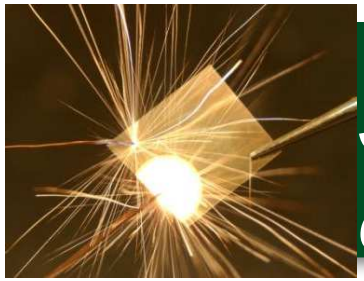

Jacques Matteau

Global Sales Manager

jmatteau@indium.com

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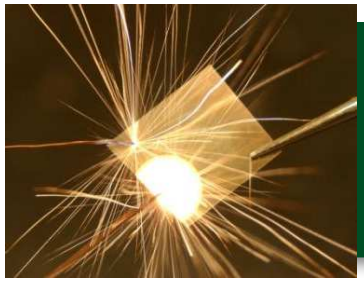
NanoBond® Assembly: A Rapid, Room Temperature Soldering Process

indium.us/F018

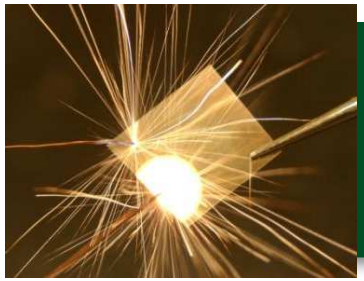
INDIUM CORPORATION®



Terminology – A few key terms…

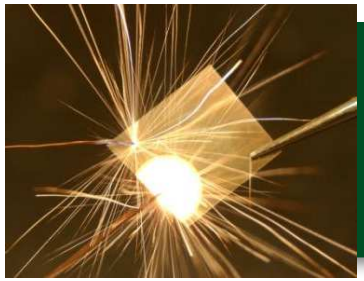
- **NanoFoil®** is the heat source **material** used to make the bond
- **NanoBond®** is the **process** of bonding materials using NanoFoil®
- **Plated NanoFoil®** is a **heat source** and a **bonding** material
  - NanoFoil can be electroplated - eg. with Tin, Gold-Tin or any solder

INDIUM CORPORATION



NanoFoil®

- Produced and fully supported by Indium Corporation
- NanoFoil® - new class of nano-engineered material, a completely self-contained exothermic chemical reaction
- Fabricated by vapor-depositing thousands of alternating nanoscale layers of Aluminum (Al) and Nickel (Ni).
- Activated by a small pulse of local energy from electrical, optical or thermal sources
- Foil reacts to precisely delivering localized heat at up to 1500°C in fractions (thousandths) of a second.

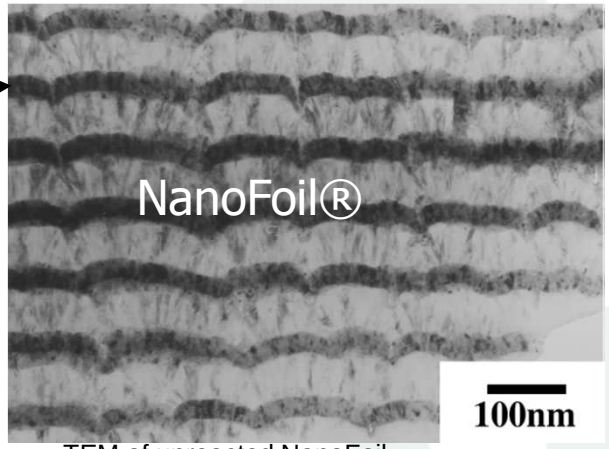


NanoFoil® Reaction

Before reaction

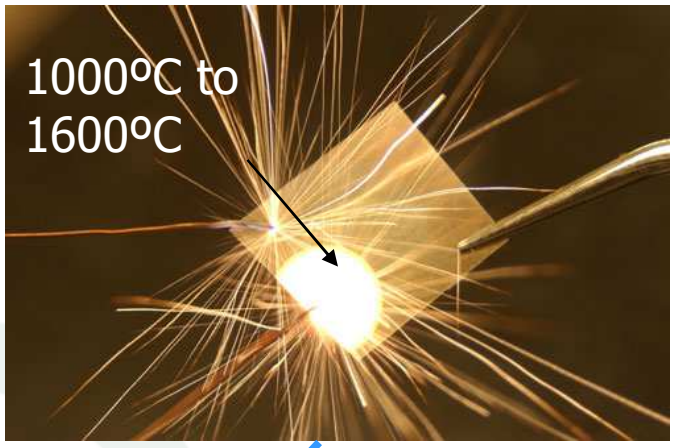
Ni

Al



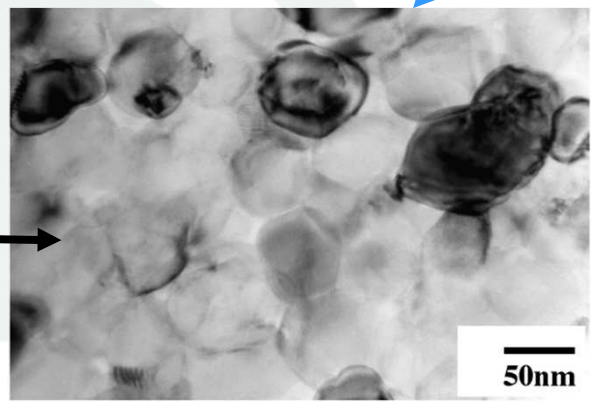
TEM of unreacted NanoFoil

During reaction



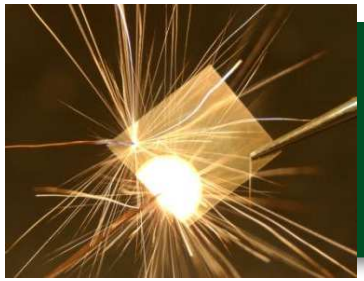
Final Product:

