LEAD-FREE ELECTROLESS NICKEL FOR ENIG

Restriction of Hazardous Substances Directive (RoHS)

- Restricts the use of the following metals
  - Lead
  - Cadmium
  - Hexavalent Chromium
  - Mercury
- Restricts allowable levels in the Nickel Deposit to Less than 0.1 % by Weight lead and 0.01 % by weight cadmium
- Mandates Compliance by July 1, 2006
- Many Customers Want to be Fully Compliant Well in Advance of This Deadline.

Typical Lead Content of Nickel Deposited From ENIG Systems

- Normal EN
  - 0.073 % RoHS COMPLIANT
- Modified EN
  - 0.036 % RoHS COMPLIANT
- Lead free EN
  - 0 % RoHS COMPLIANT
    ELV COMPLIANT

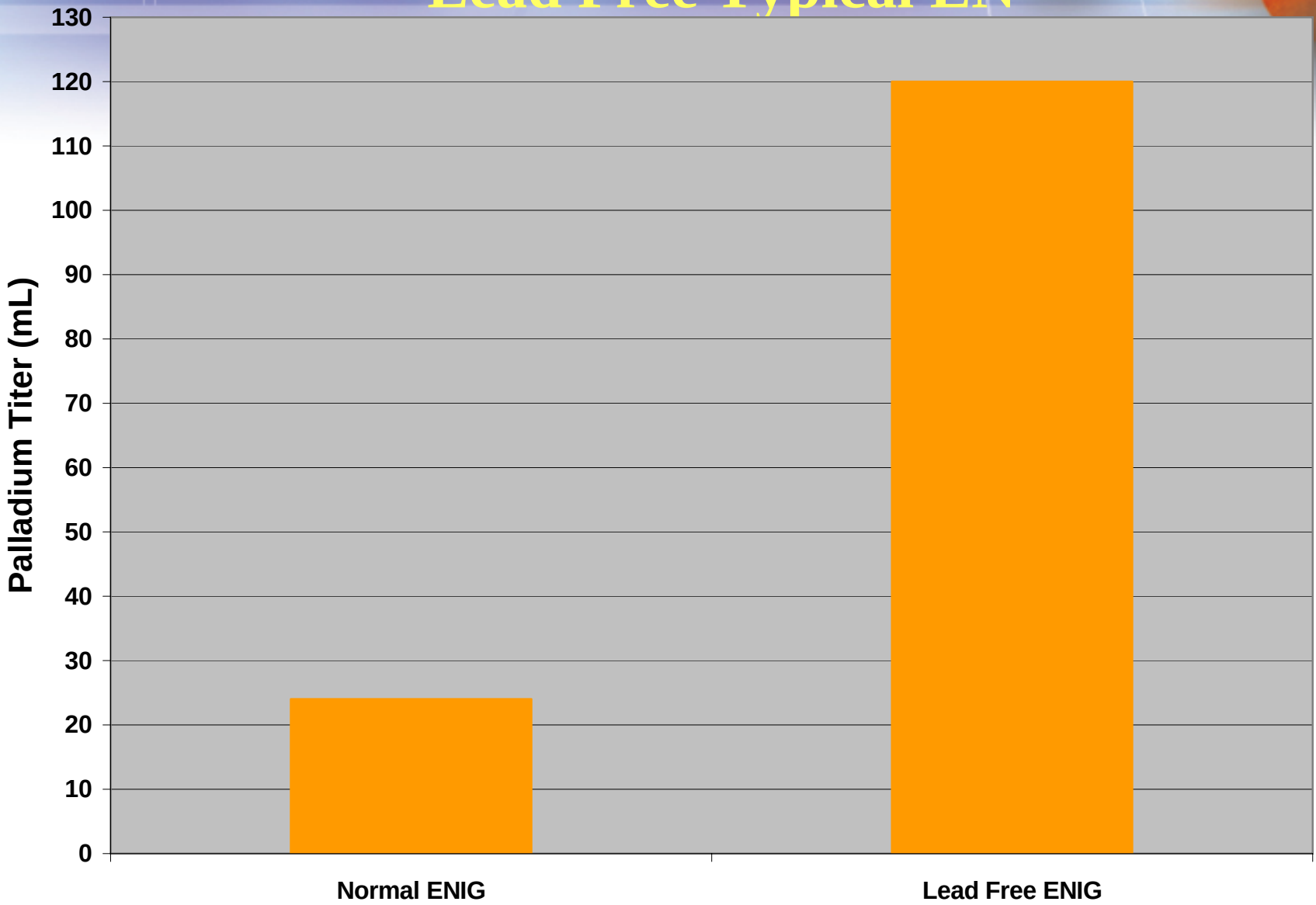
Comparison ENIG Electroless Nickel Baths

