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Soldering Technology for High and *Ultra High* Temperature Service

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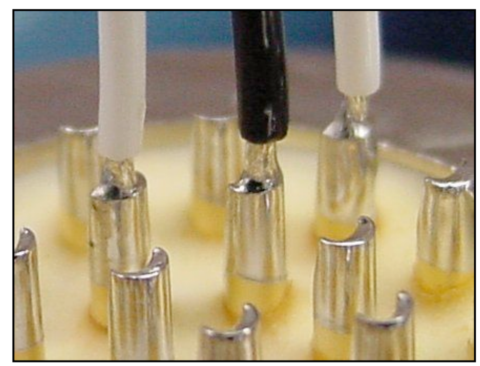
Outline

- **Introduction**
  - **The case for *soldering technology***
  - **Service environments**
  - **Process definition**
- **Approach**
  - **Commercially-available, ultra high temperature solders**
  - **New solder alloy compositions**
  - **Candidate base materials**



- **Accomplishments**

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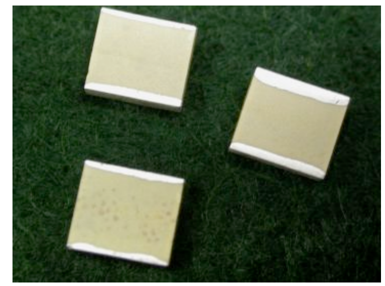
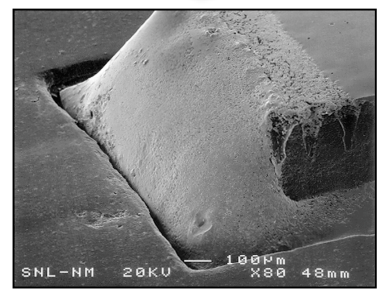
Introduction

- **In 2002, it was anticipated that, within five years (2007), electronic devices, substrates, and power supplies would become available for ultra high temperature applications*.**

***The term *ultra high temperature* refers to service environments having sustained temperatures of 300°C (572°F) and short-term, temperature excursions as high as 350°C (662°F).**



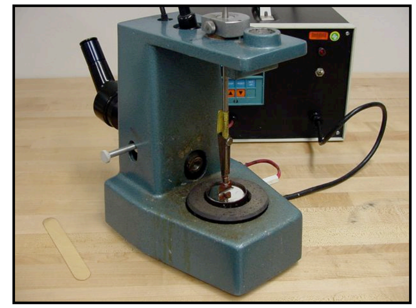


- **In a 2002 white paper, the groundwork was set by which Sandia National Laboratories would investigate *soldering technology* for the assembly of printed circuit boards to be used in electronic products for ultra high temperature applications**.**

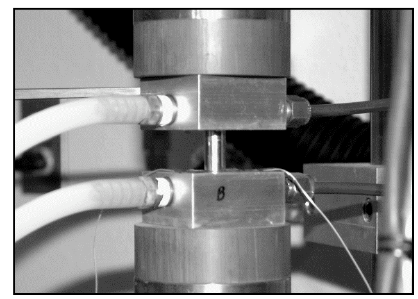
P. Vianco, "Solder Interconnect Technology for Ultra-High Temperature Applications," *Sandia Report* **SAND2002-2948, Sandia National Laboratories, Albuquerque, NM, 2002).

Introduction

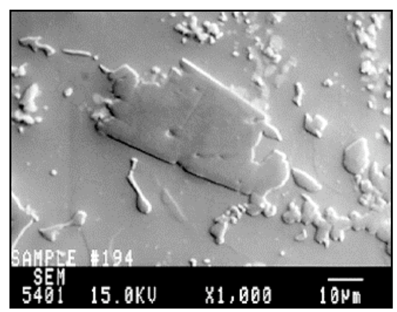
- **Sandia capabilities:**
  - **Knowledge-base and experience with the development of new solder compositions.**
  - **Solderability testing, mechanical properties, and differential scanning calorimetry (DSC) for alloy and process development efforts.**
  - **Analysis capabilities to characterize the solder physical metallurgy as well as the microstructural features of interconnections made to selected base materials.**



