MYTHS AND LEGENDS OF PROBE NEEDLES

Presented by

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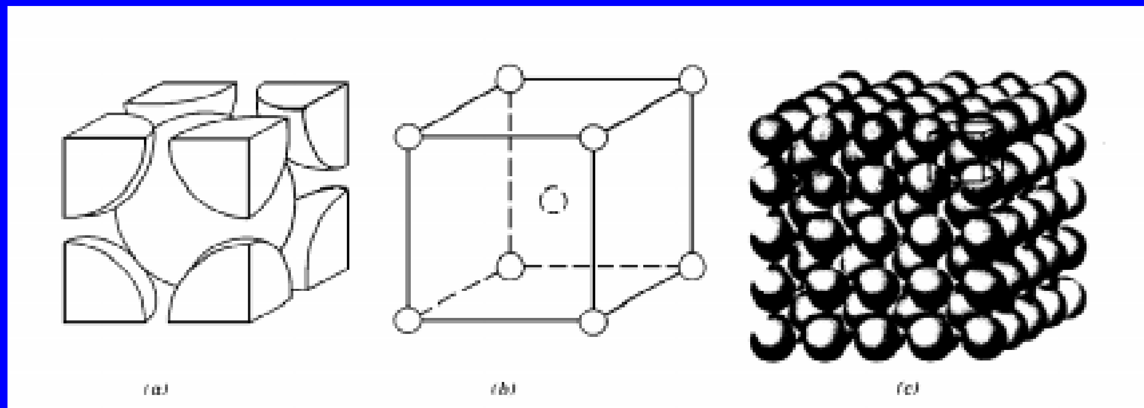
TRUE OR **FALSE** ?

Rhenium atoms are like small pebbles that fill in the gaps between the much larger tungsten atoms.

	W	Re
Atomic number	74	75
Atomic weight	183.85	186.21
Atomic radii	1.38Å	1.37Å
Covalent radii	1.30Å	1.28Å

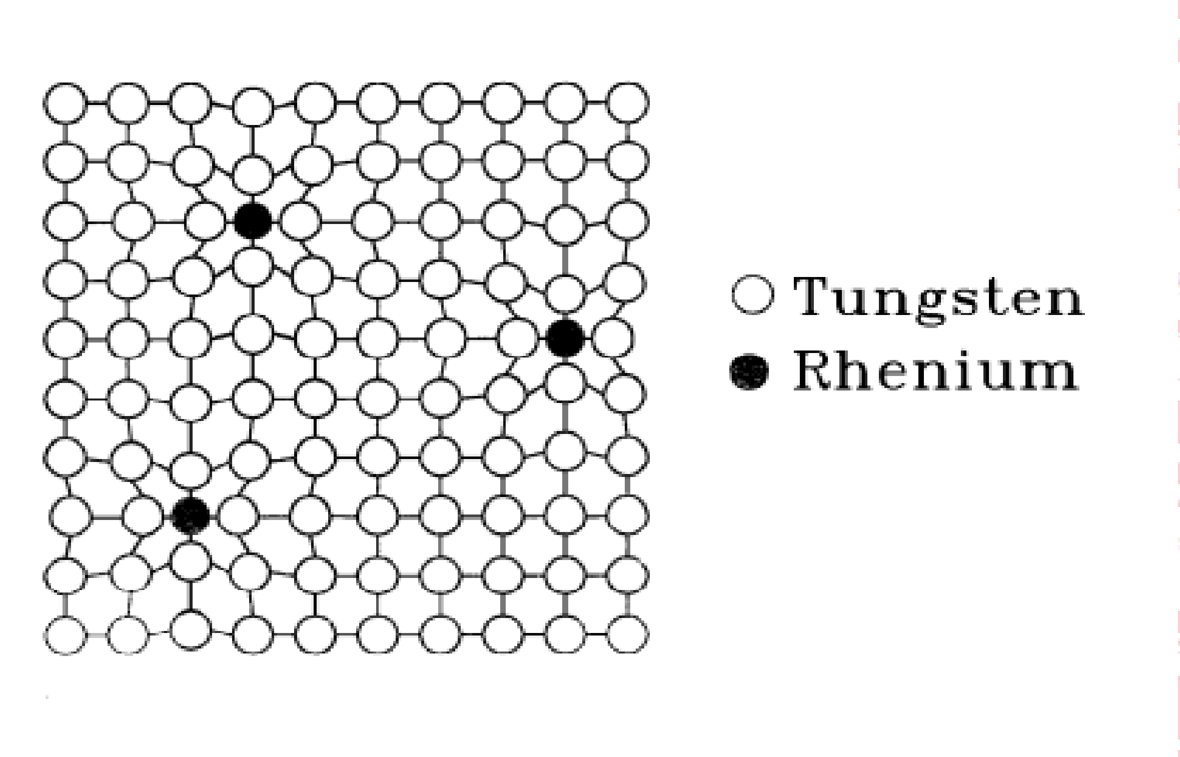
W is a crystalline metal that has a body-centered cubic (BCC) structure



