APPLICATION SPECIFIC PROBE NEEDLES

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or. . .
what does the well-dressed probe wear to a testing?

Industry Challenges

- **Shrinking Device Geometries**
- **Reduced Pad Sizes and Pitches**
- **High Pin Counts and Smaller Probe Diameters**
- **High Resolution Measurements**
- **Varied Probing Environments**

Challenges for Probes

- **Low Frequency (DC) Testing**
  - **Low Current Applications**
    - **Isolation**
    - **Leakage**
  - **High Current Applications**
    - **Power Dissipation**
    - **Series Resistance**
- **High Frequency (AC) Testing**
  - **Inductance**
  - **Probe Impedance**
  - **Cross Talk**
- **Probe Needle Service Life**
  - **Contact Resistance**
  - **Wear and Cleaning**

Probe Needle "Solutions"

- **Silver Plated Probes**
  - Reduction in probe resistivity
  - Improved current carrying ability
  - Limited high frequency benefits

- **Insulated Probes (TIP-M™)**
  - Dielectric coating on probe needles
  - Improved isolation
  - First step in the development of a shielded probe needle

- **N-TIP™ Plated Probes**
  - Greater tip hardness
  - Lower contact resistance
  - Prolonged service life

Silver Plated Probes
(DC Applications)

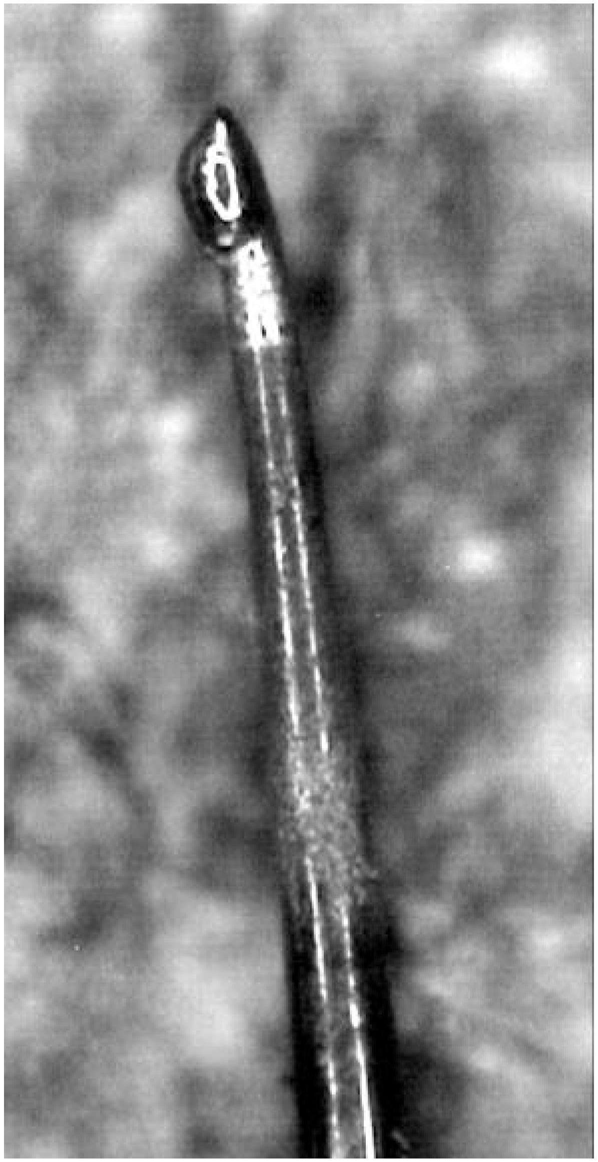
- **Electrical properties of electro-deposited metals are affected by the bath chemistry, bath impurities, current density, and additives**
- **Tungsten and tungsten-rhenium probes are traditionally nickel plated to facilitate solderability**
- **Silver is significantly more conductive than tungsten, tungsten-rhenium or nickel**