Solderability testing



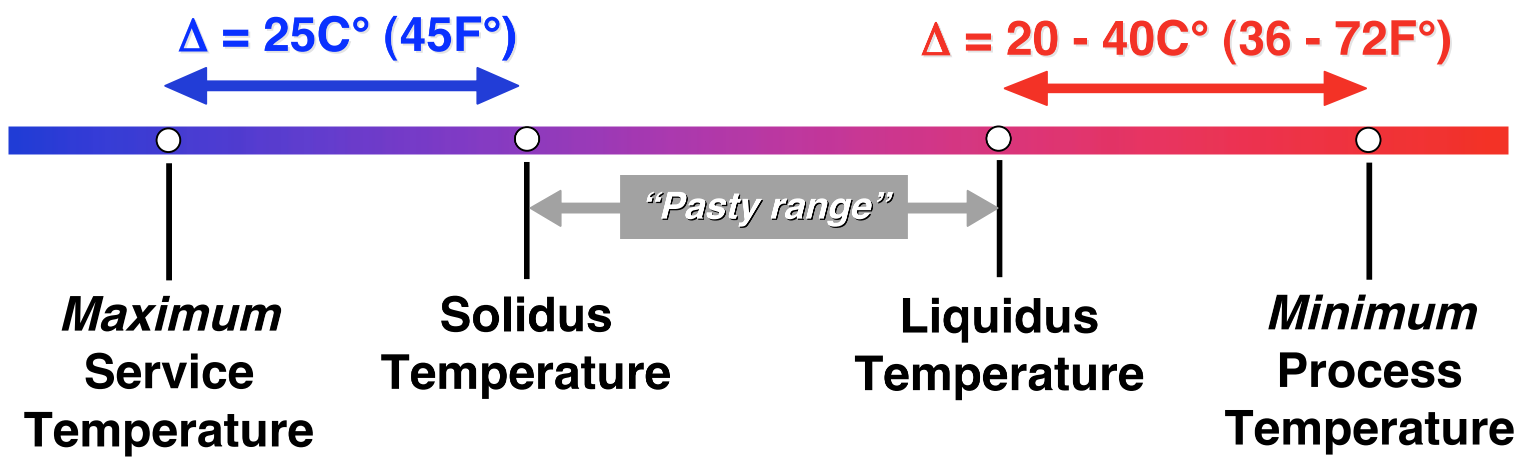
Mechanical properties



Microstructure characterization

Introduction

The service environment benchmarks the physical and mechanical properties required of the solder alloy(s).



Solder melting properties:

350°C (662°F) → **375°C** (707°F)

Ultra high temperature service

0C° (eutectic) . . . **375°C** (707°F)

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.

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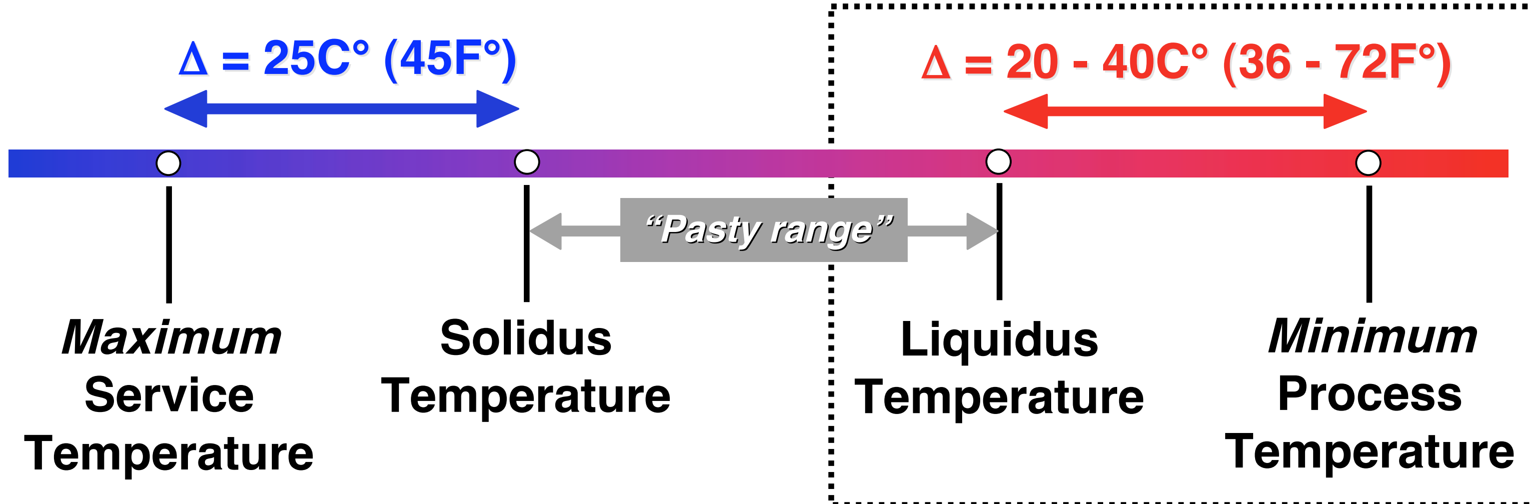
50C° (90F°) . . . . . **425°C** (797°F)