(a) hard-sphere unit cell representation
(b) reduced-sphere unit cell representation
(c) aggregate of many atoms representation

(Figures from Materials Science and Engineering: An Introduction, Callister, 1985, p. 30.)

WRe is a substitutionally strengthened solid-solution alloy



- Re atoms distort the crystalline lattice because of a reduction in the interatomic spacing between lattice points.
- The decrease in lattice spacing results in a reduction of interatomic free-space and a more tightly packed material with higher density.

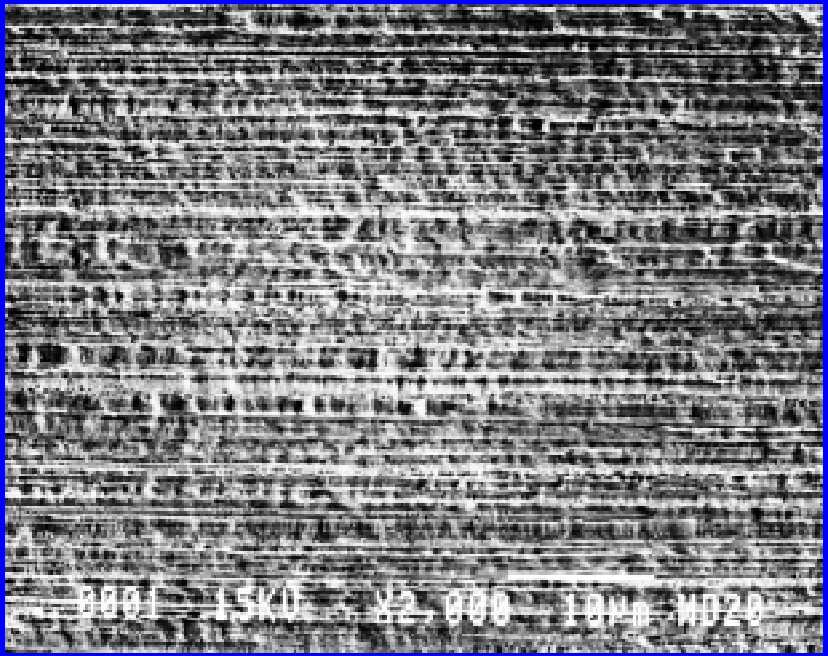
<u>TRUE</u> OR FALSE ?

Tungsten-rhenium probe needles have a smoother surface than tungsten needles.

