

## **PBS<sup>®</sup>** Measurements and CMP

The **PBS<sup>®</sup>** measurements, developed by VTI, Inc., have been used with great success to detect and map subsurface polishing damage in semiconductor wafers. The **PBS<sup>®</sup>** measurement technique, which was originally developed to evaluate polished optical surfaces, is extremely sensitive to both surface and subsurface defects. The measurement detects scattered light and, as originally designed, uses a red laser (HeNe @ 632.6 nm) to allow light penetration into the material for subsurface defect detection. More recent modifications use an ultraviolet laser (HeCd @ 325 nm) to look at surface and very near surface defects. This proved to be very useful for SOI wafers with a thin silicon layer.

Use of the **PBS<sup>®</sup>** measurement to evaluate surfaces after CMP (Chemical Mechanical Polishing) has not been considered effective because the polished layer is transparent, even in the UV, and covered a patterned surface. This patterned surface will scatter the laser light and obscure the small defects of interest. Upon further consideration, it becomes clear that an unpatterned test wafer could be used. Making an initial measurement just before CMP and a second measurement after CMP would provide sufficient information. A properly polished substrate wafer should have an extremely low background level against which the CMP polished layer would be measured. Any differences that are seen, in particular directional defects such as small scratches, or patterns of scratches, should be immediately obvious.

Such a measurement would provide a means for evaluating the CMP process and adjusting the process to achieve an optimized polish. Additionally, test patterns such as metal lines could still be used on the test wafer if the lines ran in one or two known directions and did not cover the entire wafer. Because the **PBS<sup>®</sup>** measurement is non-destructive, it would not interfere with other, possibly destructive, tests that could be done on the same test wafer.

There is an extensive background of **PBS<sup>®</sup>** measurements of optical surfaces that prove the value of these measurements on transparent materials and coatings. The following figures show the V-MAP (a specialized polar plot used to detect oriented defect structures) and the area map for a superpolished surface and for a typical surface on a quartz (SiO<sub>2</sub>) optical flat. In this case the measurements were made on the front and back surface of the same 25 mm diameter part. The measured area, in each case, is 10 mm in diameter.

Figure 1 shows the results for the superpolished surface (a polishing process designed to get the smoothest and lowest damage surface on quartz). The V-MAP has no indication of directional damage that would show up as symmetrical non-uniformities in the polar plots. The area map, which is only 10 mm in diameter, has only a few isolated red spots that are probably particles. The background level is uniform and mostly due to residual bulk scatter. Note that the average for the area map is only 0.025 PPM/Sr, an extremely low level for an optical surface.

Figure 2 has the results for a standard polish. In this case it is a standard laser quality polish, which is much better than the polish found on commercial optics that might be found in a 35 mm camera for instance. The V-MAP shows signs of significant directional damage clearly distinguished by the multiple, symmetrical lines across the polar plots. The area map shows a much higher scatter level with an average of over 1.0 PPM/Sr, 40 times higher than the superpolished surface. Examination of the map shows lines of defects in two directions going across the surface. The defects seen here are primarily subsurface and can extend to a depth of many microns into this material.

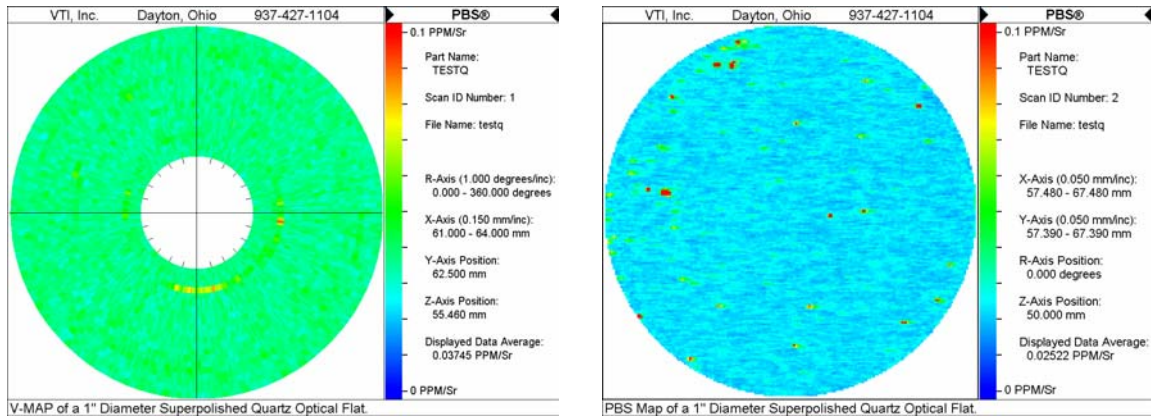


Figure 1. **PBS**<sup>®</sup> Measurements on a Superpolished Quartz Optical Flat.