Al-Ni Intermetallic



TEM of reacted NanoFoil

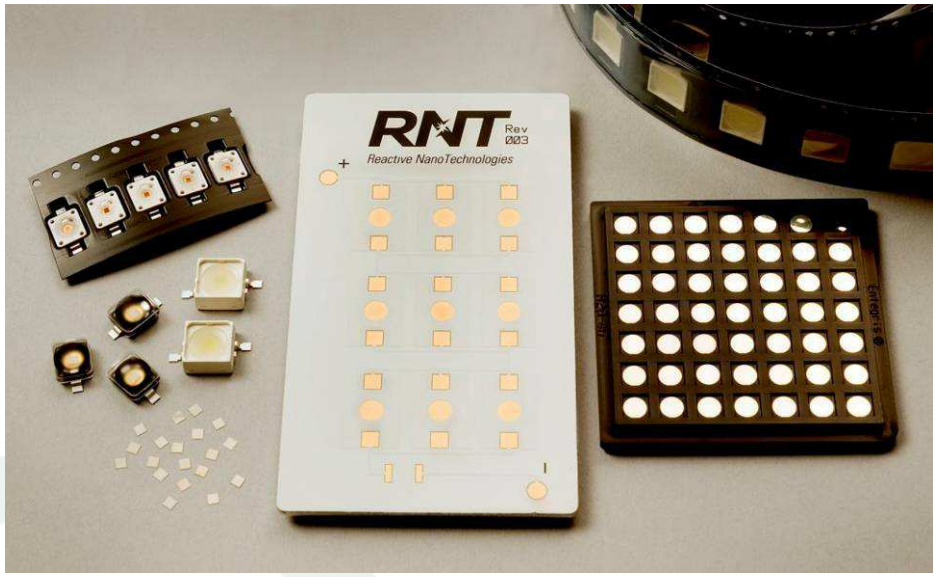
INDIUM CORPORATION®

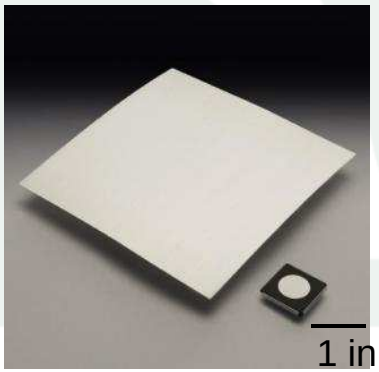


NanoFoil® Forms

- Largest Manufactured Piece: **43.5” x 9”**
- Smallest Produced Size: **.010”x .010”***
- Cutting Methods
  - Laser
  - Chemical Milling
  - Stamping
  - Hand Cutting
- Packaging
  - Tape and Reel
  - Waffle Pack
  - Freestanding

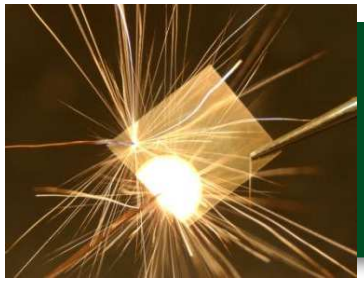
** Can be cut smaller,*





Above: NanoFoil® with LED board and components
Left: Freestanding NanoFoil®

INDIUM CORPORATION



NanoFoil - Your answer for solder bonding issues, where:

- **CTE mismatch exists**
  - –when bowing and stress are issues in bonding processes, NanoFoil produces flat uniform assemblies
- **Bond line uniformity is critical**
  - –Nanofoil bonding makes it easy to assure uniformly thick assemblies
- **Temperature sensitive materials need metal bonding**
  - –NanoFoil only heats the bondline, not the joined materials
  - –No change in crystallography, surface texture, dimensions
- **Precision application of heat is needed**
  - –A unique approach to applying heat “only” in target area resulting in a higher bonding yields
- **Bonding can be done in any atmosphere**
  - –Heat generation with NanoFoil is a completely self contained chemical reaction...in vacuum, underwater, air, N2, Ar, ... allowing the greatest flexibility in environment needed for bonding process.
- **Fastest acting precision heat source is needed**
  - –NanoFoil completely reacts in thousandths of a second resulting in vast improvement in bonding process efficiency.
- **NanoFoil is for any solder bonding applications**
  - –Precision heat source for use with ANY SOLDER.
- **Flux cleaning are concerns**
  - –NanoFoil is flux free.
- **Contamination is a concern**
  - –NanoFoil yields a “clean bond” that is at least as chemically inert with no volatile by-products
- **Ease and Safety in use is a concern**
  - –Nanofoil was designed with safety, and ease of use as key attributes of the material.
- **Reproducibility and Quality are concerns**
  - –Nanofoil yields consistent reproducible results, first time, every time.

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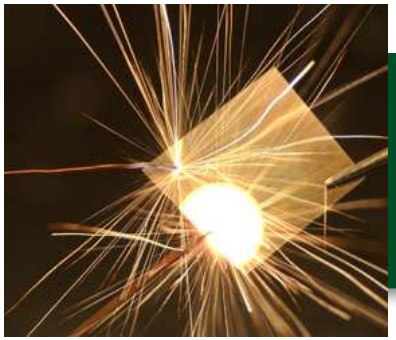
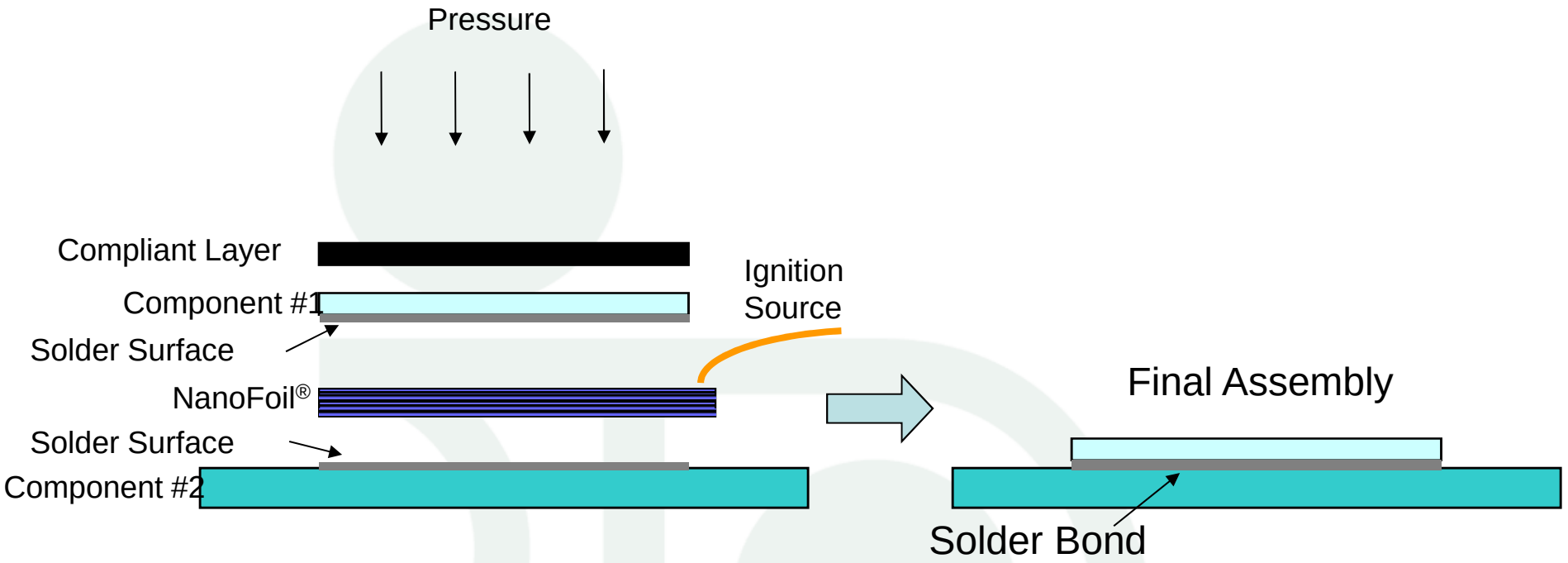
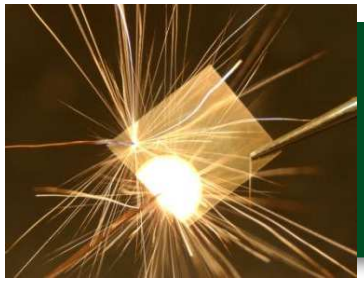