Tungsten	Tungsten-Rhenium	Plated Nickel	Plated Silver
5.5 to 5.9 μΩ–cm	9.2 to 10.1 μΩ–cm	7 to 40 μΩ–cm	1.6 to 3.2 μΩ–cm

Silver Plated Probes
(DC Applications)

- **Reduction in overall probe needle resistance**
- **Increase in probe needle current carrying capacity**
- **Overall increase in the power dissipation**

Plated Probe Needle (plate thickness = 200 µin on a 2.0 inch probe needle)	**Nominal Resistance Nickel Plated Probe** (mΩ)	**Nominal Resistance Silver Plated Probe** (mΩ)	**% Reduction Resistance**	**% Increase Current Carrying Capacity**
Tungsten				
5	229.4	148.7	35.2	19.5
6	158.9	109.6	30.9	16.9
7	114.8	83.4	27.3	14.8
8	87.5	66.0	24.6	13.2
10	56.1	44.5	20.7	10.9
Tungsten-Rhenium				
5	376.1	198.9	47.1	27.3
6	260.0	149.9	42.3	24.1
7	188.7	116.6	38.2	21.4
8	140.3	92.1	34.4	19.0
10	89.7	63.3	29.4	15.9



Case Study - Burnt Probe Tips

- **The high current being passed through power pins of probe cards built by Probe and Test, Inc. resulted in burnt probe tips**
- **This problem was successfully addressed by the use of silver plated probes within specific locations in the probe card.**

Silver Plated Probes
(AC Applications)

- **Signal loss occurs as the testing frequency increases**
  - **Non-uniform current density**
  - **Signal loss due to “Skin Effect”**
  - **Decrease in the effective bandwidth**
- **Potential high frequency benefits of silver plating**
  - **Shallow skin depth**
  - **Improved AC resistance**
  - **Reduced signal loss**
- **The effects of silver plating on the probe’s AC behavior were simulated by GigaTest Labs, Inc.**

Silver Plated Probes
(AC Applications)

- **Signal loss characteristics of tungsten and tungsten-rhenium probe needles (5, 6, and 7 mil dia.) were simulated**
- **The frequency dependent response of silver plated probes was compared to that of nickel plated probes**
- **Signal loss vs. frequency was evaluated over a frequency range of 100 kHz to 5 GHz**
  - **50 Ω impedance test environment to ensure that electrical performance differences were only due to the needle and plating differences**
  - **100 Ω impedance test environment to better represent the probe card application**

Silver Plated Probes
(AC Applications)

- **Loss in a 50 Ω impedance environment**

Plated Probe Needle (plate thickness = 100 μin)	**Loss at 1 GHz (dB)**		**Loss at 2 GHz (dB)**	
Tungsten	***Nickel Plated***	***Silver Plated***	***Nickel Plated***	***Silver Plated***
5	0.8	0.4	1.1	0.5
6	0.6	0.3	0.9	0.4
7	0.5	0.3	0.8	0.4
Tungsten-Rhenium				
5	0.8	0.4	1.2	0.5
6	0.7	0.3	1.0	0.4
7	0.6	0.3	0.8	0.4

Silver Plated Probes
(AC Applications)

- **Loss in a 100 Ω impedance environment**
  - **Probe material and plating have less of an effect on the bandwidth than inductance**
  - **The best way to increase bandwidth is to reduce probe needle inductance**
  - **Reductions in probe length have a greater effect on induction than increases in probe diameter**

- **Some needle arrangements within a probe card approximate two-wire or co-planar transmission line configurations**

- **If the impedance environment for the probes is less than 100 Ω, the silver plating may reduce signal loss**

What does the well-dressed probe wear to a testing?