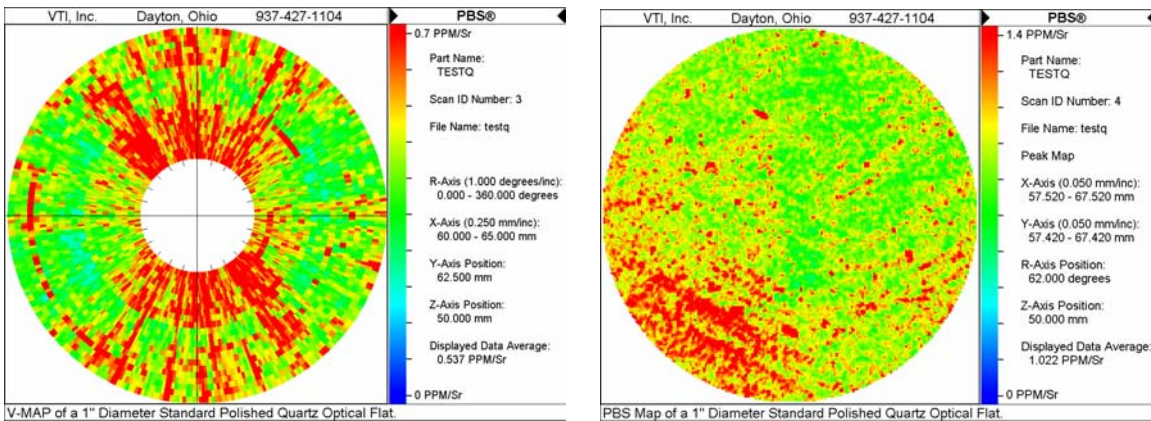


Figure 2. **PBS**<sup>®</sup> Measurements on a Standard Polished Quartz Optical Flat.

The measurements shown in Figures 1 and 2 were done with a red laser at 632.8 nm. Measurements in the ultraviolet are much more sensitive to extremely small surface defects. The ultraviolet wavelength used is 325 nm, about half the wavelength of the red laser. For this type of measurement this means that the scatter from a defect or surface roughness will be a factor of about 16 greater than when a red laser is used. The UV laser offers the possibility of detecting extremely small defects caused by the CMP process.

Figure 3 shows a **PBS**<sup>®</sup> area map of a 200 mm diameter silicon wafer, only a 100 mm diameter area was mapped, made with ultraviolet light. Careful

examination of this map shows many unusual features including stains and fine scratches that were not visible with any other standard surface mapping technique.

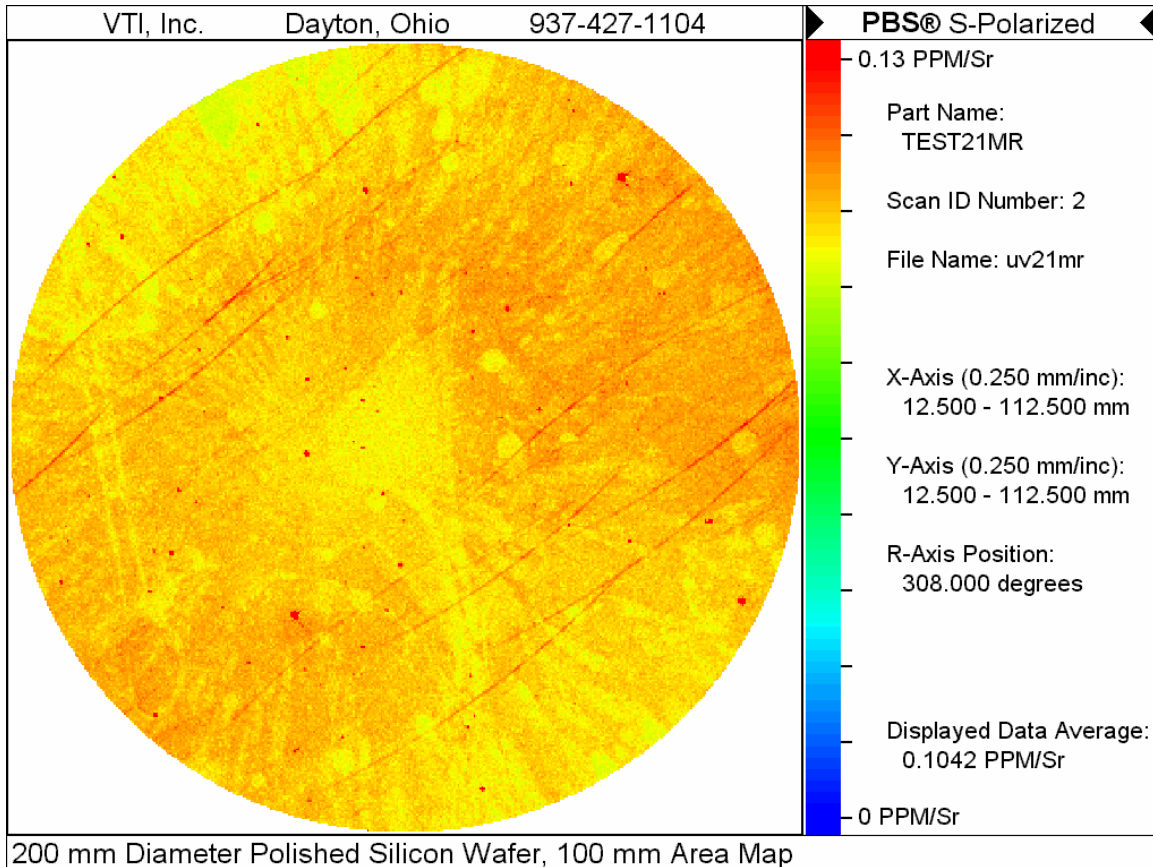


Figure 3. Polished Silicon Wafer Mapped Using Ultraviolet Light.

**PBS®** measurements in the ultraviolet or in the red can be used to evaluate CMP processes if unpatterned test wafers are used. Because the **PBS®** measurement is non-destructive, the test wafers can be used for additional testing using other techniques. This measurement has the proven capacity to detect very small defects, and oriented defect structures, on and below the polished surface yielding the kind of information necessary to facilitate CMP process improvement.