ARCHIVE 2010

INNOVATIVE SOCKET INGREDIENTS

Thermal Characterization Issues and Potential Techniques for Test
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—Intel Corporation

Using Clad Alloys to Make High Temperature Burn in and Test Sockets
Jimmy L. Johnson, Robert Bertin—Brush Wellman Inc.

Thermal Characterization Issues and Potential Techniques for Test

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Rafael Quintanilla, Jaime A. Sanchez, James C. Shipley
Intel Corporation

2010 BiTS Workshop
March 7 - 10, 2010

Agenda

- Importance of Thermals in Test
- Assembling the Thermal System Puzzle
- Automatic Temperature Control
- Optimization Need and Findings
- Summary

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Importance of Thermals in Test

- Thermals at test
  - Critical parameter at all Tests
  - Product specification compliance
  - Yield ↔ Revenue
- Test Challenges by Navid Shahriari (Intel Director of STTD, Distinguished Speaker – BiTS 2009)
  - Silicon Scaling results in higher thermal density
  - Bare die brings major thermal control challenges: Fast Transients and Spatial Uniformity
  - Better Test thermal interface materials are needed

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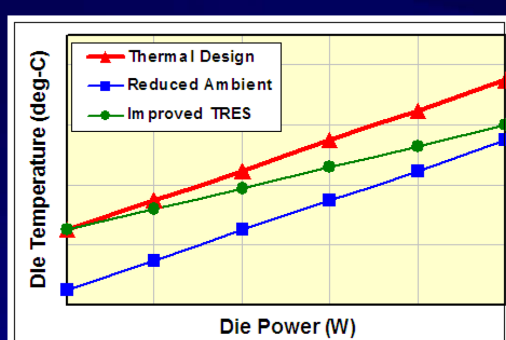
Thermal System Design: First Piece of Puzzle

- Steady State Power Removal
  - Some of the knobs
  - Focus of most work



- Good Starting Point

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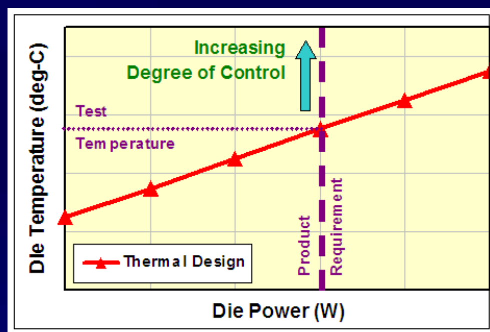
Thermal System Design: Missing Pieces of Puzzle

- Multi-core Processors



No control

- Transient are very important
  - Product Requirement
  - Temperature Setpoint
  - Saturation, Degree of Control

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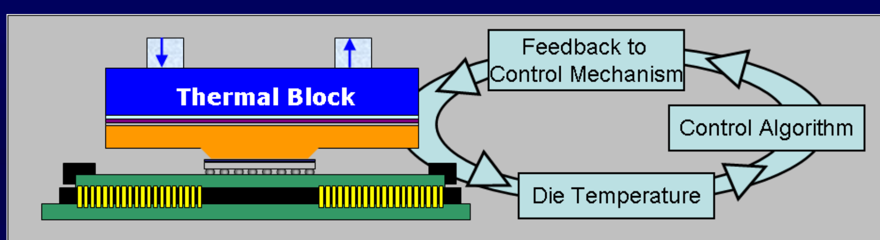
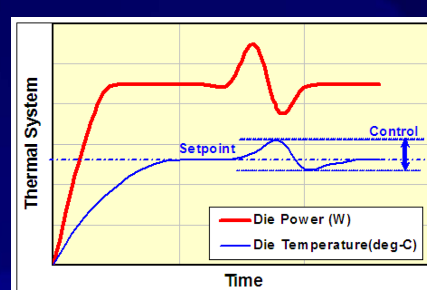
Automatic Thermal Control