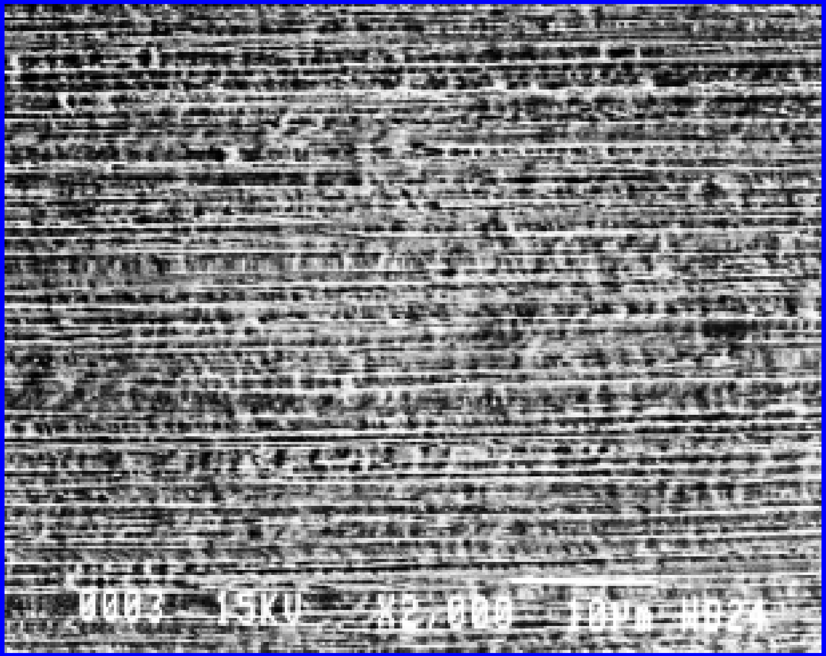
Drawing of W and WRe wire

- Plastically deforms the material
- Increases dislocation density
- Increases dislocation interactions
- Elongates the grains into a fine grained, anisotropic microstructure