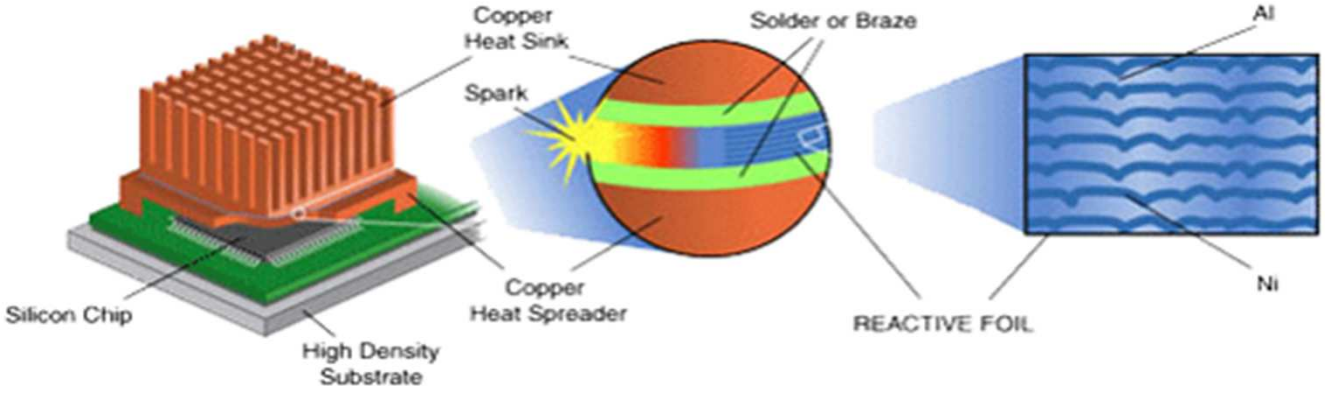
A NanoBond®


Pressure
Compliant Layer
Component #1
Solder Surface
NanoFoil®
Solder Surface
Component #2
Ignition Source
Final Assembly
Solder Bond

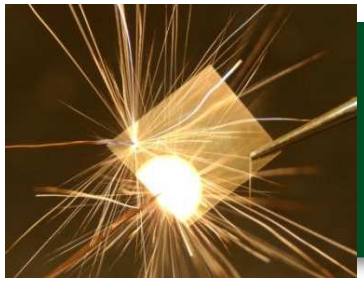


The NanoBond Process

- High-density of energy, such as, heat pulse, electrical spark and mechanical impact
- A foil with thousands of nanoscale layers of aluminum and nickel.
- Heat generated by intermixing of aluminum and nickel layers.
- Foil acts as a controllable, rapid, local heat source.
- Heat of mixing melts the adjoining solder layers.
- Melted layers lead to formation of metallic bond