Typical EN	Modified EN	Lead free
Nickel Sulfate	Nickel Sulfate	Nickel Sulfate
Sodium Hypo	Sodium Hypo	Sodium Hypo
Organic Acids	Organic Acids	Organic Acids
pH Adjustor	pH Adjustor	pH Adjustor
Sulfur Stabilizers	Sulfur Stabilizers	Sulfur Stabilizers
Lead Salt	Lead Salt	Metal stabilizer
Cadmium Salt		

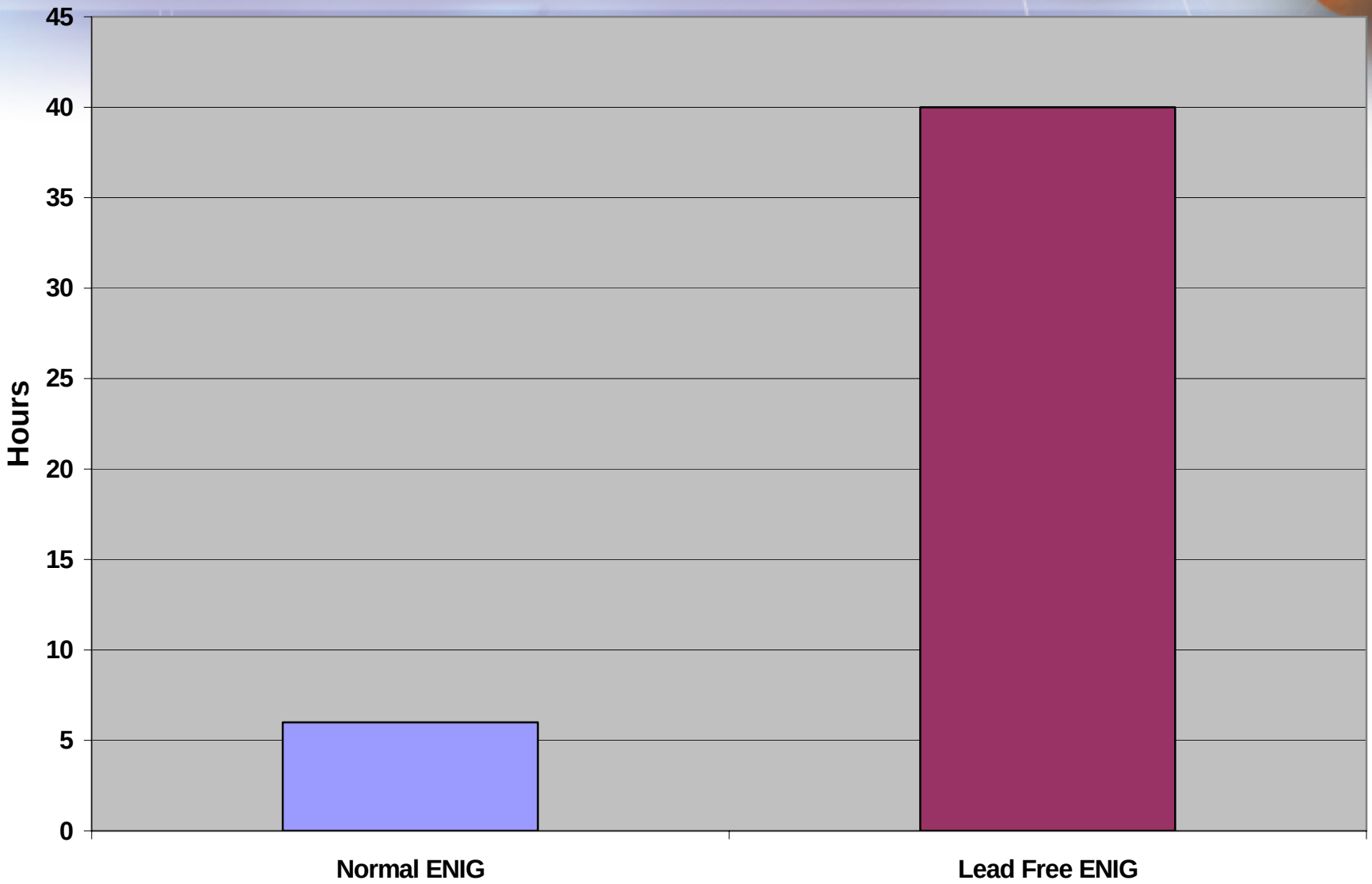
Technical Advantages to Lead-Free Electroless Nickel