Introduction

The melting properties of the solder alloy(s) benchmark the minimum, peak assembly processing temperature(s).



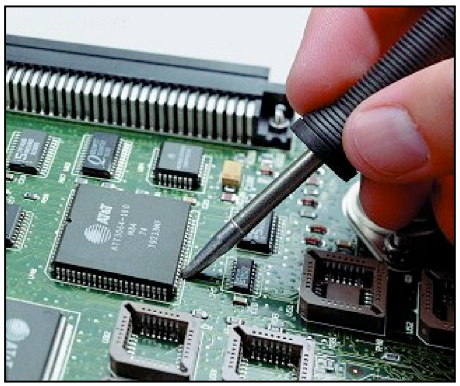
Peak processing temperature:

375°C (707°F)	**395°C** (743°F)
⋮	⋮
425°C (797°F)	**445°C** (833°F)

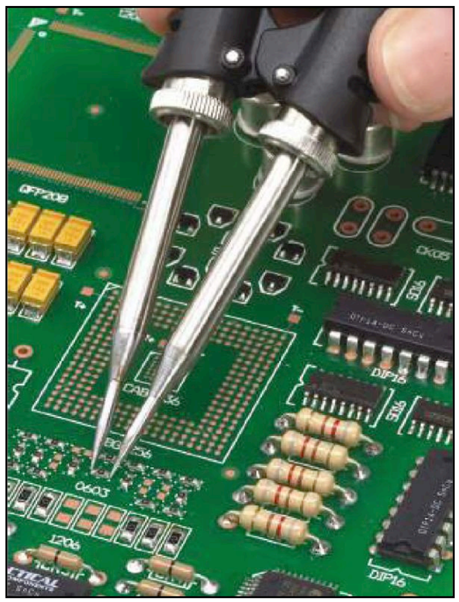
Introduction

- The process definition includes, identifying the most suitable soldering technique(s) for the product types.

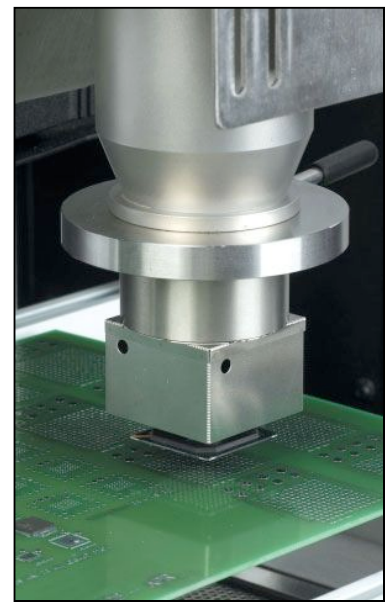
- Hand soldering provides an excellent starting point, particularly for prototype development efforts.



