a damage crater is left behind. It is necessary to move beyond this damage for the next probing. The full extent of the probe damage is difficult to observe with a microscope. The practical test for the extent of the probe damage is simply to probe across a fairly homogenous surface with various step increments. The measured spreading resistance should be independent of step size unless the damage craters overlap. From this test it would appear that a one micron step is almost possible. Unfortunately, there are other factors that discourage the use of less than two micron steps. A lot of the trouble is due to the limitations of the microscope.

a) The location of the bevel edge has an uncertainty of about a micron.
b) Our ability to align the probe tips to each other and to the bevel edge is also uncertain to within one micron.
c) It is a real eye strain to count probe marks at a one micron step increment. (The eyes of this ancient writer simply can't do it.)

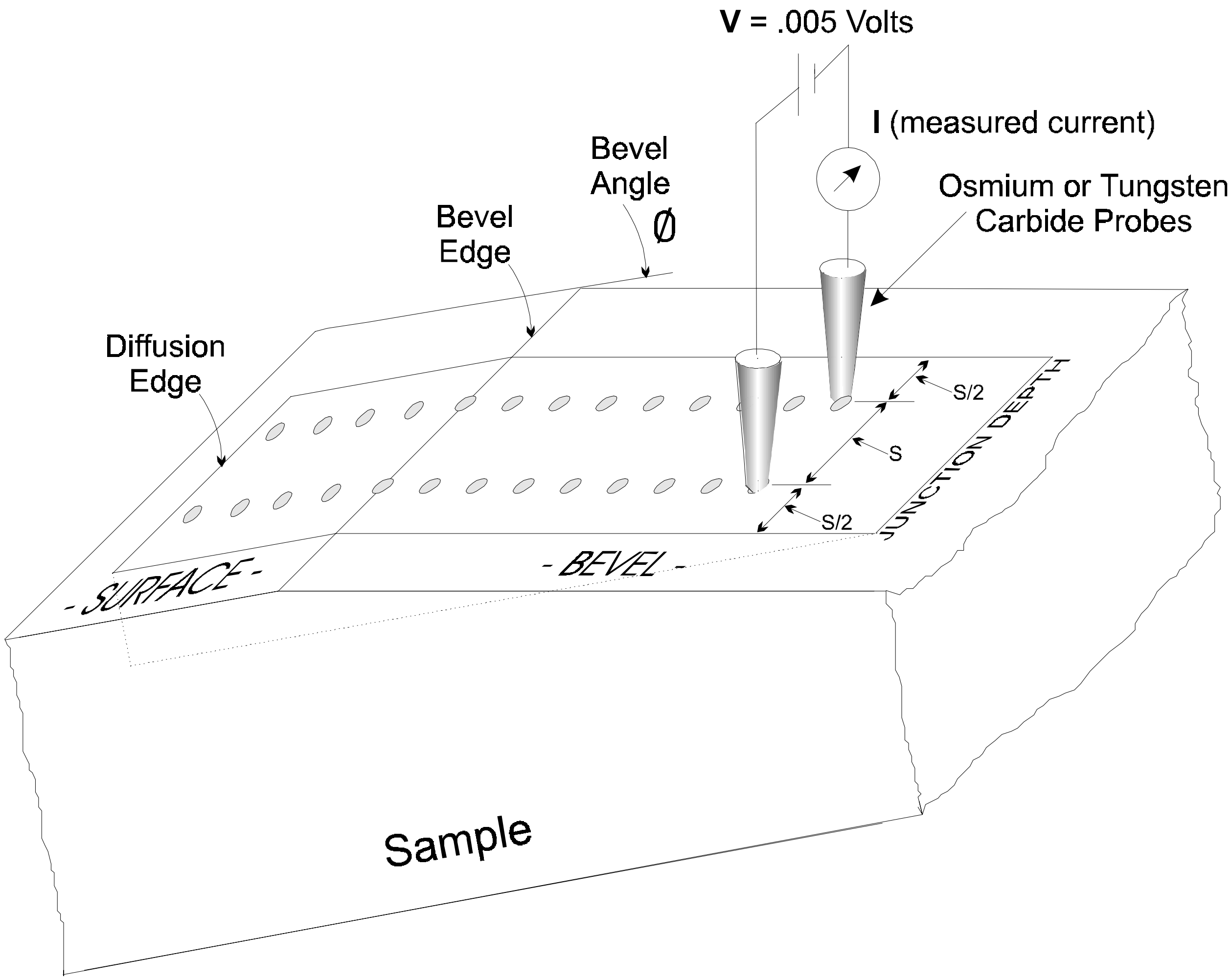

Figure 1

Q) Are you saying that all you have to do is make the probe marks just a little smaller, get a better microscope, and then you can do one micron steps?

A) Well, maybe but there is this other consideration…

As we said earlier, the distance between the probe and the edge of the structure should be a minimum of half the probe separation (S/2). The bevel edge is also an edge of the structure—not as drastic as a diffusion edge but a discontinuity nonetheless. The original surface of the sample may be VERY different from the bevel surface that we have made. It would be preferable to minimize the number of measurements (and the portion of the profile) that is less than S/2 for the bevel edge. With a 5 micron step increment, about two measurements, and with a 10 micron step, usually only one measurement.

To maintain resolution at larger step increments (i.e. hold the depth increment constant), the bevel angle should be decreased. (Incidentally, on profiles from Solecon Labs, the "bevel angle" is expressed as the sine of the angle. The depth increment is then equal to the product of the "bevel angle" and the "step increment".) Reducing the bevel angle brings up at least two considerations:

a) There is a practical limit as to how shallow an angle we can make. Beveling on a 800:1 (0.00125 radians or about 4 minutes of arc) block is somewhere near the point of diminishing returns. More shallow bevels tend to produce grief rather than more information.
b) The shallower the bevel angle, the greater the pattern length required to get through the depth of interest. Example: if the depth of interest is 5 microns and the bevel angle is 0.005, then a length of 1000 microns is required. Also, bevels much longer than 1000 microns (say 2000 microns) often prove troublesome. The likelihood of scratches increases greatly and we have difficulty staying adequately aligned to patterns.

Q) So what are you saying? How small can the pattern be?

A) Actually test (unpatterned) wafers are real nice! But if we can't have that, we can usually profile a structure 50 microns by 500 microns without appreciable compromise. If there is epi shift or both shallow and deep structures, better make that 100 microns by 1000 microns. If it is a rather simple structure, we can usually do a reasonable job with an area say 40 microns by 200 microns. And from time to time we profile areas 20 microns by 100 microns and smaller BUT WE DO NOT LIKE IT!! The profiling is difficult and expensive and the resolution gets lousy. Did I mention that we don't like to profile small patterns? I just wanted to be sure. Please see the technical note "The Desirability of Dedicated Spreading Resistance Test Patterns".