- Improves bath stability, lowers cost
- Eliminates much of black nickel problem
  - Caused by interaction of lead and sulfur stabilizers
  - Highlighted by gold bath interaction
- Minimizes Edge Pull-back
  - Lead and Cadmium are the main cause of edge pull-back
- Increases Bath life
  - Improved stability allows for >5 MTO

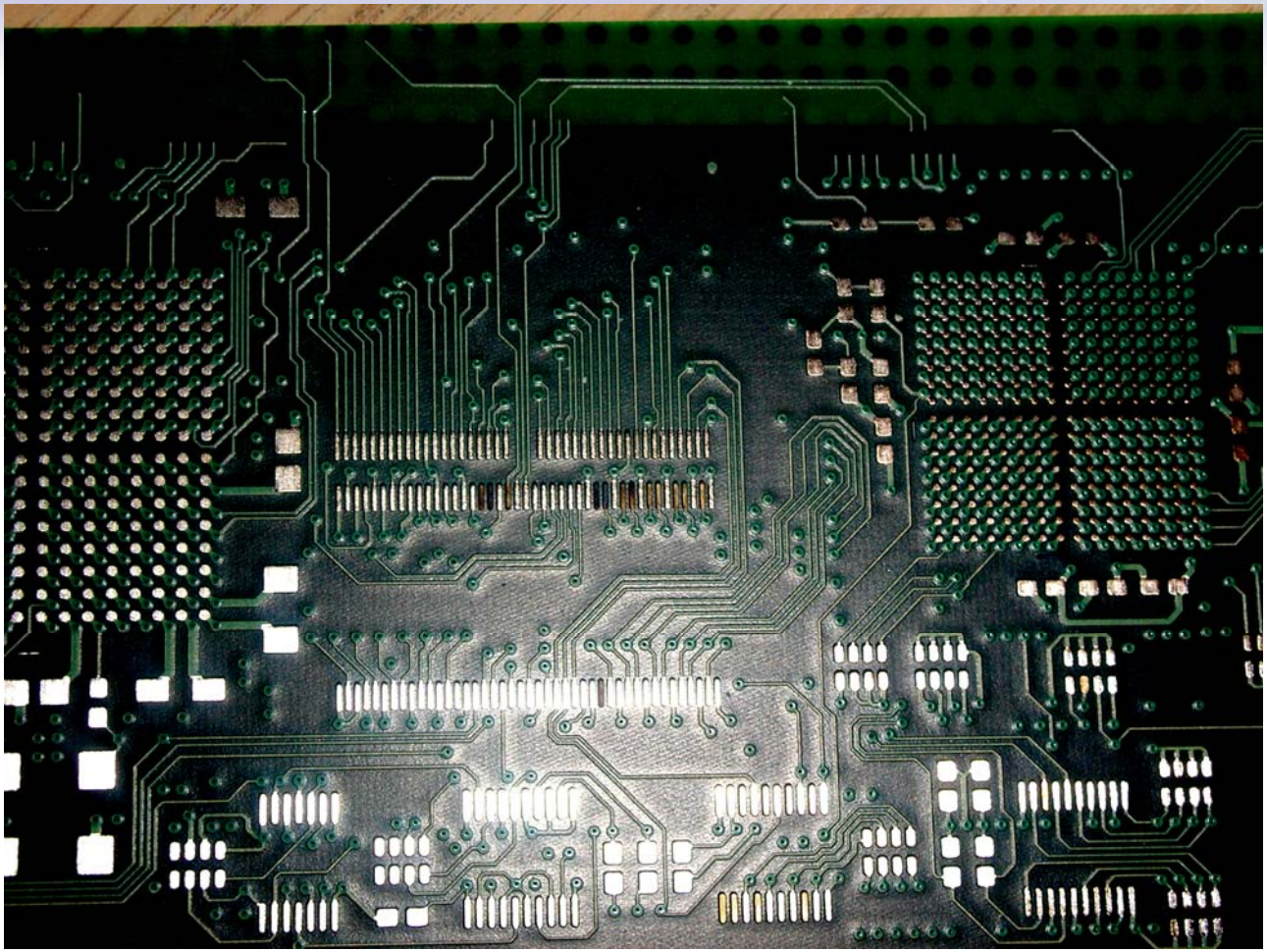
Comparison of Palladium Titers
Lead Free Typical EN