Point tip



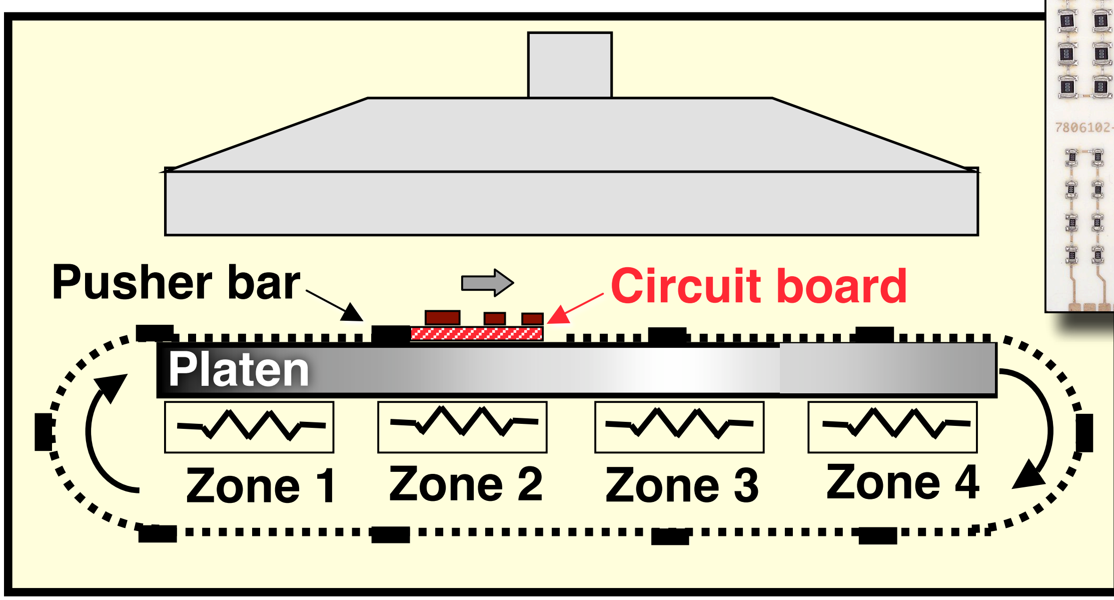
Tweezer tips

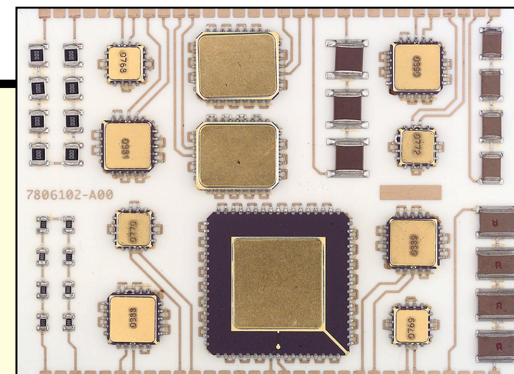


Hot gas

Introduction

- **Machine (automated) assembly should also be considered.**
- **Conduction soldering is a potential candidate for the assembly of printed circuit boards .**





Hybrid (ceramic) microcircuit technology

Approach

- **Solder compositions for ultra-high temperature service:**

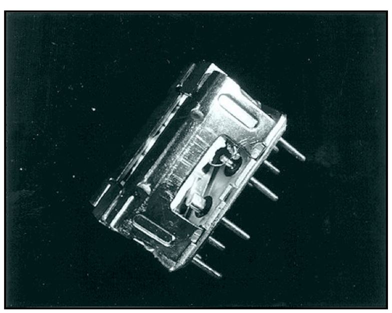
395°C (707°F) **< T_s & T_l < 445°C** (797°F)

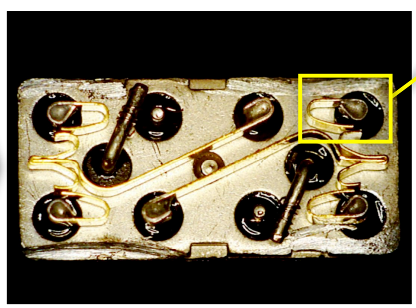
Consider both RoHS and *non*-RoHS compliant materials.