- Time to reach Setpoint
- Response to System Changes



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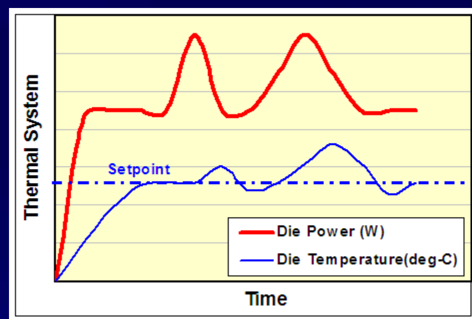
Automatic Temperature Control

- Understand control expectations
  - Power and Temperature



- Understand what can be controlled
  - System time constants
  - Certain power transitions cannot be controlled

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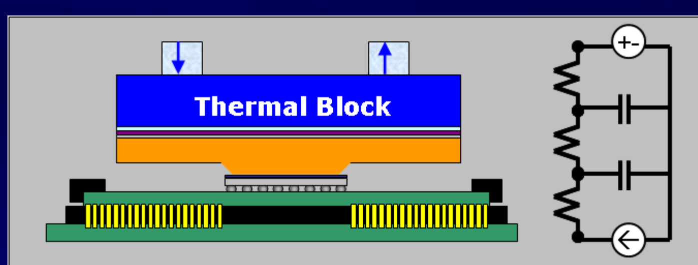
System Variability

- Dissect each component for Optimization
  - Need experiments or modeling efforts



- Finding: TIMs are usually bottlenecks in continuous optimization
  - TIMs should be integral part of optimization studies

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Thermal Interface Materials

- B.C. are very different from OEM application
- Metrics of a desirable TIM for Test
  - Thermal performance under reasonable load
  - Extreme hot and cold temperatures
  - Gimbaling
- Other VERY important factors (Metallic/Polymer)
  - Compensate for package warpage
  - Mechanical properties: Durable
  - Residue on die
  - Reliability

- Above are also system dependent

Thermal Interface Materials

- Basic TIM evaluation
  - Resistance with pressure
  - Steady state power removal
  - Temp and humidity chambers
- Additional TIM evaluations required for Test (Gap)
  - Spatial Uniformity, Repeatability
  - Temperature Cycling } *Combined*
  - Mechanical Cycling } *Combined*
  - Transients

Summary

- Thermal Characterization
  - What is present? → Max power removal
  - What is missing? → Transient and Control
- Automatic Temperature Control
  - Product requirement and setpoint range (hot & cold)
  - Understand and Optimize in Transient Domain
  - Robust against system input change / variability
- Thermal Interface Materials
  - Bottleneck during Optimization
  - Improvement in characterization needed for Test

Need to start assessing the "Entire" Thermal System in a Transient Domain

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Using Clad Alloys to Make High Temperature Burn in and Test Sockets

Jim Johnson and Robert Bertin
Brush Wellman Alloy Products

2010 BiTS Workshop
March 7 - 10, 2010

Presentation Outline

- Research driving forces
- BEM HPAs used in BiTS applications and their properties
- Mathematical determination of clad metal composite properties
- Cladding process
- Clad metal performance and property evaluation
- Conclusions
- Next steps

03/2010 Using Clad Alloys to Make High Temperature Burn in and Test Sockets 2

Research Driving Forces

- 2009 BiTS Workshop
- Processor higher pin count
- Finer pitch
- Lower package profiles
- Higher current density
- Higher ambient temperatures during burn-in

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Research Driving Forces

Type	Feature	Metric	2003	2005	2007	2009	2014	2019	Barrier
Test Sockets	Packages	Types	SO, LGA, BGA, mBGA, QFN, DFN, CSP, etc.						
	Contact Matl.	Alloy	Cu Alloy [brass, BeCu]					Same/New	None
	Max. # Contacts	#	1,000	1,000	2,000	3,000	5,000	10,000	10,000
	Max. # Cavities	#	1	1	2	4	8	16	64
	Min. Pitch	mm	0.65	0.4	0.3	0.3	0.25	0.2	100mm
	Max. Edge Rate	GHz	3	6	12	24	40	≥ 10Gbps	20Gbps
	Inductance	nH	1	1	0.4	0.3	0.2	0.1	0.1
Burn-In Sockets	Contact Matl.	Alloy	Cu Alloy [BeCu]					Same/New	None
	Max # Contacts	#	1,000	5,000	10,000	10,000	10,000	10,000	Pkg Size
	Max. # Cavities	#	16	32	32	64	64	64	64
	Min. Pitch	mm	1	0.8	0.65	0.5	0.3	≤0.3mm	0.2
	Max. Temp.	°C	150	150	150	175	250	250	250
	Housing	Material	Thermoplastic					250°C	250