LONGITUDINAL CROSS SECTION

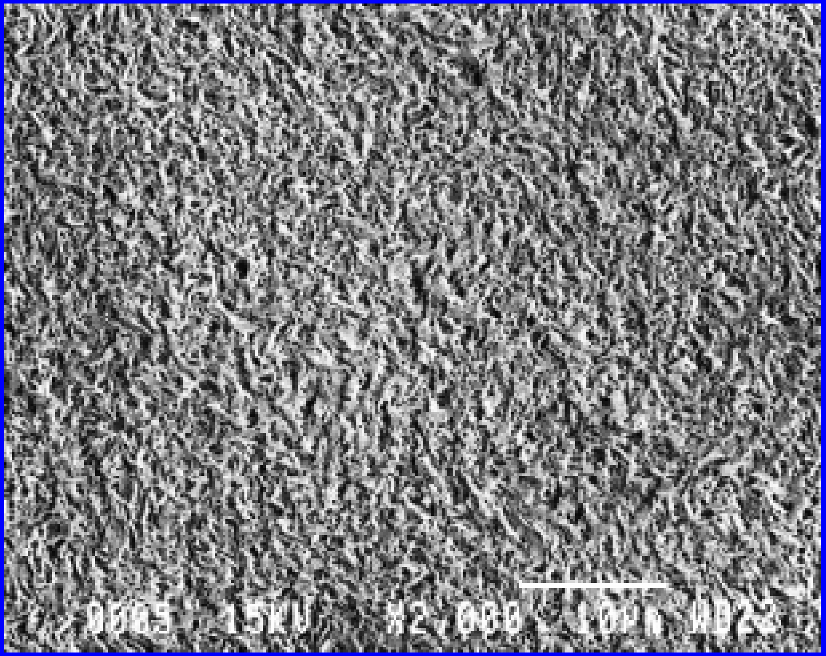


W



WRe

TRANSVERSE CROSS SECTION



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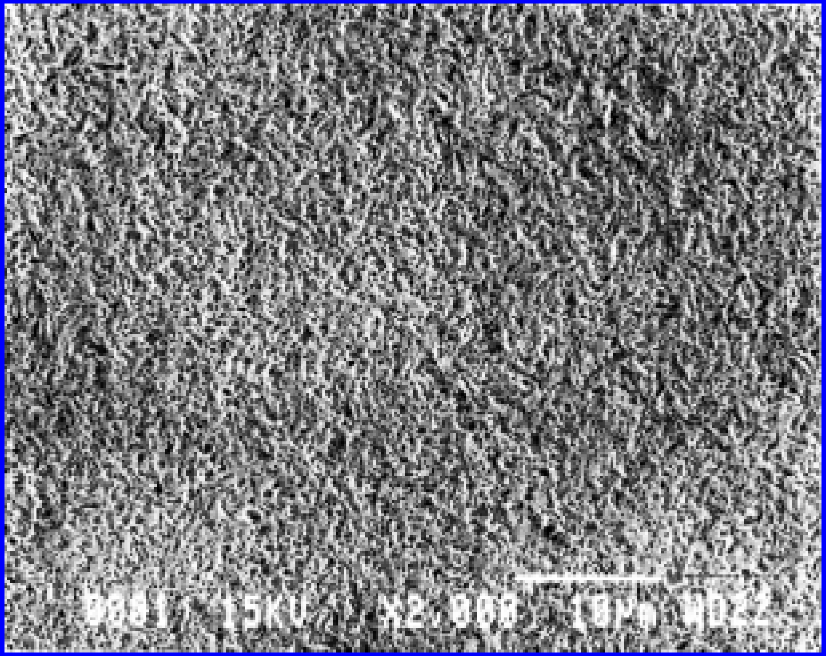


WRe

The addition of Re to W probe needles

- Causes the interlocking structure to become more pronounced
- Refines the grain size
- Increases the grain boundary area significantly

- The grain boundaries act like barriers to dislocation motion
- The refined microstructure contributes to the material’s resistance to surface penetration
- The result is a more wear-resistant material

▲ TECHNICAL TIP ▲

With a more refined grain structure at the tip contact surface, the probe tip surface of the WRe probe will be smoother and more wear resistant than the coarser-grained W.

TRUE OR FALSE ?

Tungsten and tungsten-rhenium probe needles perform identically.

TRUE OR FALSE ?

Tungsten and tungsten-rhenium probe needles require no different handling.

PROPERTIES	W	WRe	BeCu
Elastic Modulus (GPa)	394.5 ± 6.1	395.7 ± 6.4	131.5 ± 5.5
Flexural Yield Strength (GPa)	5.52 – 6.05	5.95 – 6.48	2.90 – 3.10
Flexural Yield Strain (mm/mm x 10^{-3})	13.7 – 14.3	15.3 – 15.9	22.4 – 24.0
Knoop Hardness (100 gm load) (kg/mm^2)	705 – 832	818 – 891	300 – 350
Vicker's Hardness (100 gm load) (kg/mm^2)	665 – 738	745 – 877	288 – 325

The advantages of WRe probe needles are a result of the increased hardness of WRe probes over W probes.