Standing Stability in hours for Normal ENIG and Lead Free Nickel at Operating Temperatures



Black Nickel



Characteristics of Black EN

- **B**lack Color On Surface Of Nickel
  - Oxidized nickel due in part to gold bath “hyper-corrosion” of a compromised nickel deposit.
- Thin Deposit
  - Thicknesses generally range from 30 to 50 micro inches but can be higher**.**
- Weak Solderability Characteristics.
  - Characterized by very poor intermetallic formation.
  - Highlighted by inferior bond strengths.

Contributing Factors to Black EN Formation

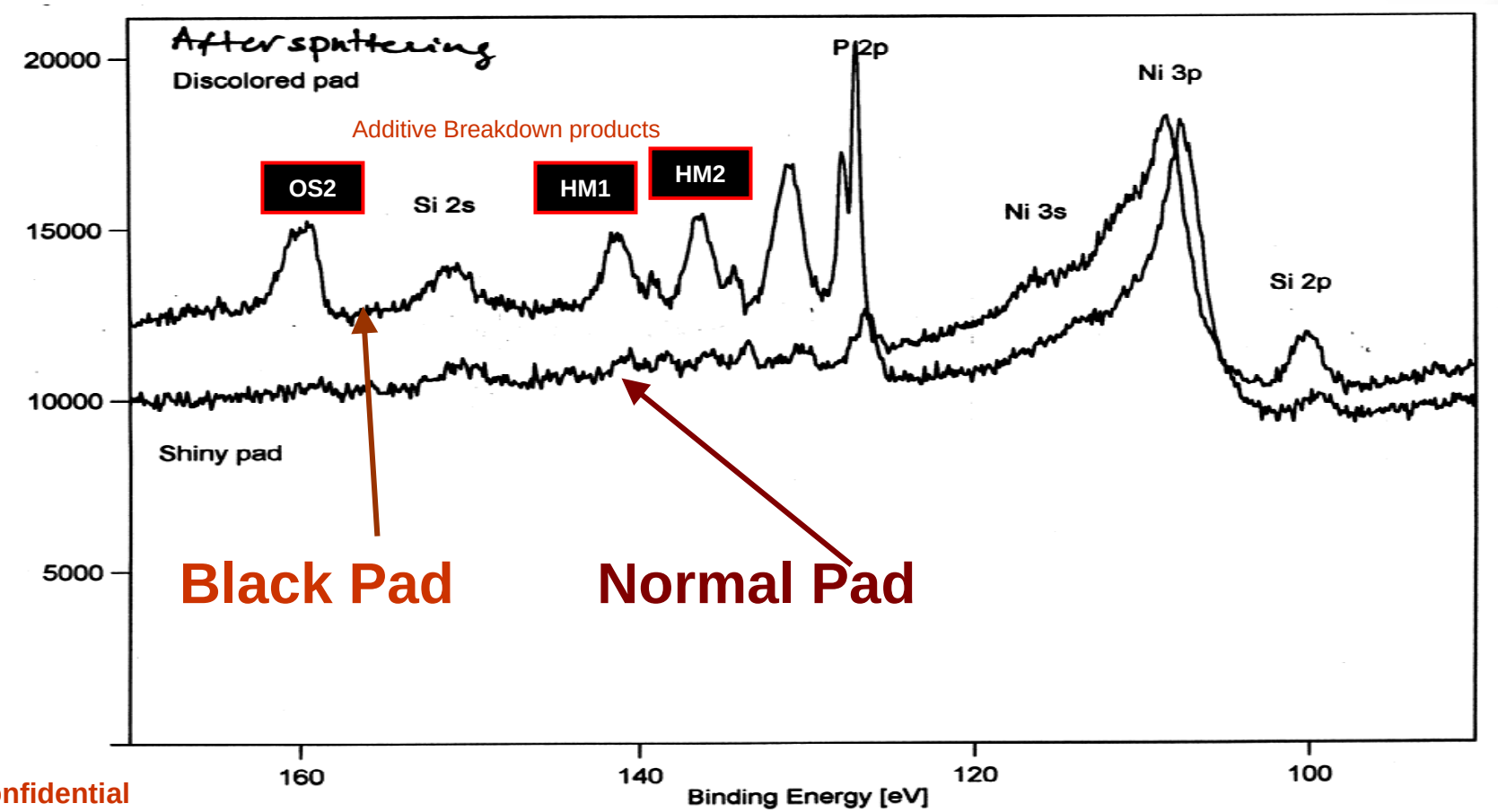
- Type of sulfur stabilizer used
  - All mid-phosphorous EN Baths contain sulfur additives
  - There are essentially 3 groups of sulfur stabilizers
  - 2 of these groups are “bad actors”
- Use of Lead as the metal stabilizer
  - In conjunction with a sulfur additive from a “bad acting” group
  - Facilitates co-deposition of stabilizers and their by-products