Source: Bishop & Associates Inc., Post Recession Outlook Electronics Industry and Connector Road Map 2009-2019

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BEM HPAs Used in BiTS Applications and Their Properties

- Alloy 25 (C17200)
  - Be 1.8 to 2.00%
  - Co + Ni 0.20% min
- Alloy 390 (C17460)
  - Be 0.15 to 0.50%
  - Ni 1.0 to 1.4%
- Alloy 390E (C17500)
  - Be 0.40 to 0.70%
  - Co 2.4 to 2.7%
- Alloy 3 (C17510)
  - Be 1.8 to 2.00%
  - Co + Ni 0.20% min
- Alloy 360 (NO3360)
  - Be 1.85 to 2.05%
  - Ti 0.4 to 0.6%

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BEM HPAs Commonly Used in BiTS Applications and Their Properties

Alloy	2% Offset Yield Strength ksi (MPa)	Modulus of Elasticity Mpsi(GPa)	Electrical Conductivity %IACS	!000 Hr Stress Relaxation Resistance (% stress remaining)			*Formability 90° Bend R/t	
				100C	150C	200C	Long	Trans
25 HT	165-205 (1130-1420)	19 (131)	22-28	95	87	55	2.0	0.7
390 HT	135-153 (930-1055)	20 (138)	44 min	96	84	68	2.0	2.0
390E EHT	138 min (951 min)	20 (138)	42 min	96	84	68	2.0	2.5
3 HT	95-120 650-870	20 (138)	48-60	96	85	66	1.0	1.0
360 HT	230 min	28-30 (195-210)	6 min	100	100	100	0.8	1.5

* Note: Formability at thickness = 0.1 mm, Alloys 25 and 360 formability rating prior to heat treating

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BEM HPAs Commonly Used in BiTS Applications and Their Properties

- Alloy 360 has excellent stress relaxation resistance, has good formability, and very high strength, but the electrical conductivity is poor

Alloy	2% Offset Yield Strength ksi (MPa)	Modulus of Elasticity Mpsi(GPa)	Electrical Conductivity %IACS	!000Hr Stress Relaxation Resistance (% stress remaining)			*Formability 90° Bend R/t	
				100C	150C	200C	Long	Trans
360 HT	230 min	28-30 (195-210)	6 min	100	100	100	0.8	1.5

* Note: Formability at thickness = 0.1 mm, Alloys 25 and 360 formability rating prior to heat treating

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Mathematical Determination of Clad Metal Composite Properties

- If we could clad a higher conductivity alloy with Alloy 360 would the hybrid material provide a unique combination of properties?
- The properties of hybrid alloys can be predicted using simple equations, but first a decision regarding which alloys to use must be made.

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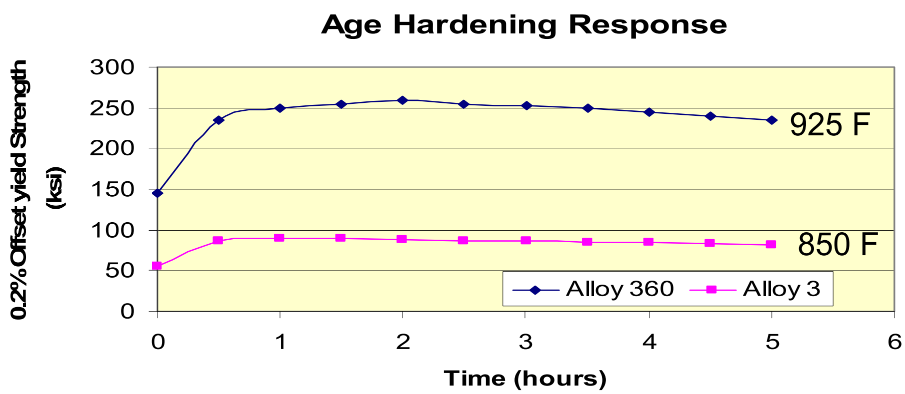
Mathematical Determination of Clad Metal Composite Properties