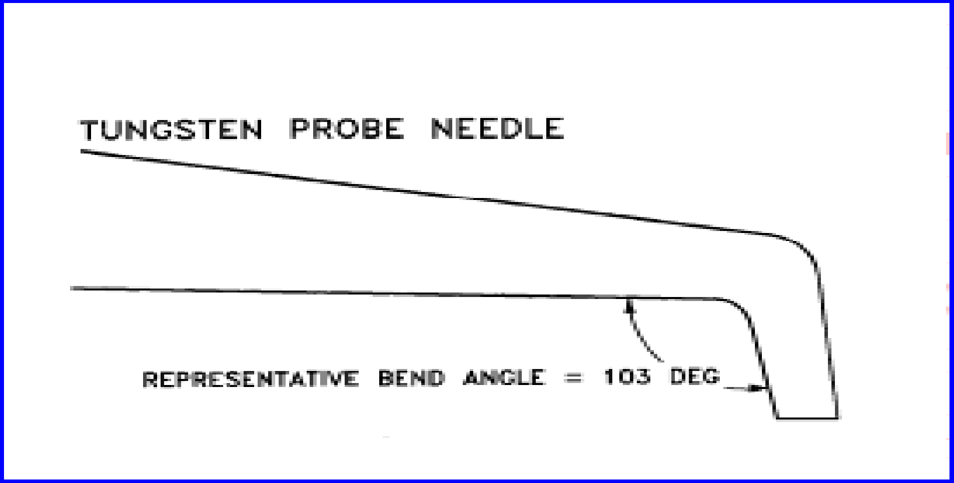
▲ TECHNICAL TIP ▲

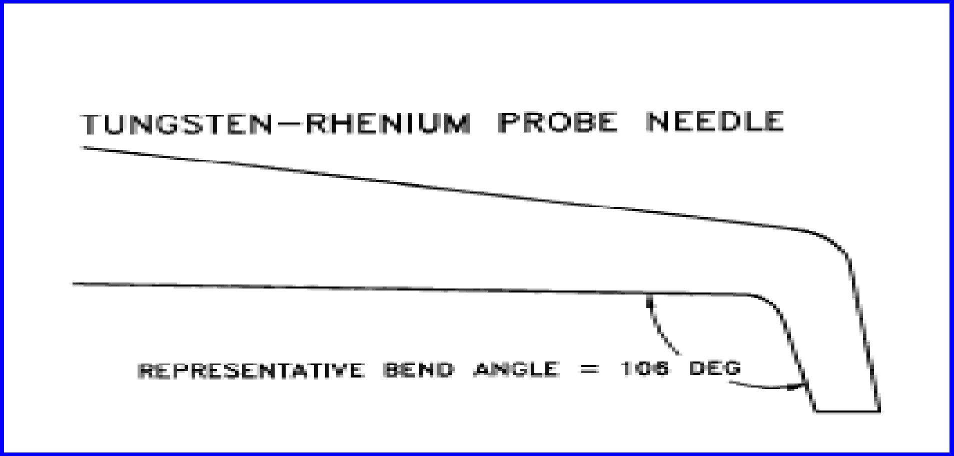
The hardness, stress and strain properties of probe needle materials are dependent on the annealing schedule and drawing process used during production.

▲ TECHNICAL TIP ▲

Since the flexural yield strength and strain properties of WRe probes are significantly greater than those of W, the application of identical bend deformation to identical WRe and W probes will cause greater permanent deformation in the W probe.