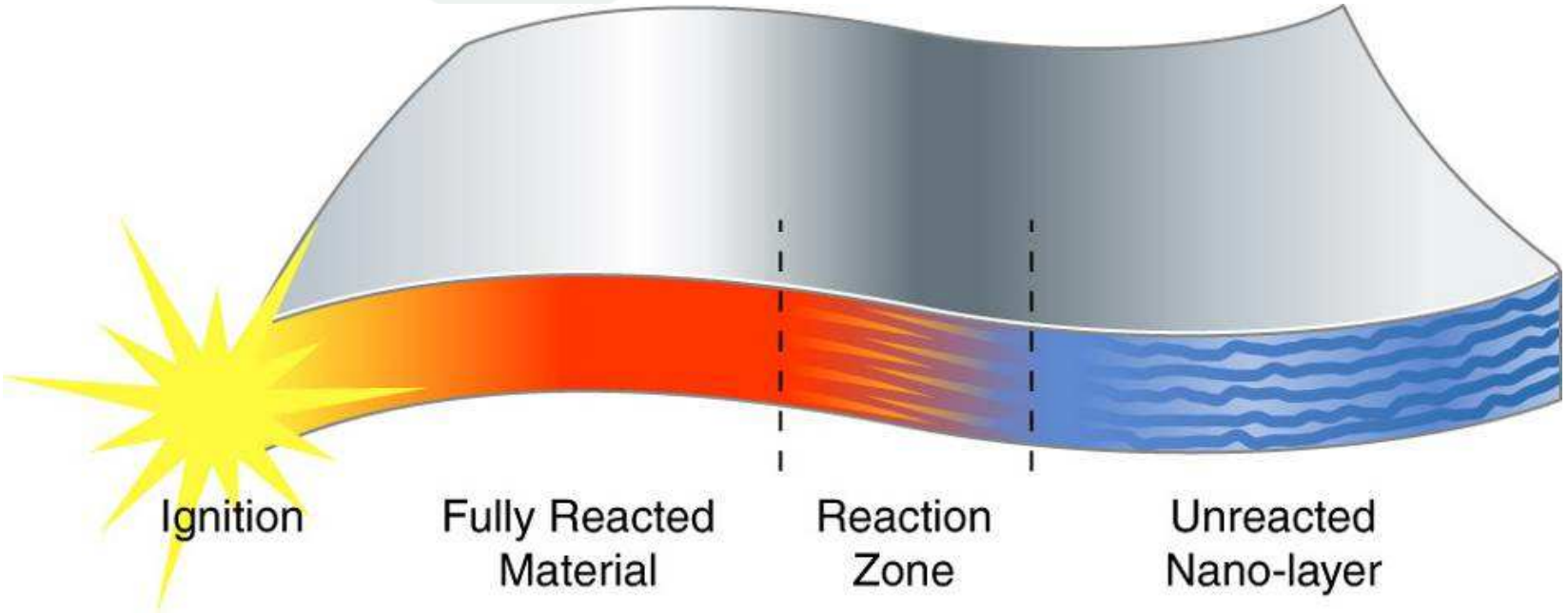
INDIUM CORPORATION

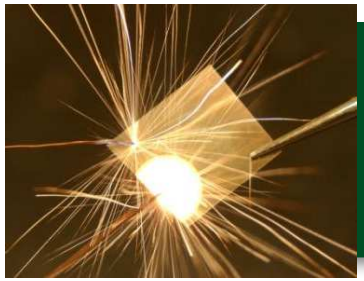


Live Product Demo

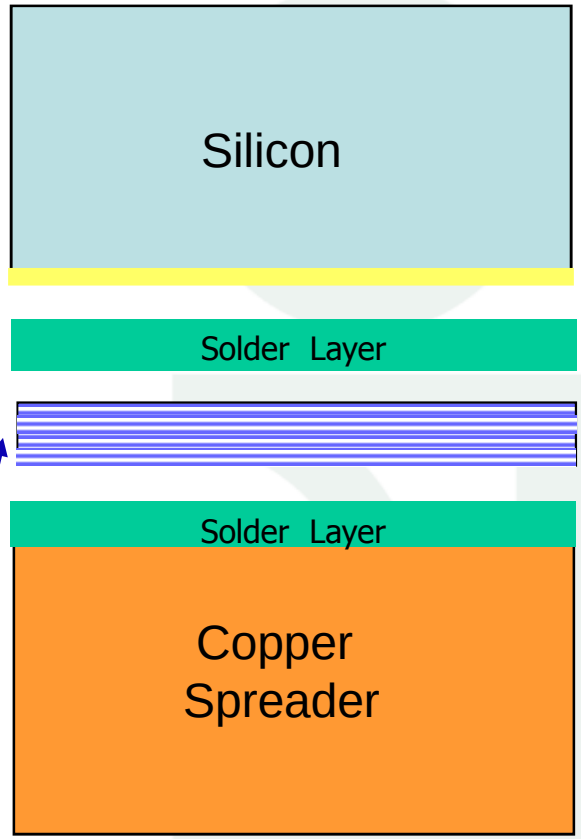
- The Nanotechnology:
  - A Sputtering process is used to deposit thousands of alternating layers of Al and Ni
  - The surface area of the reaction is increased significantly