Alloys 3 and 360 have mutually compatible annealing and age hardening temperature ranges

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Mathematical Determination of Clad Metal Composite Properties

$$\rho = A / \sum_{n} A_n / \rho_n$$ **Eq 1**

Where ρ = resistivity of composite

A_n = area of each layer

A = Area of composite

ρ_n = resistivity of each layer

$$E = t^{-1} * \sum_{n} E_n * t_n$$ **Eq 3**

Where E = elastic modulus

E_n = elastic modulus of each layer

t_n = Volume fraction of each layer

t = thickness of composite

$$\sigma = 1 / \rho$$ **Eq 2**

Where σ = conductivity of the composite

$$S = \sum_{n} S_n * \alpha_n$$ **Eq 4**

Where S = 0.2% offset yield strength

S_n = yield strength of each layer

α = layer fraction of x-section

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Mathematical Determination of Clad Metal Composite Properties

	Material	Modulus (Mpsi)	Fraction of X-Section (%)	Yield Strength (ksi)	Conductivity (%IACS)	Resistivity Ohm-in
Top Layer	3	20.0	20%	110	45	1.509E-06
Middle Layer	360	30.0	60%	188	6	1.132E-05
Bottom Layer	3	20.0	20%	110	45	1.509E-06
Composite		26.0	100%	157	21.6	3.14E-06

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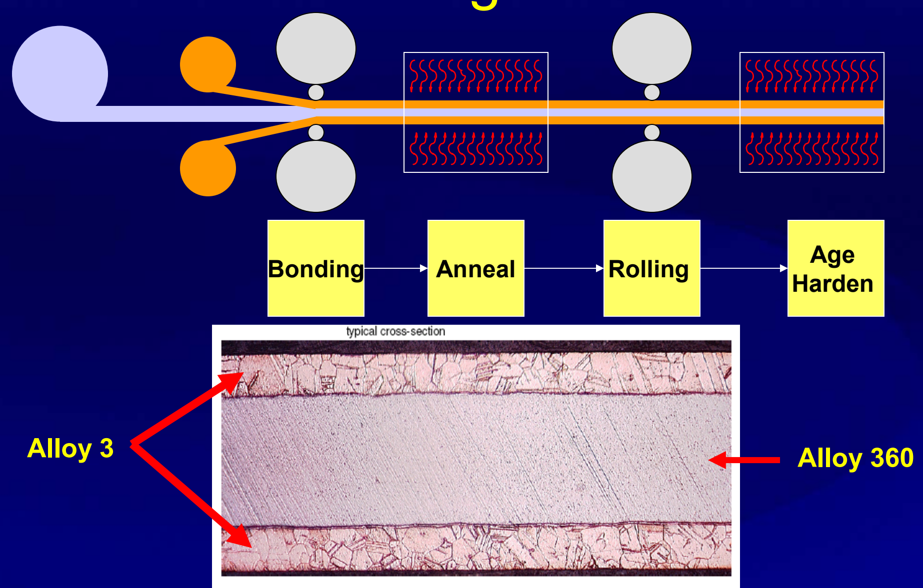
Cladding Process