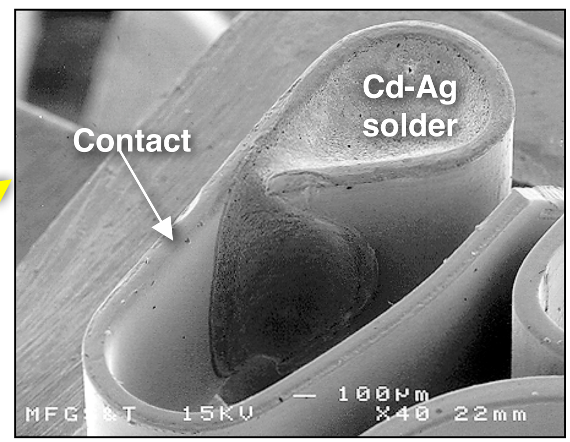
- **Commercially-available solder alloys (wt.%):**

100Zn	**T_s = 420°C (788°F)**	**T_l = 420°C (788°F)**
95Cd-5Ag	**T_s = 343°C (649°F)**	**T_l = 393°C (739°F)**

The Cd-Ag solder is used primarily in the construction of relay devices.







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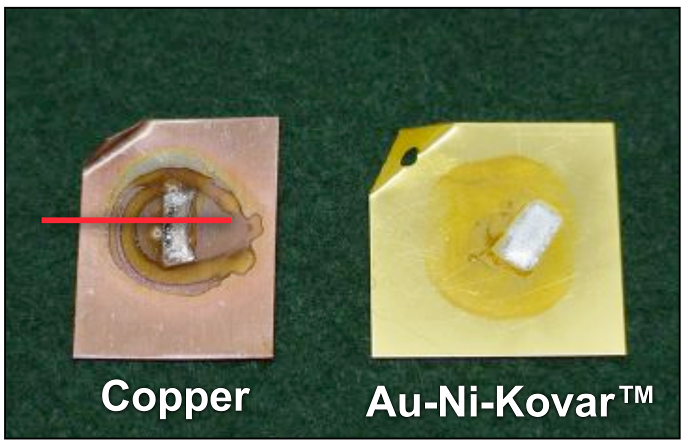
Approach

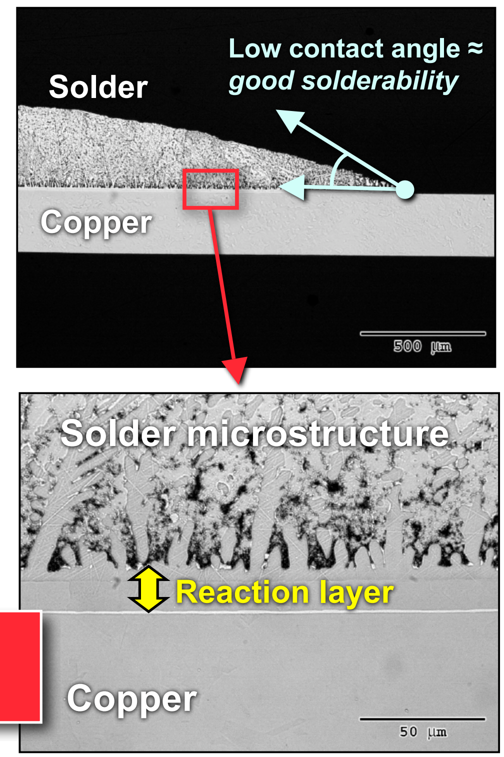
- New solder alloy development has considered Zn-based compositions having the appropriate melting properties.

- Bench-top evaluations:

  Sessile drop tests provide a very efficient methodology to evaluate solderability, fluxes, and the joint microstructures.



Metallographic cross sections



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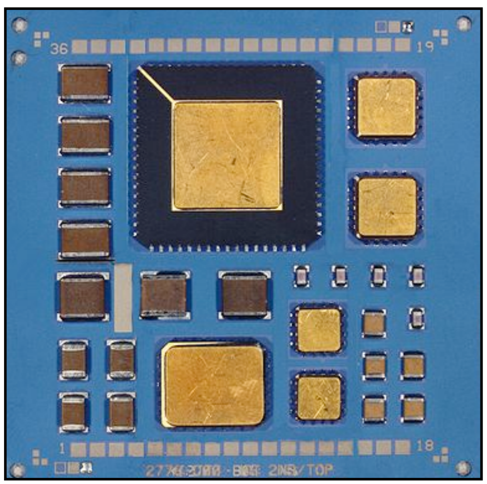
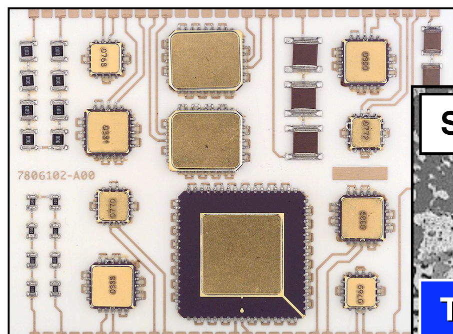
Approach