How To Avoid Black EN

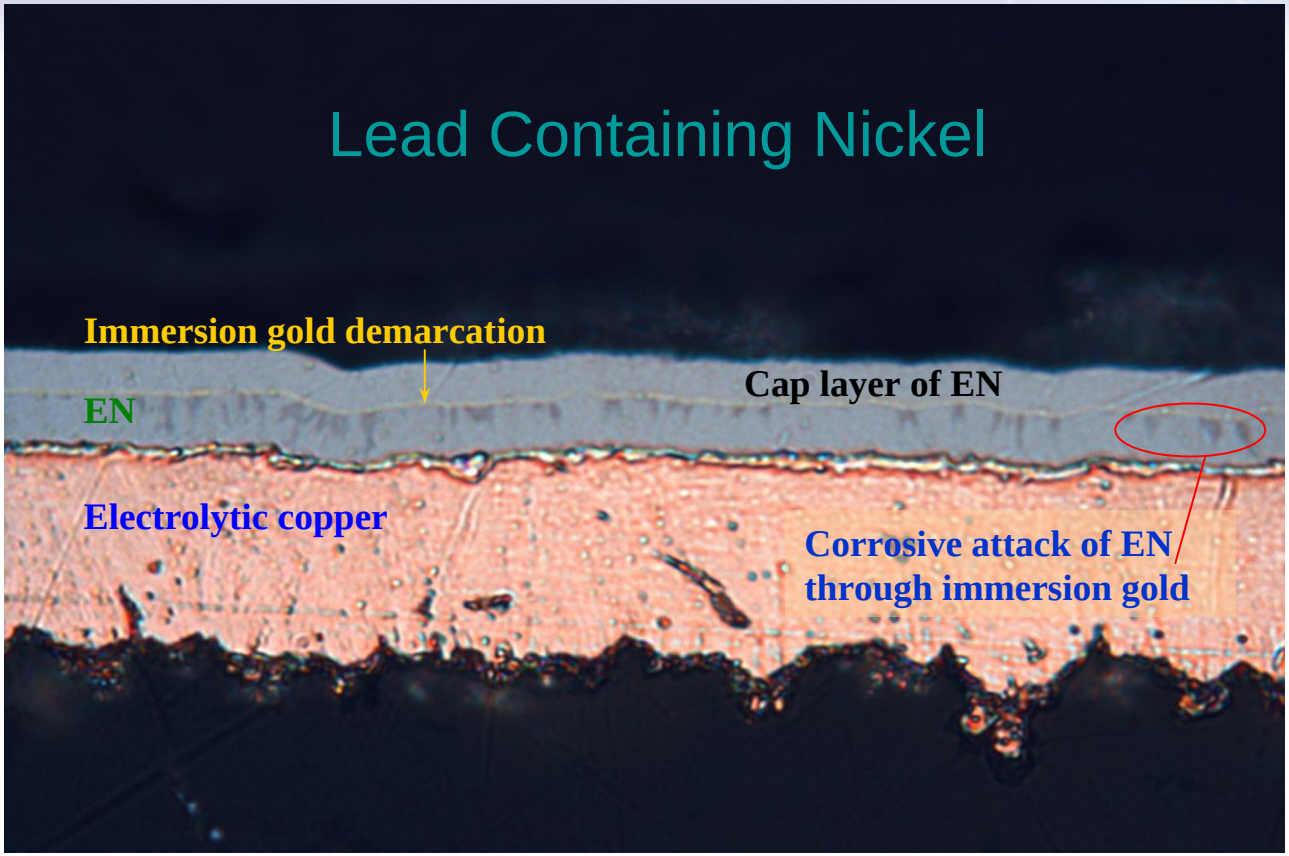
- Proper Choice of Sulfur Stabilizers
  - Prevent/slow degradation and co-deposition
- Lead-Free Electroless Nickel
  - Eliminate lead/sulfur interactions
- Engineer Proper Solution Movement
  - Proper Tank Configuration
  - Laminar flow