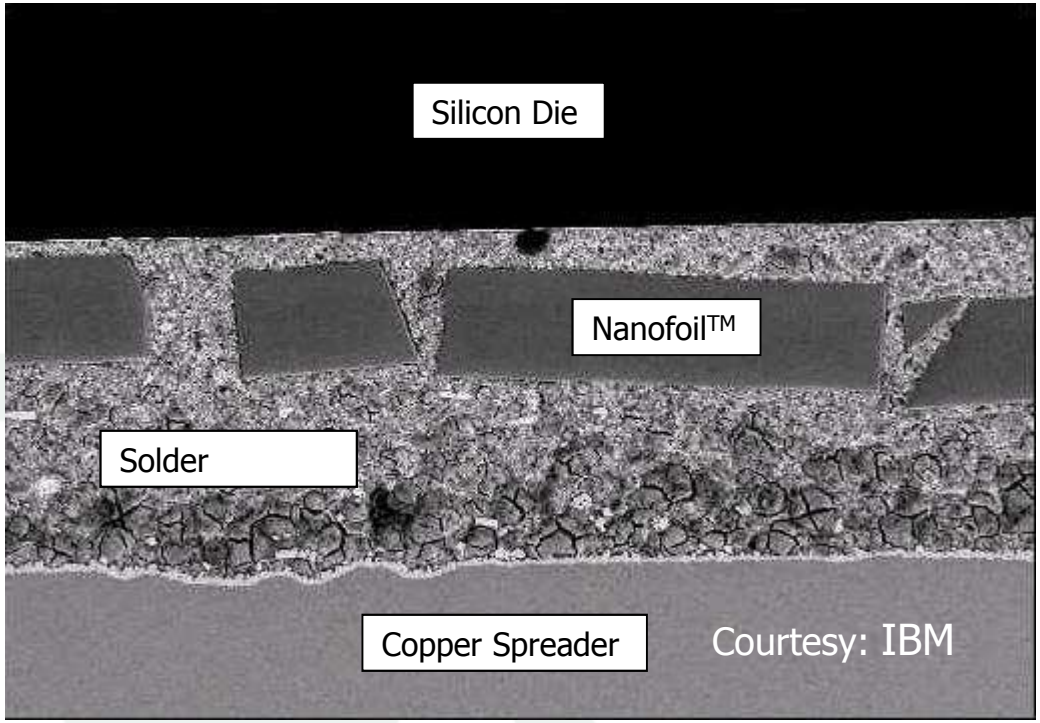
Al + Ni ⟶ AlNi





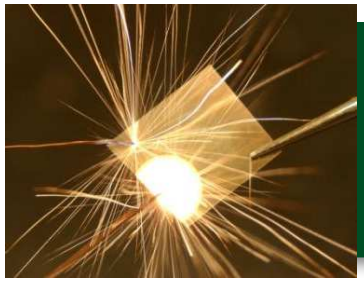
NanoBond® Configuration for TIM



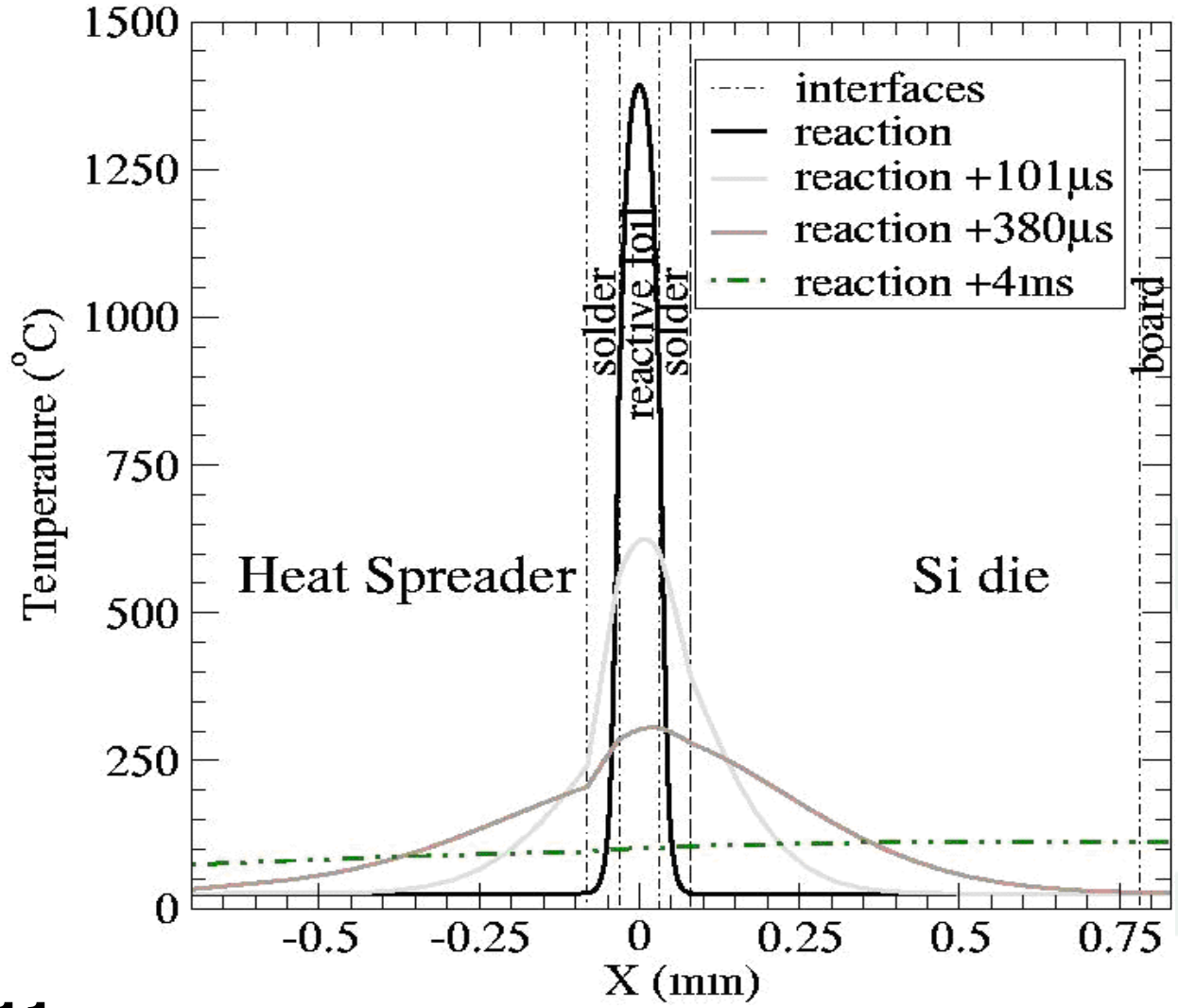


Lower Thermal Resistance of Interface
Can use Lead-Free, High-temperature solders

INDIUM CORPORATION

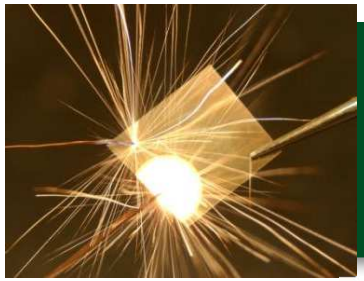


Results of the Model

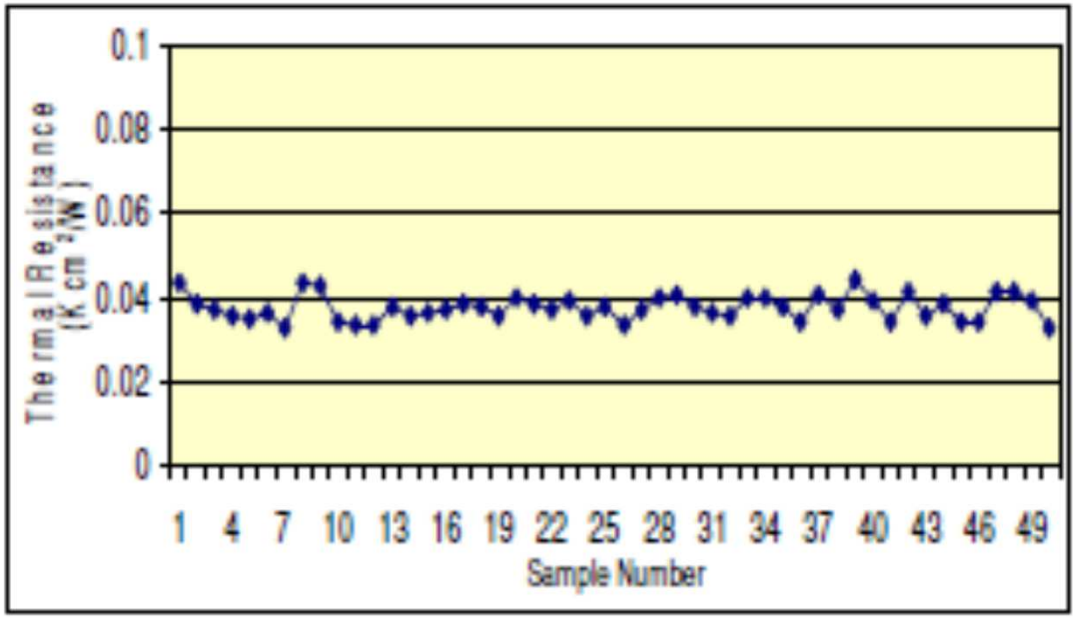


Maximum temperatures predicted during bonding

Die Thickness (µm)	700
Foil Thickness (µm)	60
Top of Spreader (°C)	60
HS/Solder (°C)	243
Solder to Foil (°C)	943
Foil to Solder (°C)	943
Solder to Die (°C)	389
Top of Die (°C)	113

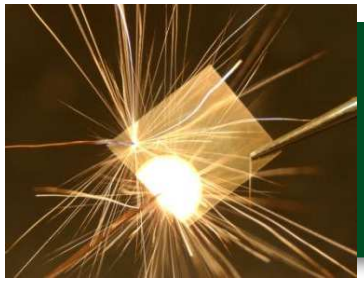


Bond Reliability



- **Number of samples in this study: 50**
- **Bonding pressure: 50 psi**
- **Mean Thermal Resistance: 0.04 °C cm2/W (0.006 °C in2/W)**
- **Standard Deviation: 0.003 °C cm2/W**
- **Die Size: 17.5x17.5 mm**
- **R = 0.01°C/W**

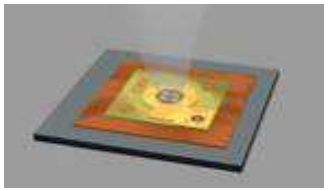
INDIUM CORPORATION



NanoFoil® Applications

Joining of Materials or Components

- **Microelectronics Applications**
  - RF Power Attach
  - LED Attach
  - Packaged Part Attach
  - CPV Receiver Attach
- **Large Area Joining of Dissimilar Materials**
  - Sputter Target Bonding
  - Ceramic-Metal Joining
- **Energetics**
  - Heater
  - Propellant, Flare igniter
  - Decoy, Delay Detonator