BENT PROBE TIP





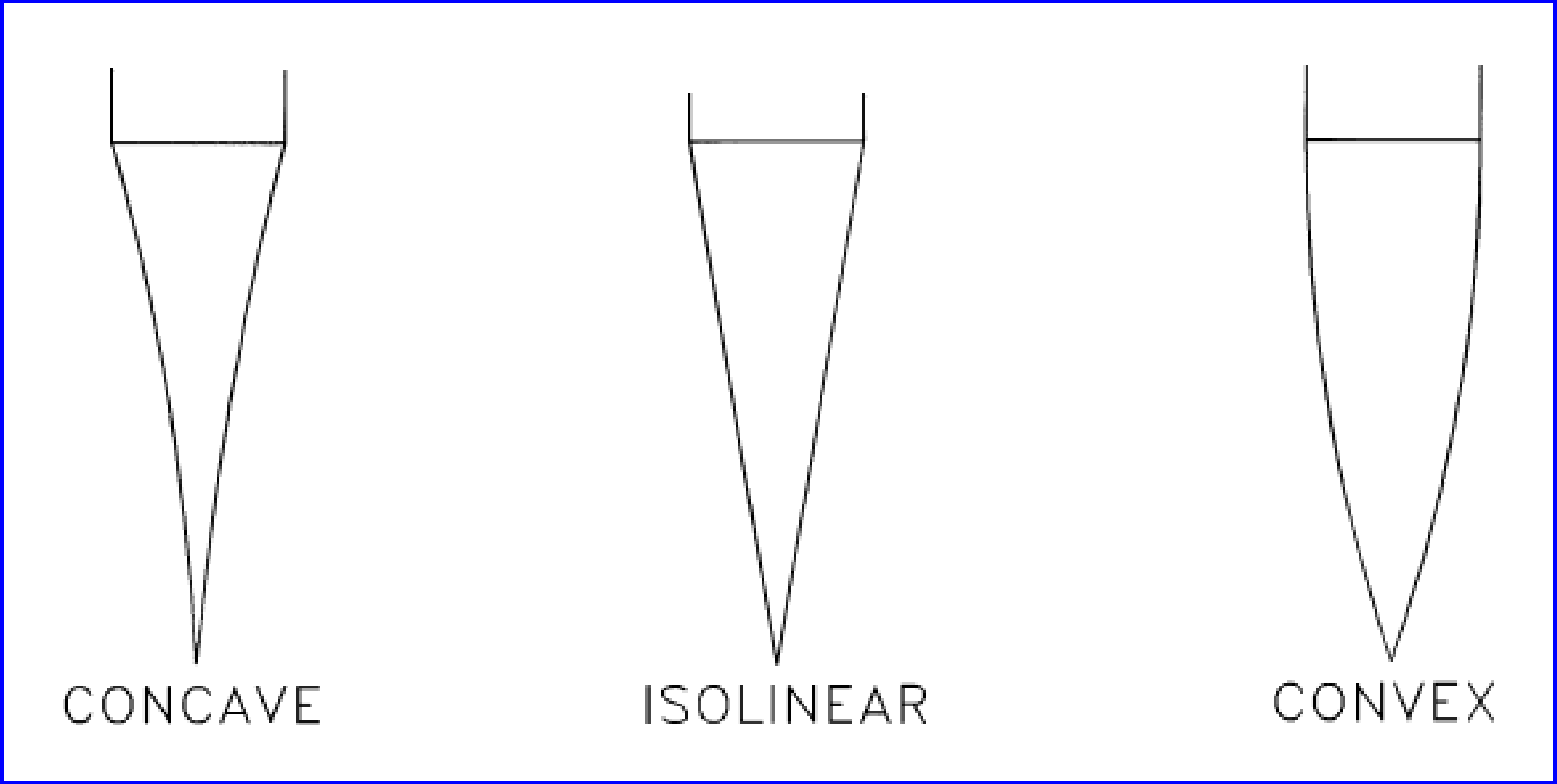
▲ TECHNICAL TIP ▲

Cleaning practices for WRe and W probes should consider the different metallographic microstructures of these materials.

TRUE OR <u>FALSE</u> ?

All probe needles are etched with an isolinear taper.

ISOLINEAR



TRUE OR FALSE ?

Probe needles demonstrate behavior often referred to as "needle memory".

- When probe needles are bent, they are plastically deformed.
- Plastic deformation is permanent and nonrecoverable after release of the applied load.

- What is commonly referred to as material “memory” is actually thermoelastic martensitic transformation.
- Thermoelastic martensite occurs in a category of metals referred to as “shape memory alloys”.
- Only these materials demonstrate the ability to return to a previous shape when heated.