Surface Analysis of Black Vs. Normal Pad

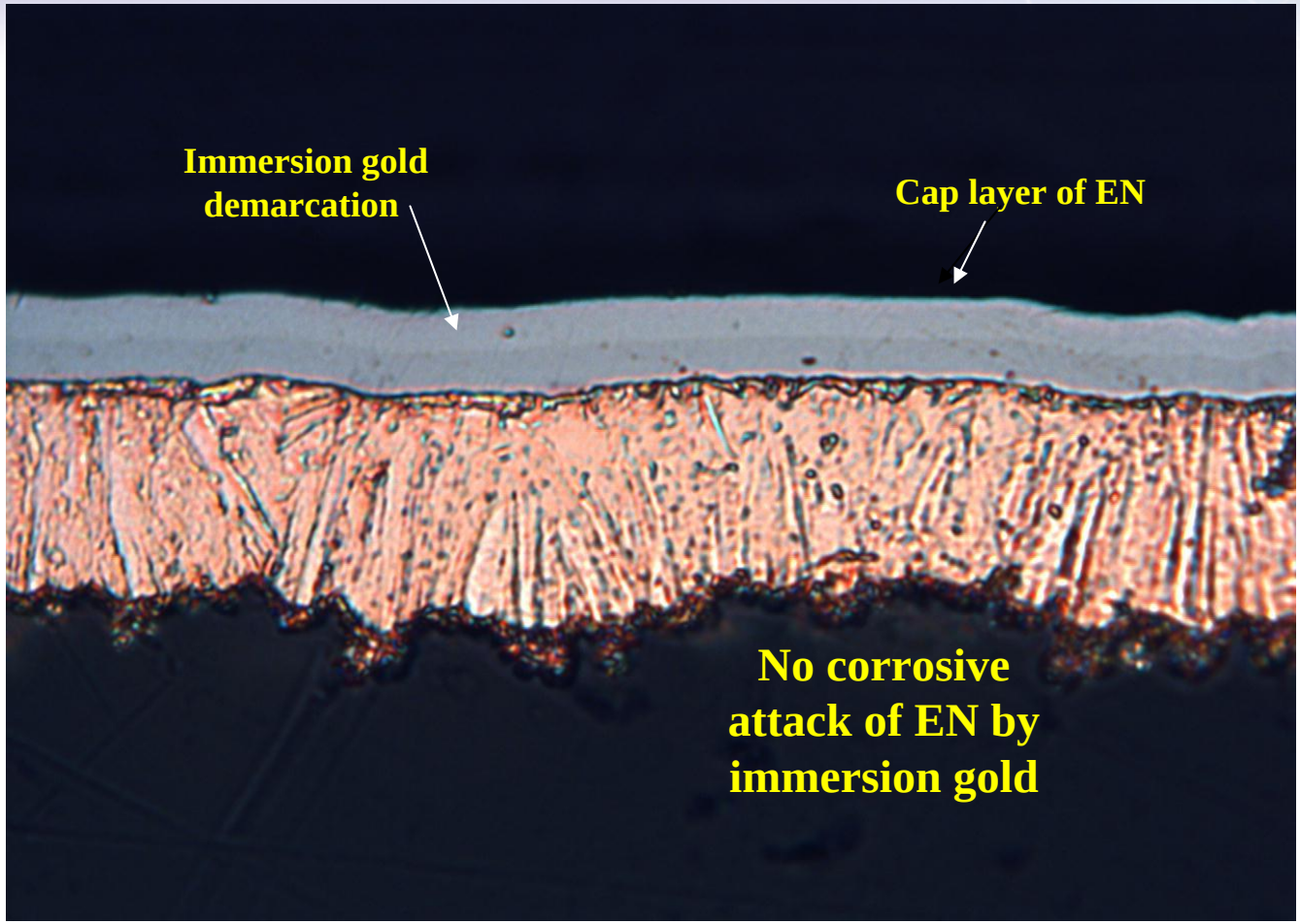
X-Ray Photo-Electron Spectroscopy



Corrosion Of Nickel From Gold Bath



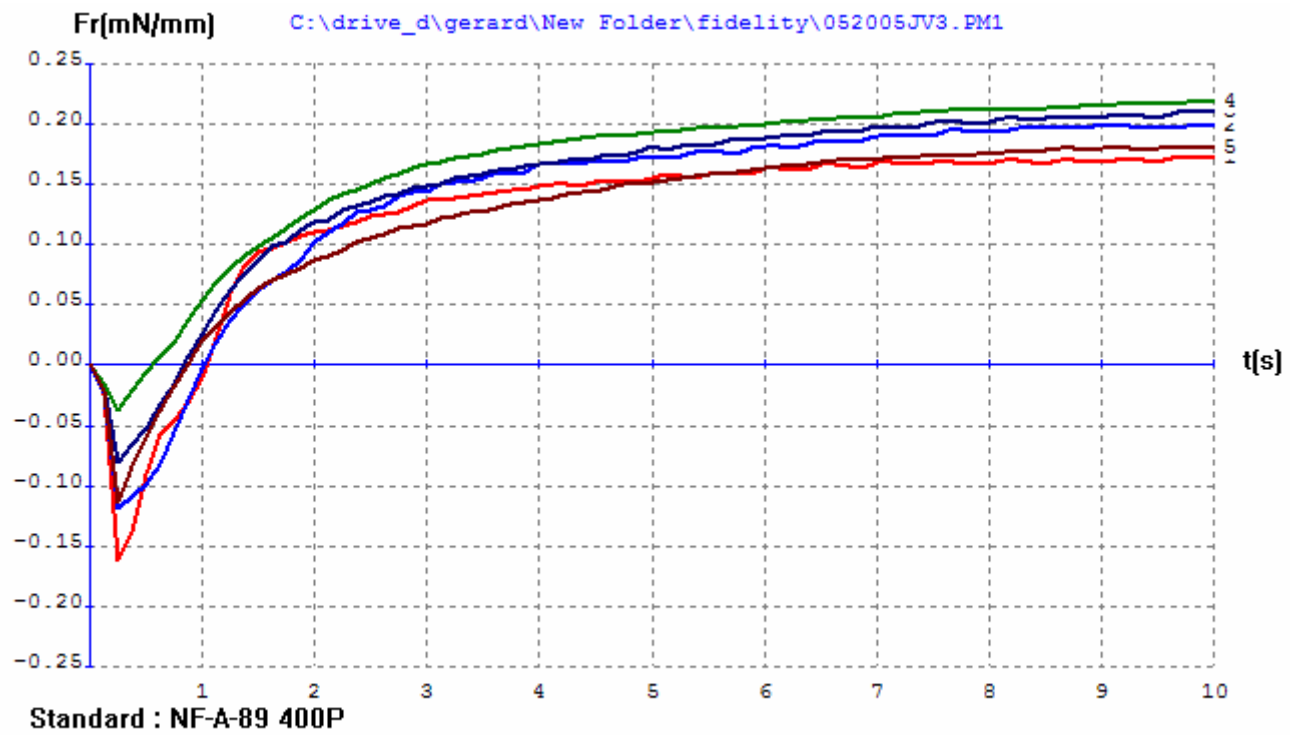
Lead Free Nickel Corrosion Resistance



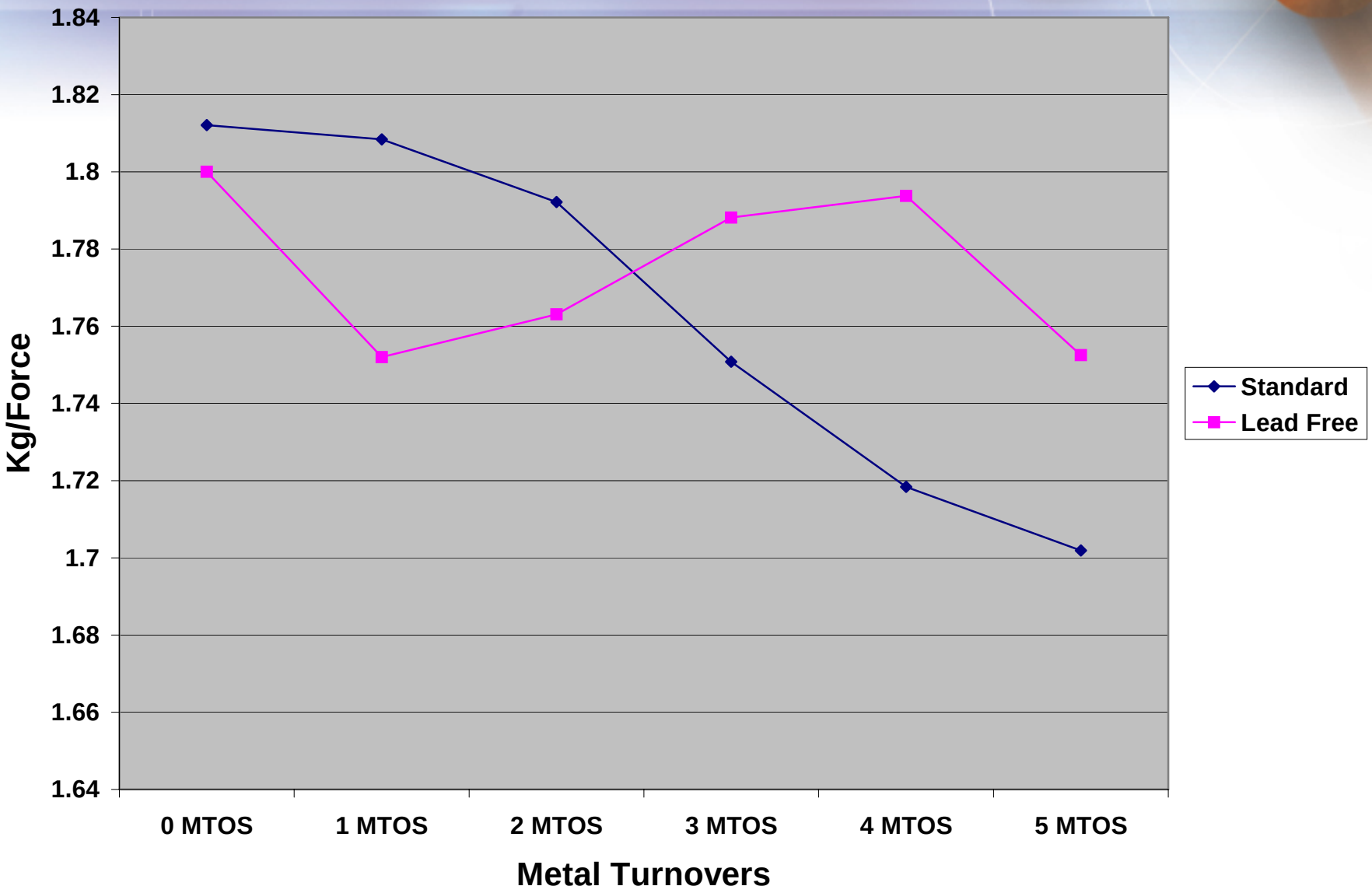
Process Control Methods

- Nickel & Gold Deposit Thickness
  - X-Ray Florescence Spectroscopy
- Phosphorous Content Of Nickel Deposit
  - EDX (9-10%)
- Solderability
  - Wetting Force Via Wetting Balance
- Bond Strength
  - Ball Shear Testing

Wetting Force for Lead Free Deposit at 5 MTO



Ball Shear Data: Standard vs. Lead Free



SUMMARY FOR LEAD FREE ENIG

- Environmentally friendly
  - Exceeds new regulatory restrictions (RoHS, ELV)
- More stable manufacturing process
  - Reduces running costs
  - Reduces assembly failures
- Plug-in for current ENIG lines
  - No extensive re-training for manufacturing personnel