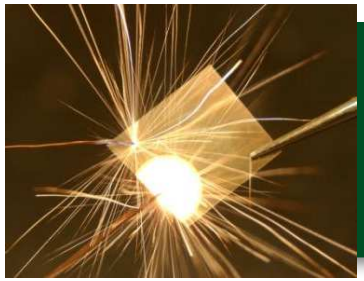
DBC Attach

LED Attach

Thermal Management

Large Area Joining

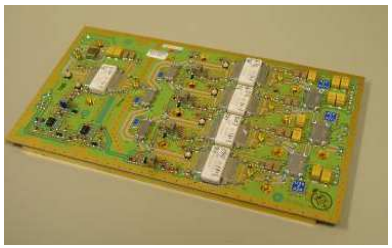
INDIUM CORPORATION



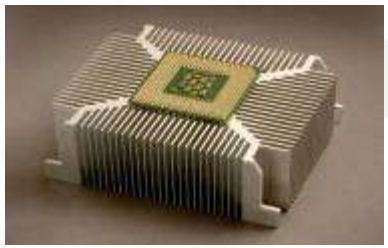
Electronics Applications

HB LED Attach

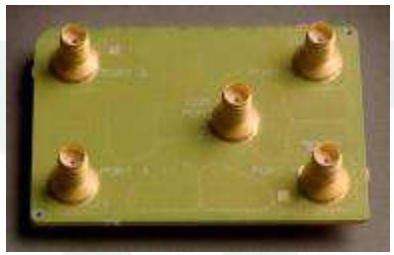
Concentrated PV



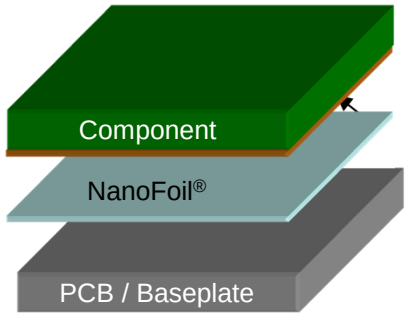
Power Amplifiers



Thermal Management



Component Mounting

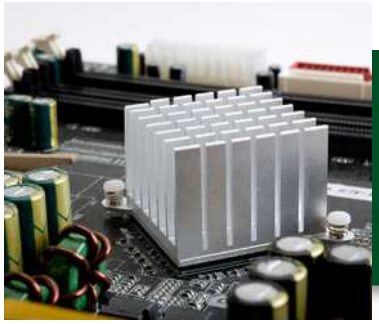


Benefits

- **Thermal Conductivity of Solder**
- **Manage CTE mismatch**
- **Room Temperature Process**
- **Use with any solder**
- **Millisecond reaction time**
- **RoHS Compliant**

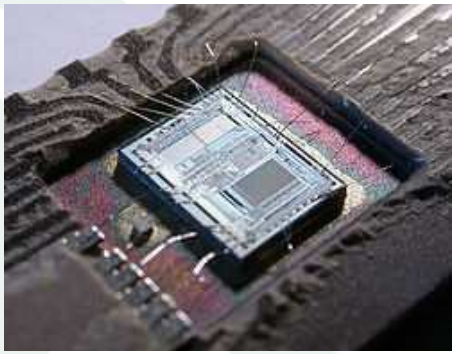
NanoFoil addresses many significant thermal management challenges encountered in the design and manufacture of electronic assemblies.

INDIUM CORPORATION

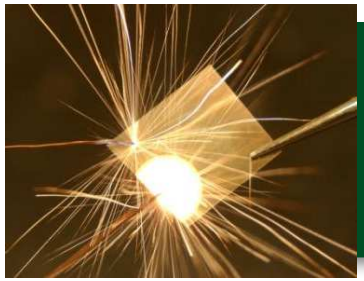


Electronics Assembly

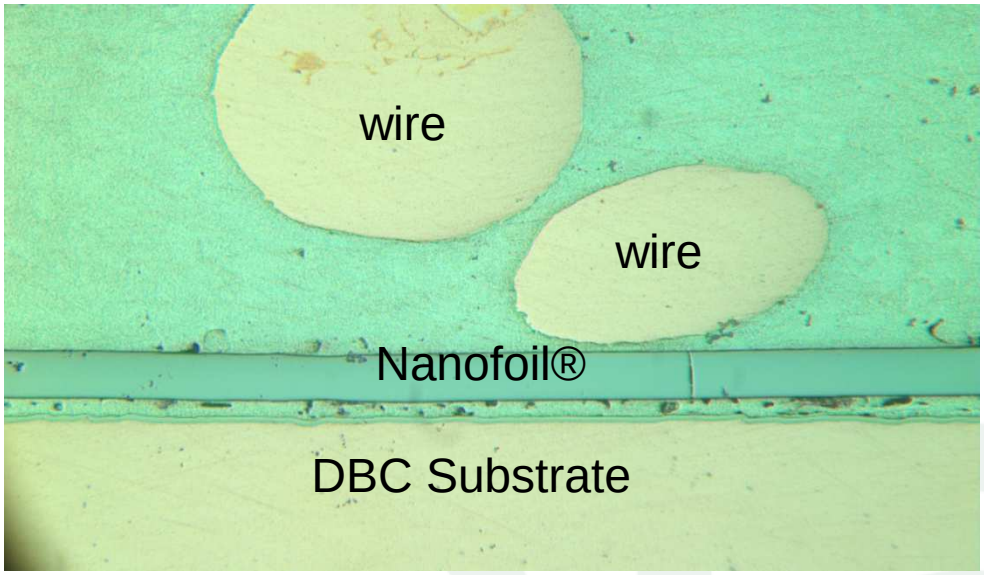
- NanoBond®
  - freedom in choice of solders
  - bonding process is flux free
    - eliminates a cleaning operation and
    - minimizes voids in the solder bond
  - compatible with dissimilar materials having a coefficient of thermal resistance (CTE) mismatch
  - example uses:
    - flex circuits
    - metal core substrates,
    - LTCC
    - graphite heat spreaders
    - …