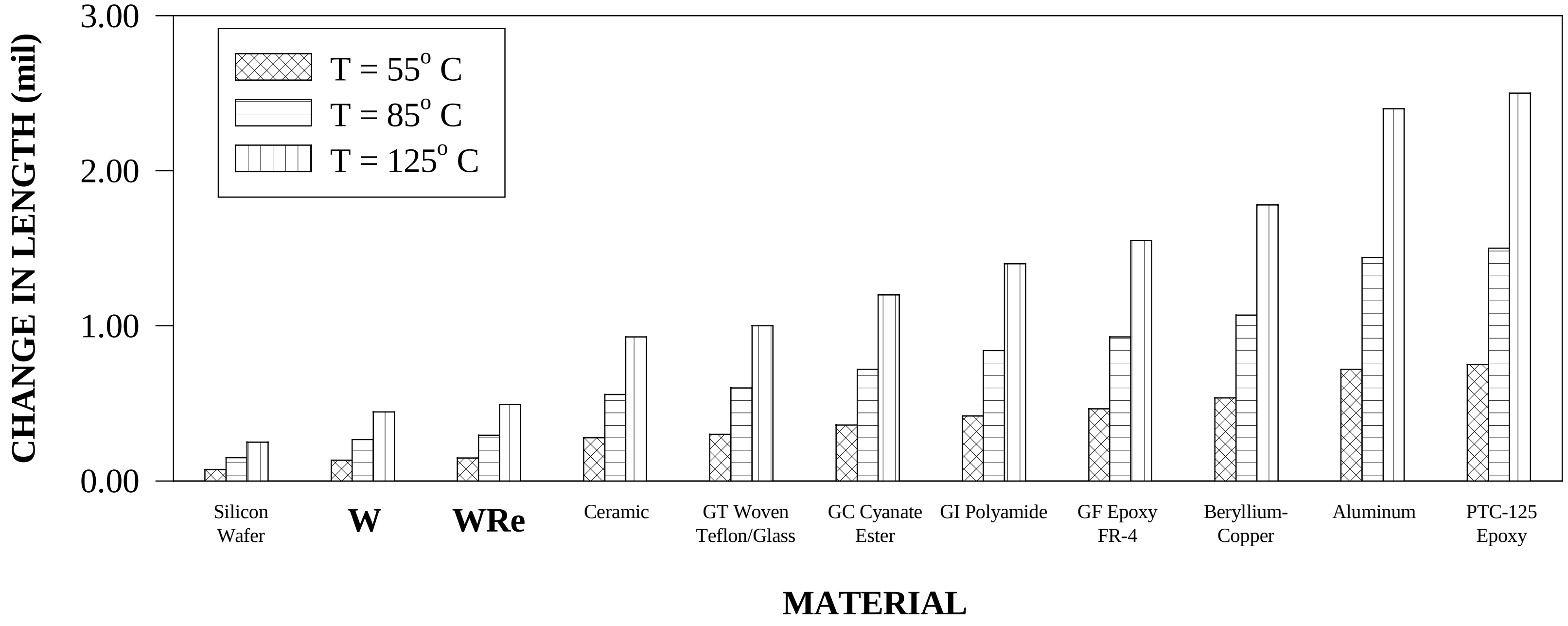
- Tungsten-rhenium, tungsten and beryllium copper do not demonstrate any such "memory" characteristics at ambient or high temperatures.

- Polymeric materials, such as epoxy, will demonstrate viscoelastic recovery when the stress is removed.

HOT-CHUCK TESTING

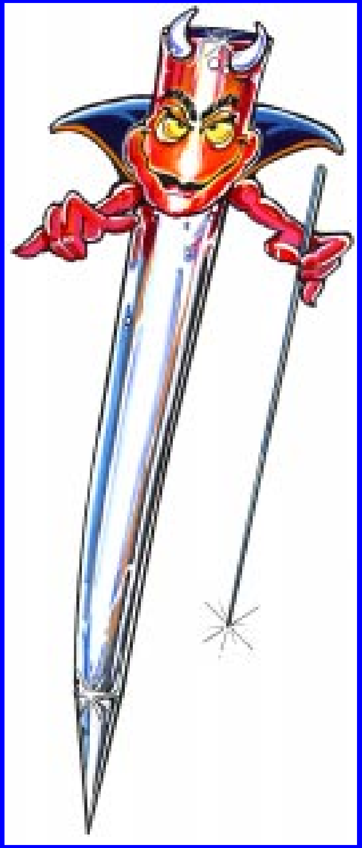
- The movement (perhaps interpreted as "memory") of probe needles at temperature may be attributable to the combinations of volumetric changes and thermal mismatches that occur between the other probe card materials.

Change in linear dimension (x & y axes) for a 1000 mil length of material



TRUE OR FALSE ?

Whatever goes wrong, the probe needle did it!



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APPENDIX 1
Glossary of Terms

<u>anisotropic</u> -- having different properties in different directions.

<u>austenite</u> -- face-centered cubic phase of an alloy that is stable over a specified temperature range.

<u>body-centered cubic (bcc)</u> -- a cubic structure in which the center of the unit-cell is identical to the cube corners.