Probe Needle "Solutions"

- **Silver Plated Probes**
  - ♦ Reduction in probe resistivity
  - ♦ Improved current carrying ability
  - ♦ Limited high frequency benefits

- **Insulated Probes (TIP-M™)**
  - ♦ Dielectric coating on probe needles
  - ♦ Improved isolation
  - ♦ First step in the development of a shielded probe needle

- **N-TIP™ Plated Probes**
  - ♦ Greater tip hardness
  - ♦ Lower contact resistance
  - ♦ Prolonged service life

TIP-M™
(Thermoset Insulating Polymeric Material)

- **DUT requirements (i.e., small pitches and high pin counts) reduce signal isolation between probe needles**
- **Probe card leakage performance and signal integrity are affected**
- **Leakage current can flow between probes within the epoxy ring of a probe card**
- **A reduction in the leakage current between probe needles may be accomplished with improved signal isolation**

15

TIP-M™

PROPERTY	TIP-M™
Physical: Appearance of 0.1 to 0.5 mil coating Solderability	 Light to Dark Amber Removable with Solder Iron
Mechanical: Bond Strength - 2 mil thickness at 25^{o}C Durometer Hardness (ASTM D2240)	 43 lbs Shore A92
Electrical: Dielectric Strength (ASTM D149) Volume Resistivity (ASTM D257) Dielectric Constant (ASTM D150)	 3,100 volts/in > 10^{15} Ω-cm 1 MHz = 3.2
Thermal: Degradation Temperature	 > 200^{o}C
Solvent Resistance (2 hour immersion): Acetone and IPA	 Excellent

16

TIP-M™

- **TIP-M™ provides an appropriate substrate onto which a highly conductive layer can be added**

- **A "shielded" probe needle is obtained by application of a conductive layer to the insulated probe needle**

- **Shielded tungsten, tungsten-rhenium, and beryllium-copper probe needles are in the final phases of development**

What does the well-dressed probe wear to a testing?

Probe Needle Wear and Service Life

- **Tungsten (W) versus Tungsten-Rhenium (WRe) Probes**
  - **The addition of Re results in alloy with**
    - **More refined microstructure**
    - **Improved hardness and wear characteristics**
    - **Increased ductility**
    - **Greater yield strength**

- **Wear resistance and contact resistance stability of WRe probes are attributable to increased hardness and refined microstructure**

Probe Needle Wear and Service Life

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
Vicker's Hardness (100 gm load) (kg/mm^2)	665 – 738	745 – 877	288 – 325

Probe Needle Wear and Service Life

- **Contact Resistance during Test**
  - **Metallized or "Setup" Wafer**
    - **Aluminum oxide on contact pads**
    - **Adhesive interactions at the probe-pad interface**
    - **"Self cleaning" with sufficient scrub**
    - **Increased film resistance**
  - **Production Wafer**
    - **Residues from IC production processes**
    - **Adsorbtion of airborne contaminants on contact pad**
    - **Adherent probe tip contaminants**
    - **Significant increase in contact resistance**

Probe Needle "Solutions"

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- **Insulated Probes (TIP-M^{TM})**
  - Dielectric coating on probe needles
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  - Greater tip hardness
  - Lower contact resistance
  - Prolonged service life

N-TIP™
(The "Noble" Probe Needle Tip)

- **N-TIP ™ Plated Probe Tips**
  - **Advantages**
    - **Reduced adhesion between probe tip and contact pad materials**
    - **Excellent oxidation resistance**
    - **Low contact resistance**
    - **Extremely high hardness, i.e., enhanced wear and abrasion resistance**
    - **May prolong the service life of "softer" probe needle materials**
  - **Drawback**
    - **Abrasive cleaning will remove the material**
    - **Production issues**

23

N-TIP™
(The "Noble" Probe Needle Tip)

PROPERTIES	W	WRe	BeCu	N-TIP™ Material
Resistivity (μΩ-cm)	5.5 to 5.9	9.2 to 10.1	6.1 to 7.9	4.2 to 8.4
Knoop Hardness (kg/mm^2)	705 to 810	780 to 875	300 to 350	750 to 1000