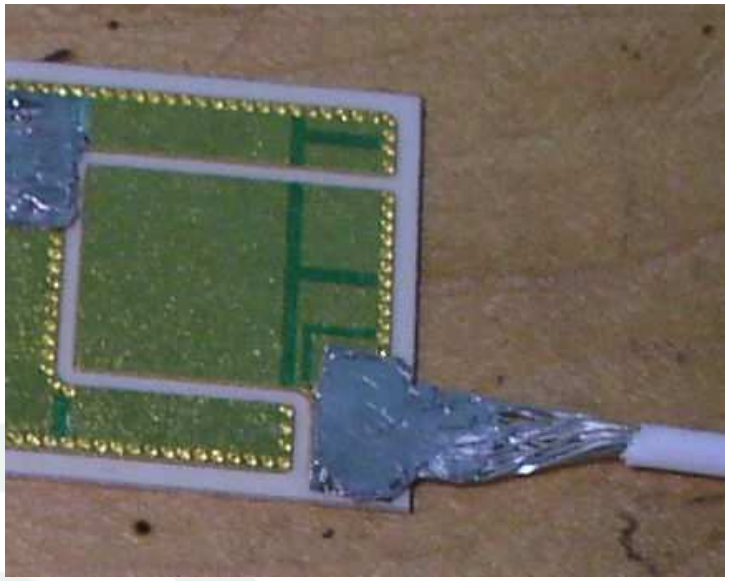
INDIUM CORPORATION



Wire Attach

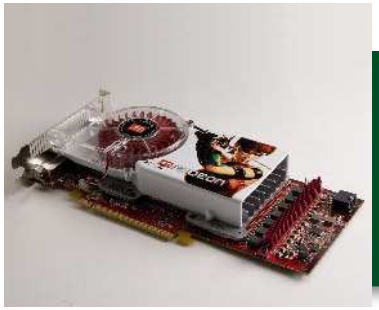


Cross section of reflowed 16 gauge stranded wire bonded to DBC



Physical bond on DBC

INDIUM CORPORATION



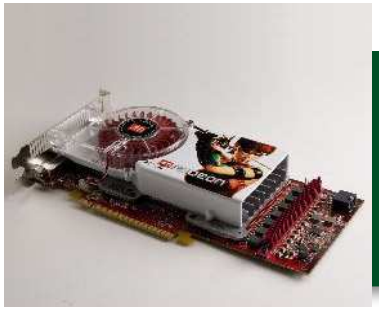
Power Electronics

SMT Assembly process techniques are used in combination with the NanoBond® process.

- NanoBond® can be used to bond the back side of power amplifier boards to heat spreaders.
  - **heat spreader surface finishes suitable for NanoBond® include electroplated or reflowed tin and lead-tin.**
- NanoBond®
  - **eliminates warping seen in reflow processes**
  - **de-lamination seen in reflow processes**
  - **provides greater 10X heat transfer than thermal epoxy.**
- NanoBond® can be used to bond expensive Power Amplifier packaged components to the heat spreader.
  - **can be used during the first manufacturing pass process and for a rework process.**

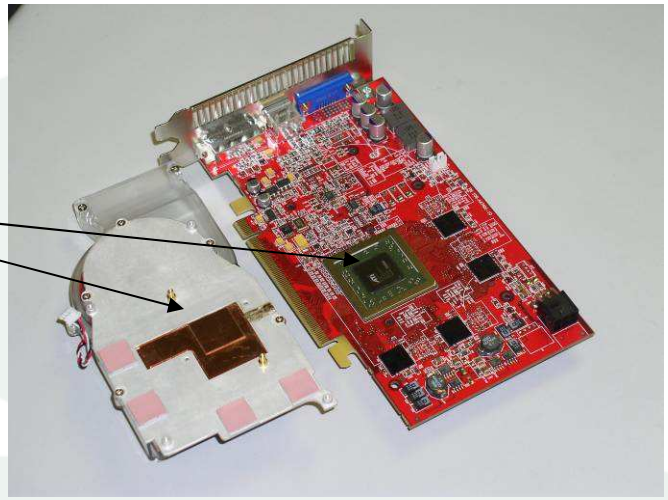
Advantages:

- Millisecond Soldering
- Strong Metallic Bonds
- No Thermal Damage
- Lead Free
- RoHS Compliant Process



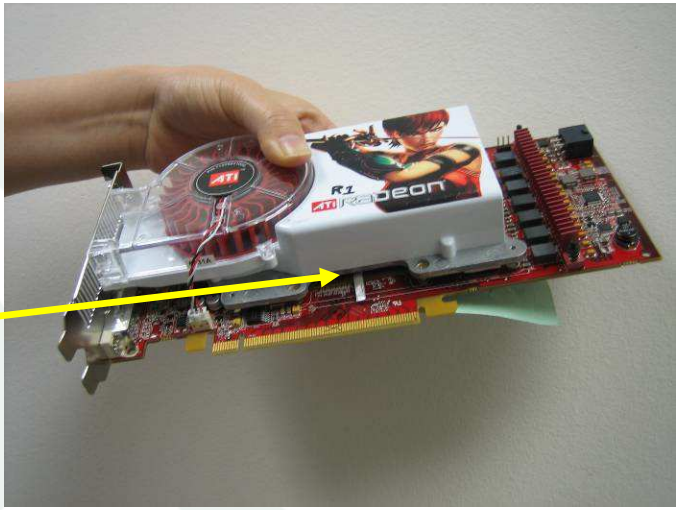
Power Electronics

NanoBond silicon die to copper heat sink using indium solder

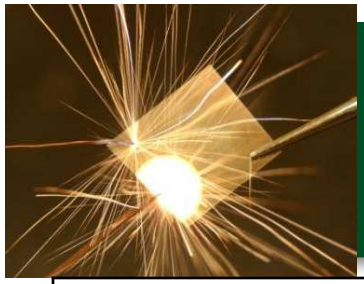


- Current thermal interface materials do not meet the heat dissipation requirements of the next generation of GPU

Line of sight to interface



INDIUM CORPORATION

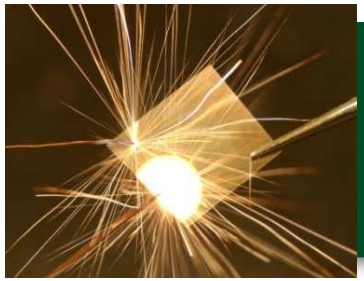


Benchmark Performance
on ATI X1900 Boards

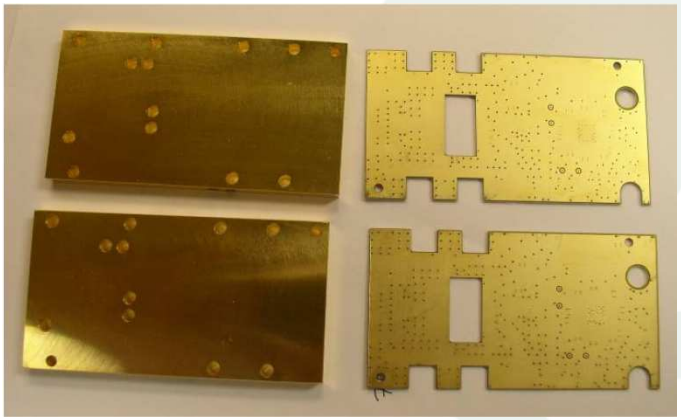
TIM	Highest Junction Temp.	Avg. Inlet Temp.	Avg. Ambient Temp.	ΔT (highest-inlet)	Interface resistance
	° C	° C	° C	° C	° C/W
NanoBond® Indium	92.125	28.07	22.24	64.05	**0.015**
PCM (Indium-based)	93.500	28.36	22.58	65.14	**0.041**
LMA (Indium-based)	92.792	27.67	22.02	65.12	**0.041**
Organic Grease B	94.958	28.78	22.64	66.18	**0.066**
Organic Grease A	95.250	28.74	22.57	66.51	**0.073**