<u>coefficient of thermal expansion (CTE</u>) -- the change in dimension per degree change in temperature.

<u>covalent bond</u> -- stable electron configuration in which the valence electrons in the outer orbitals are shared between adjacent atoms.

<u>covalent radii</u> -- an indication of the size of an atom in a covalent compound; measured as half of the internuclear distance between atoms bonded together.

<u>crystalline solid</u> -- a material in which the atoms are situated in a repeating or periodic array over large atomic distances.

<u>dislocation</u> -- a crystalline defect around which there is atomic misalignment.

<u>elastic modulus</u> -- stress per unit of elastic strain; also known as Young's Modulus.

<u>elastic deformation or strain</u> -- deformation or strain that is recoverable when the applied load is removed.

<u>face-centered cubic (fcc)</u> -- a cubic structure in which the centers of the unit-cell faces are identical to one another and to the cube corners .

<u>grain</u> -- an individual crystal in a polycrystalline material.

<u>hardness</u> -- the measure of a material's resistance to deformation by surface indentation.

<u>Hooke's Law</u> -- stress and strain are proportional to each other where the constant of proportionality is the elastic modulus.

<u>Knoop Hardness Number (KHN)</u> -- material hardness determined with a diamond indenter that produces a "long" diamond-shaped indent having an approximate ratio between the long and short diagonals of 7:1.

<u>lattice</u> -- a three-dimensional array of points coinciding with atomic potions in crystal space.

<u>long-range order</u> -- a repetitive pattern over many atomic distances.

APPENDIX 1
Glossary of Terms

martensite -- a metastable body-centered phase that is produced from austenite by a shear transformation.

metallic bond -- interatomic bonds in metals characterized by delocalized electrons in the energy bands.

plastic deformation -- deformation that is permanent or nonrecoverable after release of the applied load. It is accompanied by slip or permanent atomic displacement via dislocation motion.

slip -- plastic deformation as the result of dislocation motion; also, the shear displacement of two adjacent planes of atoms.

Rhenium Effect -- the increase in low temperature ductility that results from alloying tungsten with rhenium.

substitutional solid solution strengthening -- the hardening and strengthening of metals wherein the solute atoms replace or substitute for the host atoms.

unit cell -- the basic structural unit of a crystal structure, generally defined in terms of atom positions within a parallelepiped.

Vicker's Hardness Number (VHN) -- material hardness determined with a diamond indenter that produces a square based pyramid shaped indent with an angle of 136^o between the faces .

viscoelastic material -- a material that demonstrates a combination of time-dependent and elastic mechanical behavior.

viscoelastic recovery -- the time dependent mechanical response of a viscoelastic material following the removal of a stress or strain.

viscous strain -- the time dependent strain response of a viscoelastic material to an applied or removed stress.

yield point -- the point which corresponds to the intersection of the 0.002 strain offset line and the stress-strain curve as it bends over in the plastic region.

yield strength -- the stress required to produce a very slight specific amount of plastic deformation.

yield strain -- the strain associated with the onset of plastic deformation (with an offset of 0.002 is commonly used).

APPENDIX 2

Coefficient of Thermal Expansion

Material	**Coefficient of Thermal Expansion (x & y axes)** (in/in x 1/°C)
Silicon Wafer	2.50×10^{-6}
Tungsten	4.45×10^{-6}
Tungsten-Rhenium	4.92×10^{-6}
Ceramic	9.30×10^{-6}
GT Woven Teflon/Glass †	9 to 12×10^{-6}
PCB (Polyamide)	12 to 16×10^{-6}
GH Multifunctional Epoxy †	12 to 15×10^{-6}
GM BT Epoxy †	12 to 16×10^{-6}
PCB (FR4)	13 to 18×10^{-6}
Beryllium Copper	17.8×10^{-6}
Aluminum	24.0×10^{-6}
Epoxy (PTC125)‡	25.0×10^{-6}
Epoxy (Typical)	65.0×10^{-6}

† - Wasserberg, SWTW, 1996.
‡ - Griffin, SWTW, 1995.