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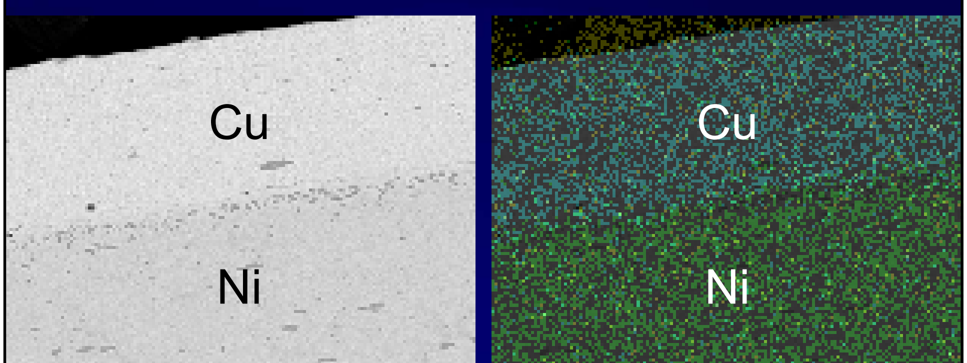
Clad Metal Performance and Property Evaluation

- Two samples were prepared and tested.
  - Sample A, was rolled to a final composite thickness of 0.004”
  - Sample B, was rolled to a final composite thickness of 0.010”
  - Both samples were given to customers for evaluation. Only part of the testing was completed in time for paper submission deadline.

Clad Metal Performance and Property Evaluation

Bond Integrity Analysis, using SEM



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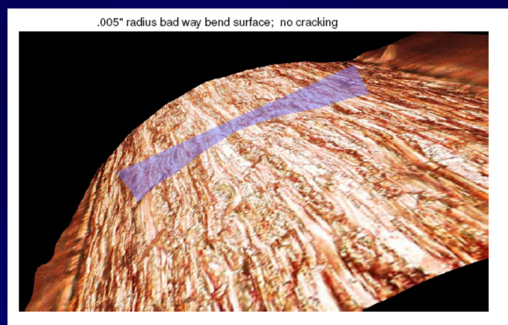
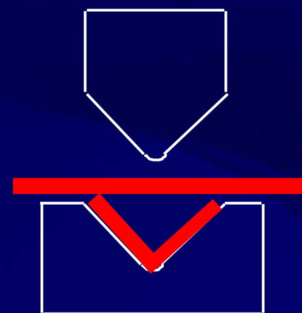
Clad Metal Performance and Property Evaluation



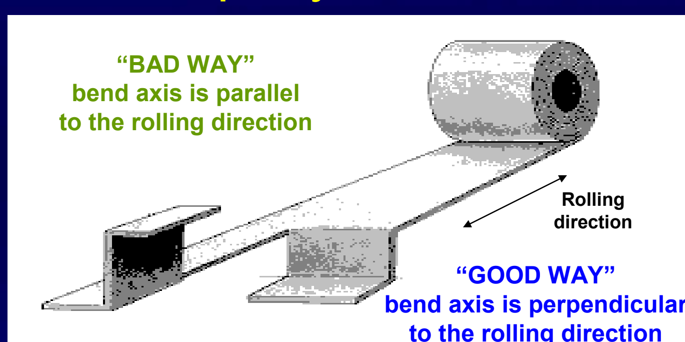
180 ° Bend Tested Sample



"Vee" block formability die

- Ratio of bend radius to thickness (R/t) 90 degree bend

Clad Metal Performance and Property Evaluation



Test Direction	R/t Ratio Sample A 180° R/t	Sample A 90° R/t	Sample B 180° R/t	Sample B 90° R/t
Transverse	1.2	0.5	1.6	0.5

*Bad Way Formability Measured After Heat Treating

Clad Metal Performance and Property Evaluation

Copper alloys use %IACS

- **%IACS = % of International Annealed Copper Standard conductivity**
- **Pure copper = 100%**
  (6.79×10^{-7} ohm-in)@ 20ºC
  (1.72×10^{-6} ohm-cm)@ 20ºC
  (1.72 µohm-cm)@ 20ºC