- Measured power to die: 42W
- Die size 17.5x17.5mm

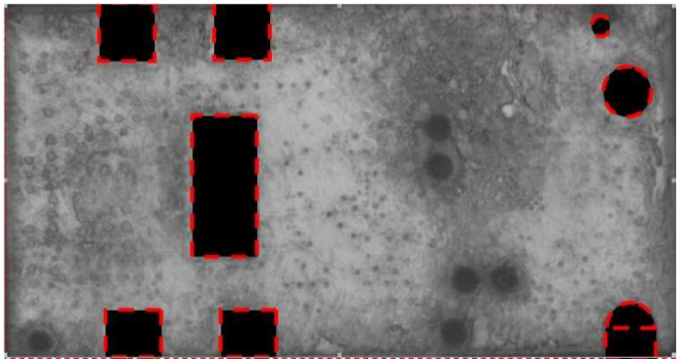
INDIUM CORPORATION



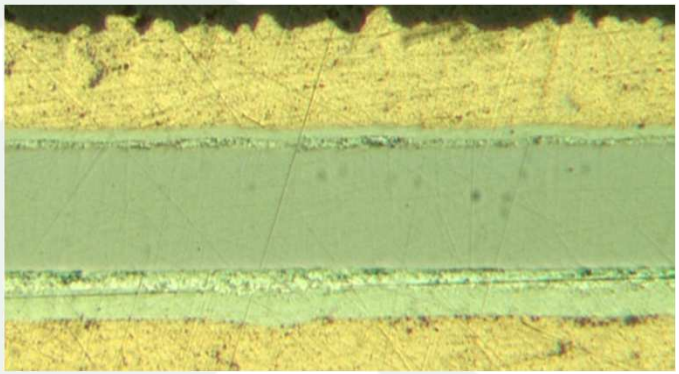
PWB's



ENIG finished PWBs and Heatsinks



C-Scan Image of PWB bonded to a Heatsink



Cross section of PWB to heatsink Attach

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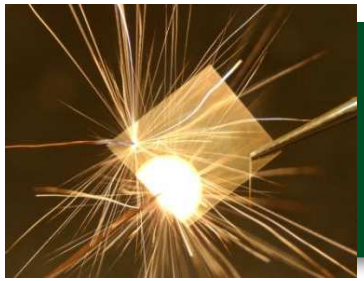
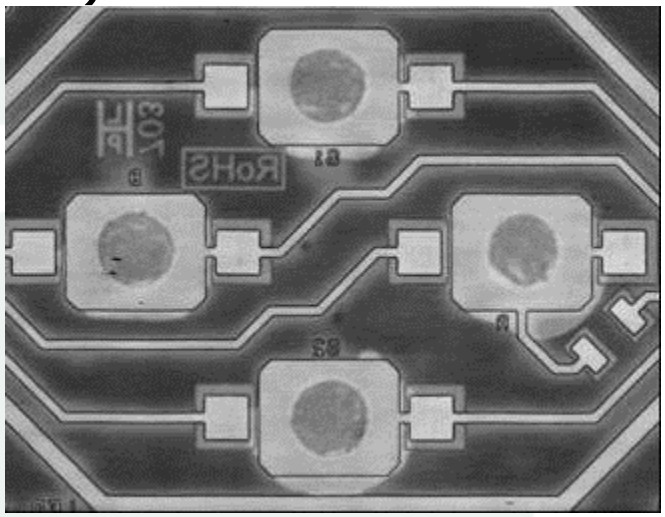


Component Mount

Optimization of Center Slug Bonding:

Effect of Pad finish on bond quality

- Optimized bonds exhibit high strengths (>30MPa, ~45kg) for Sn-plated bonds
- Resulting bonds exhibit low (<5%) void contents



C-SAM Image of Center Pad Bonds

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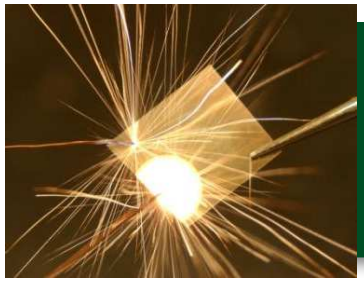
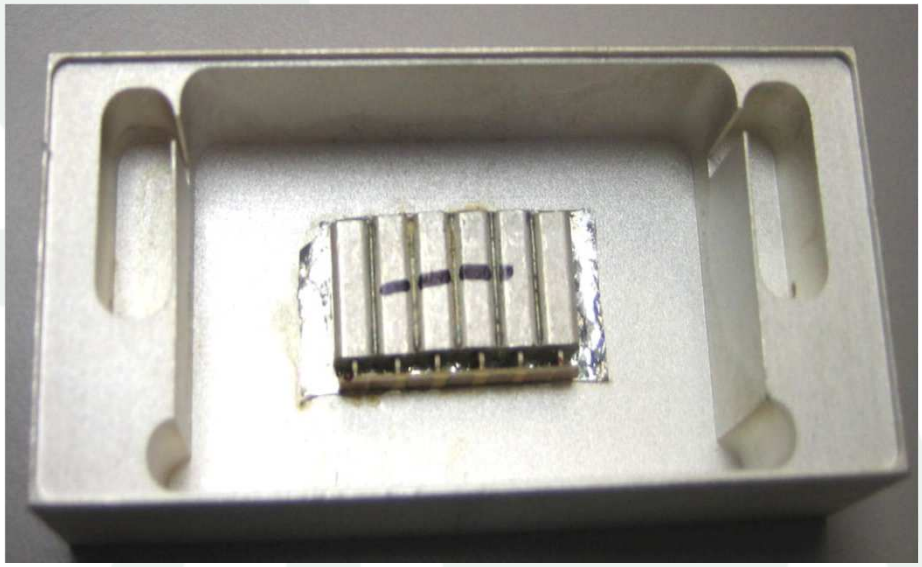
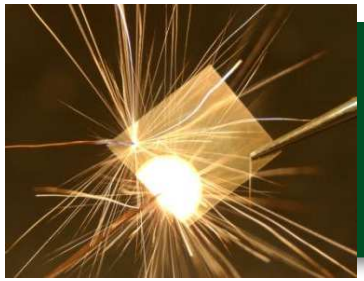


Component Mount

- RF Filter components mounted inside of a Ag plated case with Sn plated NanoFoil





Summary

- NanoBonding can be done with no damage to the components being joined
- NanoBonding results in stress free joining of materials with dissimilar CTE's
- Unique process can join dissimilar materials in virtually any environment, in milliseconds
- Any solder can be used with NanoFoil
- NanoFoil joining process increases productivity, overcomes technical barriers, and reduces cost

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