QUANTITATIVE METALLOGRAPHY OF PROBE NEEDLES

The improved hardness, strength, and wear resistance properties of tungsten-rhenium (WRe) over tungsten (W) probe needles can, in part, be attributed to the smaller average grain sizes and the larger number of grain boundaries.

	W	WRe
Yield Strength (GPa)	5.52 to 6.05	5.95 to 6.48
Vicker's Hardness (kg/mm^2)	575 to 715	720 to 850

Probe needle strength and hardness properties.

As the diameter of W and WRe-wire is reduced by drawing, the grains are elongated into an anisotropic microstructure. Grain boundaries act like barriers to dislocation motion due to crystallographic orientation mismatches between adjacent grains and to slip plane discontinuities within each region. Virtually all strengthening techniques rely on this simple principle: restricting or hindering dislocation motion renders a material harder and stronger. Thus as the wire grain structure is altered by alloying or drawing, the strength and hardness values will systematically increase.

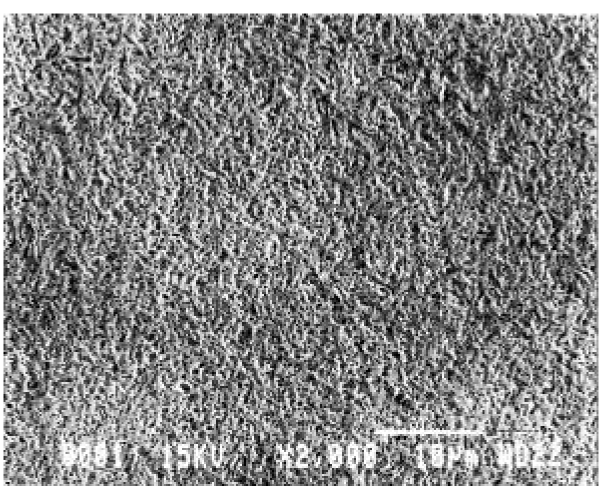

Figure 1a: Tungsten-rhenium probe transverse cross-section.

Several W and WRe-probes were prepared to reveal the transverse and longitudinal microstructures at 2,000X magnification using a scanning electron microscope (SEM). The morphologies were evaluated with standard quantitative microstructural analysis procedures and digital image measurements of local blur that are directly related to small feature content.

In the transverse sections (Figures 1a and 1b), the W-surface appears "rougher" and more coarsely-grained than the "smooth" fine-grained WRe-surface. However, it is difficult to visually differentiate between the individual grains. Computerized image analysis showed a number of notable local pixel differences and a significantly higher content of small features in the WRe-micrograph. These results are indicative of a more refined grain-structure.

At low magnifications, the longitudinal microstructures of W and WRe-probe needles are very similar. The highly elongated grains that form the tough, interlocking, fibrous longitudinal microstructure of W and WRe-probe needles are visible in the SEM micrographs (Figures 2a and 2b).

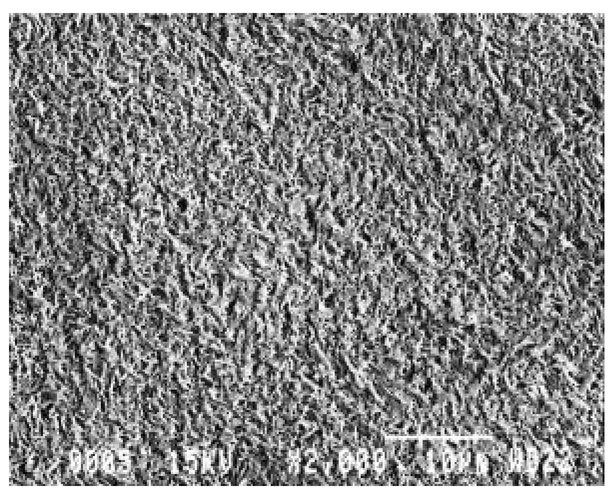

Figure 1b: Tungsten probe transverse cross-section.

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The grain refinement effects were quantified by counting intersection points per unit test line, P_L, at several locations and orientations within the micrograph. For the highly oriented and elongated grains of W and WRe-probes, a large value for P_L indicates a more refined microstructure. Average P_L values for the WRe-probes were 15% higher than those of the W-probes. The computer analysis showed that local pixel differences between the two materials were statistically significant ($p<0.0075$) for all measurements. Similar to the transverse sections, these results are indicative of a refined grain-structure.

It is important to remember that these trends will hold for all W and WRe-probe needle diameters; though, they may not be in the same proportions or magnitudes.

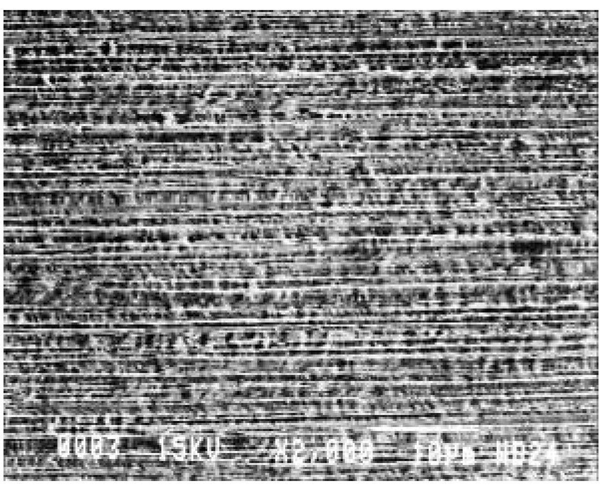

Figure 2a: Tungsten-rhenium probe longitudinal cross-section.

The addition of 3%-rhenium to tungsten causes a significant increase in the grain boundary area, a considerable reduction in the average grain size, and a more pronounced interlocking microstructure. The result is a smoother probe tip surface with a larger number of grain boundaries.

With a more refined grain structure, the WRe-probe tip surface will be more wear resistant than that of the coarser-grained W-probe. Thus, the WRe-probes will exhibit higher hardness numbers and will demonstrate better overall resistance to surface penetration.

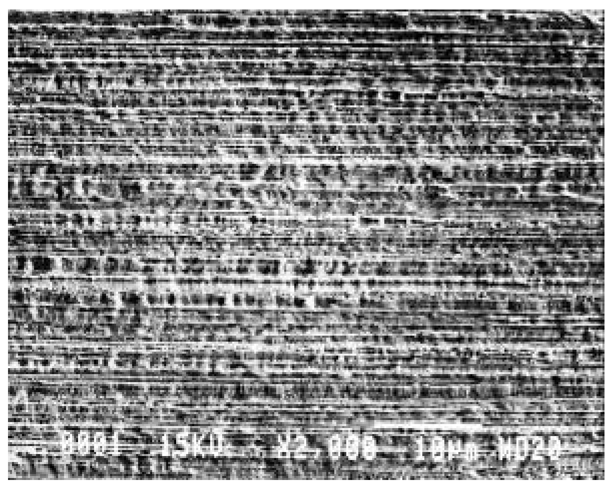

Figure 2b: Tungsten probe longitudinal cross-section.