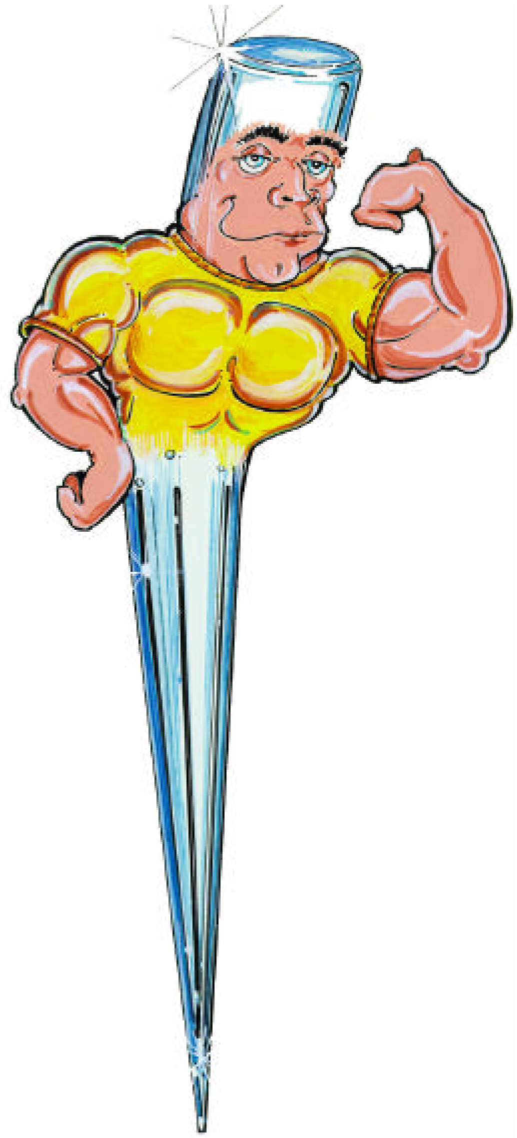
24

N-TIP™
(The "Noble" Probe Needle Tip)

- **Wear Life Experiment**
  - **Probe card built by MicroProbe, Inc.**
    - **"Standard" tungsten and tungsten-rhenium probe needles**
    - **Tungsten and tungsten-rhenium probe needles with N-TIP ™ plating**
  - **Touchdown testing performed on an aluminized wafer**
    - **Effects on contact resistance were evaluated**
    - **Probe tip metrology was used to quantify differences in wear characteristics**
  - **Results**
    - **No significant benefits for tungsten-rhenium**
    - **There was an obvious advantage for N-TIP™ tungsten vs. standard tungsten**
    - **There may be applications for N-TIP™ on softer probe materials and in vertical probing**

25

What does the well-dressed probe wear to a testing?



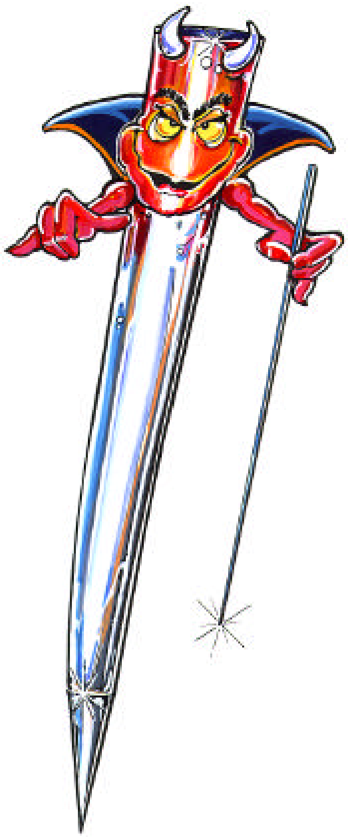
Summary

- "Standard" probe needle performance can be enhanced to address the challenges of wafer test

- Application of specialty coatings and plating materials can result in:
  - Improved electrical properties
  - Reduced signal loss
  - Extended service life

In 1997, APS dispelled the myth . . .

Whatever goes wrong, the probe needle did it!



In 1998, when it all goes right . . .

THE PROBE NEEDLE

<u>DID</u> DO IT!

29

Acknowledgments

- GigaTest Labs, Inc., Cupertino, CA
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- Probe and Test, Inc., Santa Clara, CA

30

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31