	Measured	
Predicted	Sample A	Sample B
21.6	21.0	23.1

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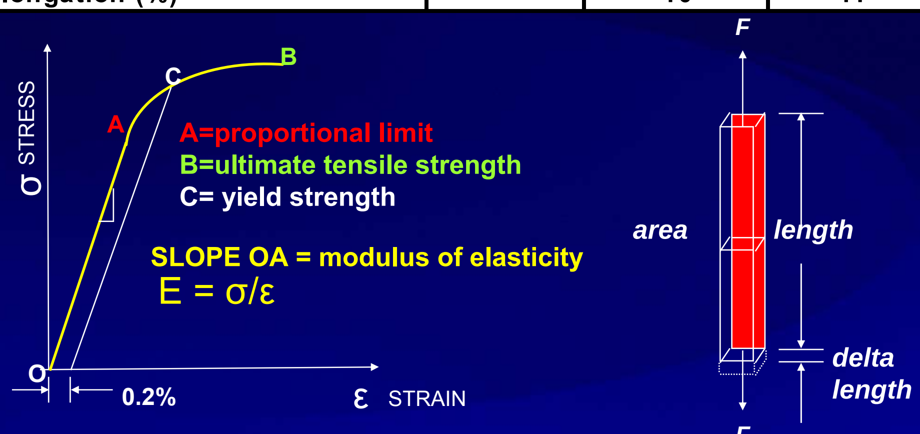
Clad Metal Performance and Property Evaluation

		Measured	
Property	Predicted	Sample A	Sample B
Yield Strength (ksi)	157	154	161
Ultimate Tensile Strength (ksi)		185	189
Elongation (%)		10	11



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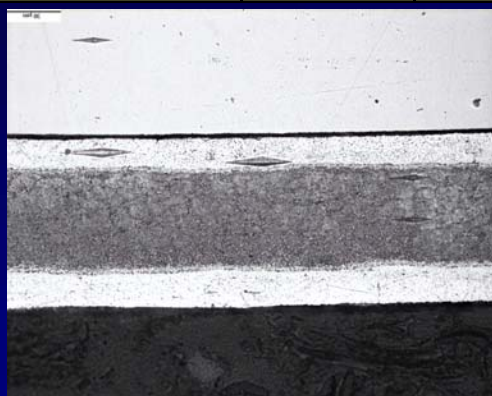
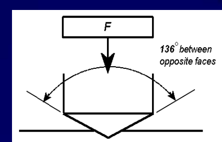
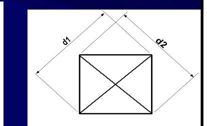
Clad Metal Performance & Property Evaluation

Hardness Distribution in HK @ 25 gm load				
Sample	As Rec - L	As Rec - T	1000Hr - L	1000 - T
Alloy 3	248.9	248.9	215.8	212.6
Interface	555.7	257.0	233.8	395.2
Ni Near Interface	592.6	514.2	522.1	522.1
Mid Ni Strip	555.7	502.7	530.2	573.7
extra pokes Alloy 3		257.0		192.3
extra pokes Alloy 3		232.6		155.6
extra pokes Alloy 3		254.3		210.5

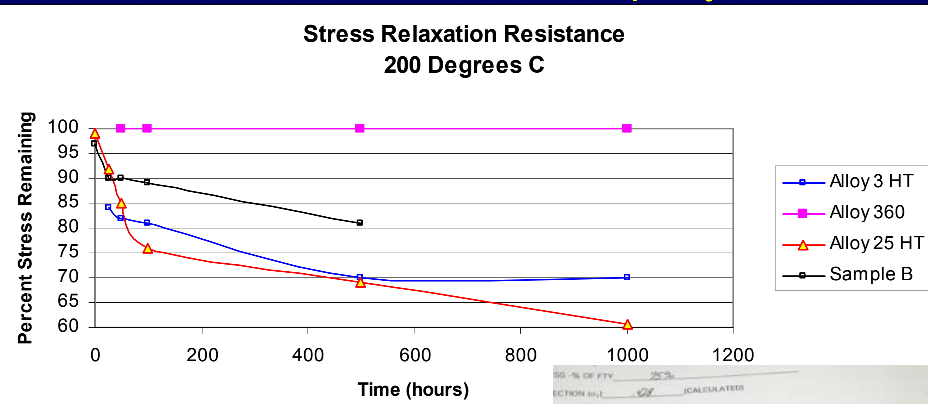






Alloy	Vickers Hardness		
	Sample A	Sample B	Peak H.T.
3	271	249	216-287
360	477	529	395-695