- **Ceramic substrates provide suitable base materials for ultra high temperature applications; candidates include:**
  - **alumina,**
  - **beryllia,**
  - **aluminum nitride, and**
  - **low-temperature co-fired ceramic (LTCC).**

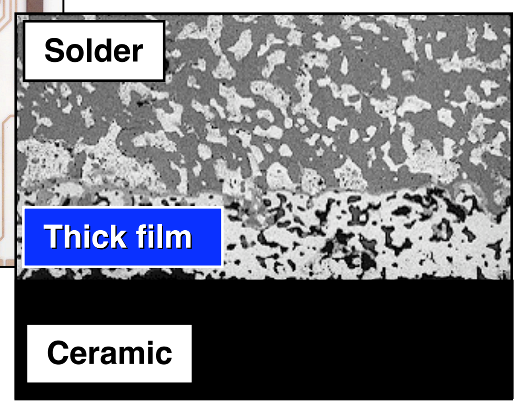
- **Both thick film ink and deposited thin film layers would provide suitable conductor technologies.**



Low-temperature co-fired ceramic (LTCC)



Alumina



Accomplishments

- During the development of ultra high temperature solders, efforts have also addressed Pb-based, high temperature solders for advanced prototype development.

295°C (563°F) < T_s & T_l < 345°C (653°F)

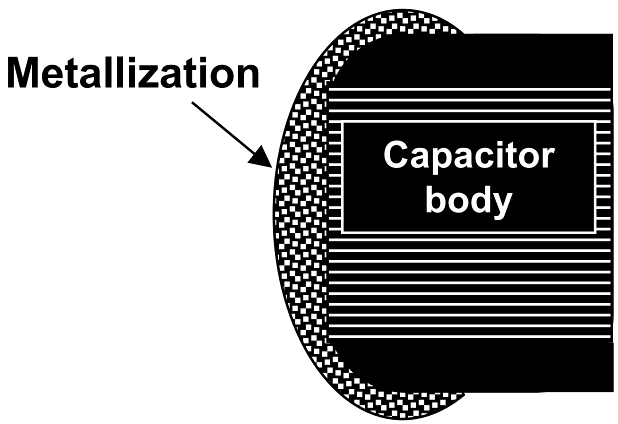
- The candidate alloys are:

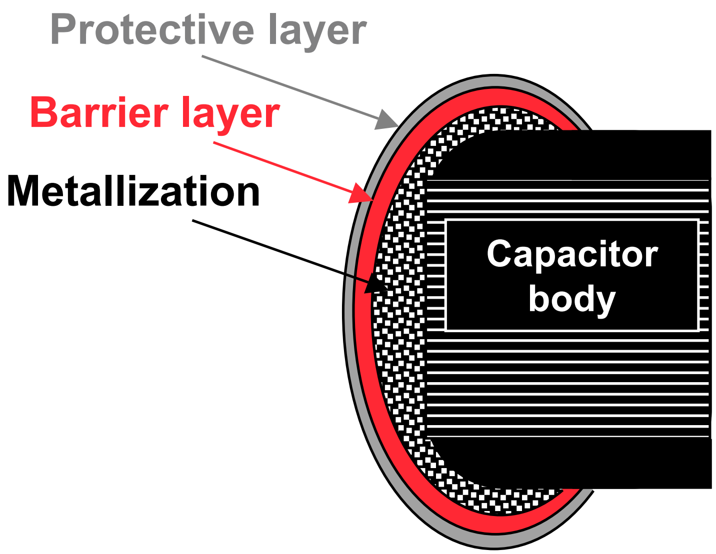
95Pb-5Sn	T_s = 308°C (586°F)	T_l = 312°C (594°F)
97.5Pb-2.5Ag	T_s = 304°C (580°F)	T_l = 380°C (716°F)

- The particular application was the attachment of Ni plated wires to chip capacitor terminations.