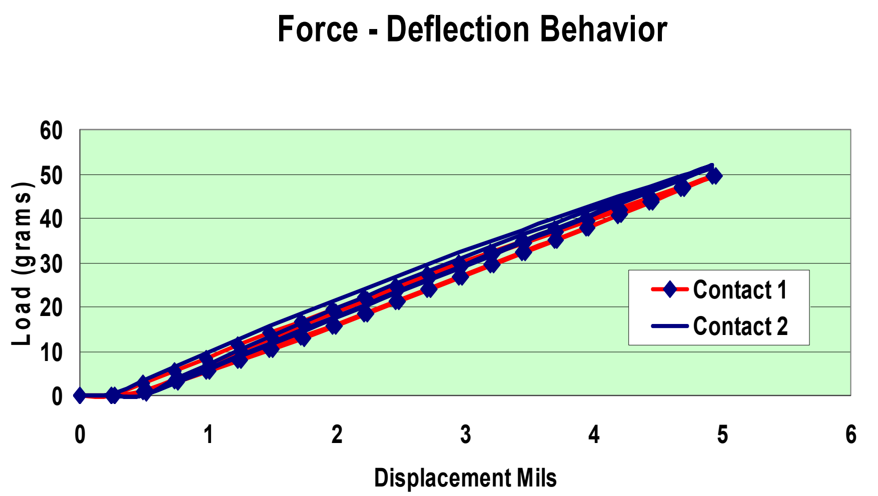
Clad Metal Performance and Property Evaluation



max surface stress, beam width, normal force, beam thickness, beam length

$$P = \frac{S_{max} w t^2}{6l}$$

Clad Metal Performance and Property Evaluation



Data Provided by Neoconix

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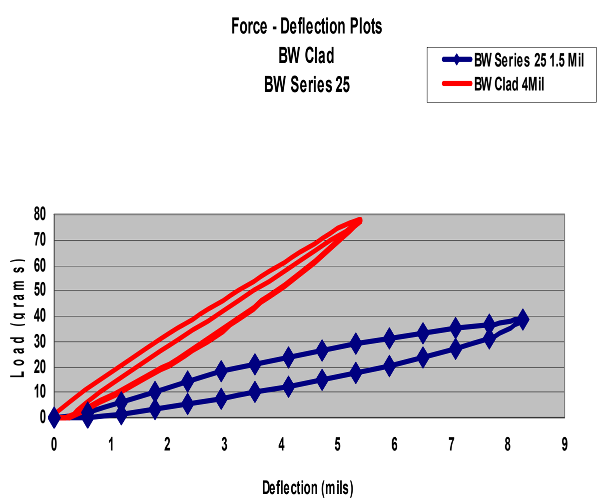
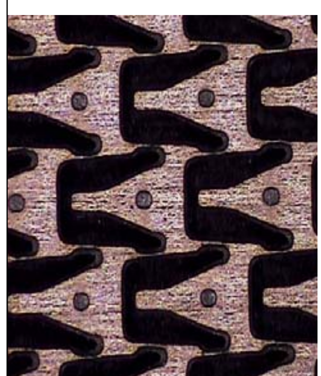
Clad Metal Performance and Property Evaluation





NCX PC BEAM

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Conclusions

- Mathematical predictions of clad metal properties correlated well with the empirically measured properties
- Clad metal can withstand extremely high temperatures
- Clad metal electrical conductivity similar to CuBe Alloy 25
- Clad metal formability is excellent in both rolled tempered and mill hardened conditions

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Next steps

- More field trials with customers in high temperature burn-in applications
- Try other combinations of materials and layer thickness to meet application requirements

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