Accomplishments

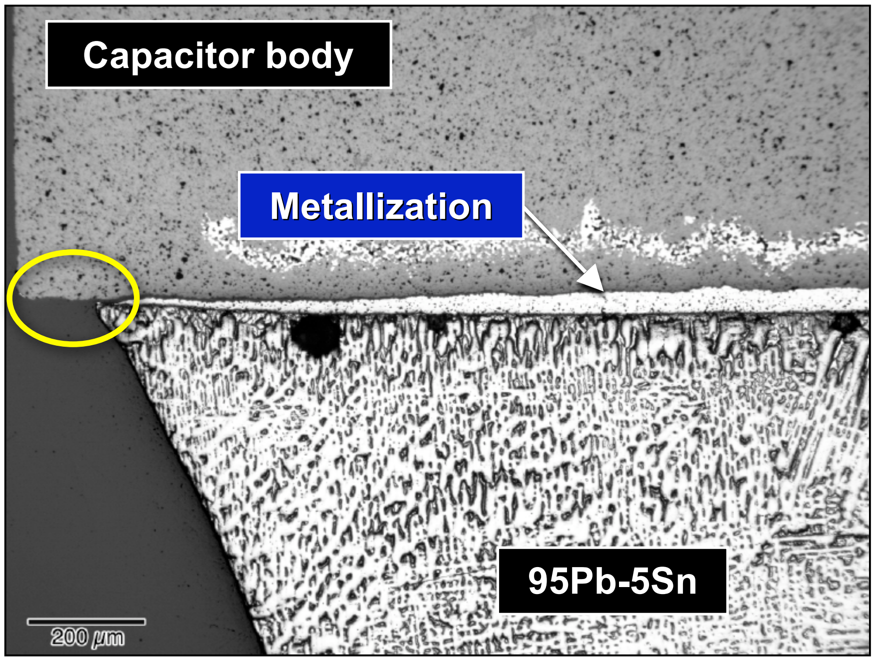
- **Concerns that were raised in this study included:**
  - **Metallization dissolution in the absence of a barrier layer (Ni or Cu).**
  - **Fracture at the interface between the metallization and capacitor body**

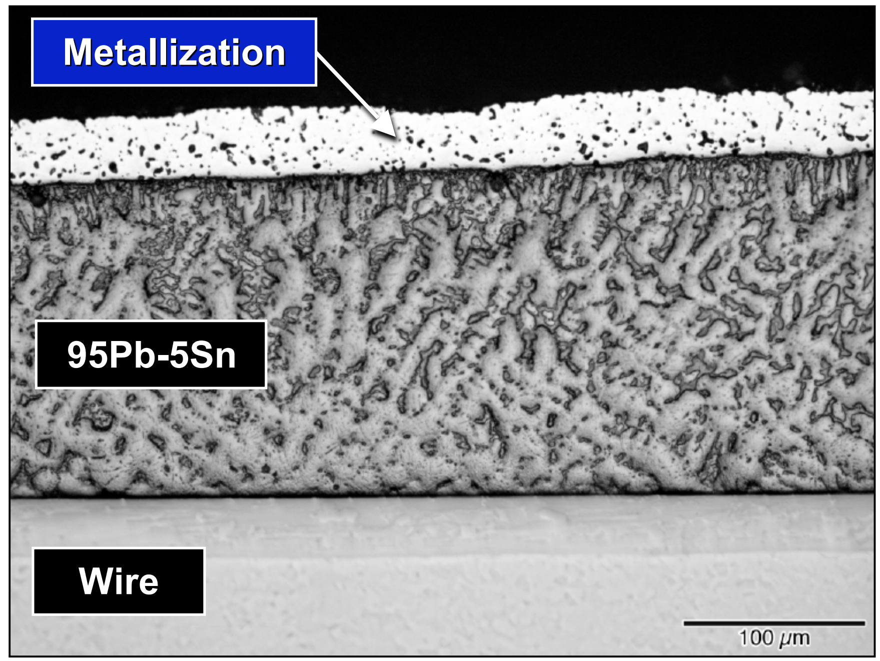




Accomplishments

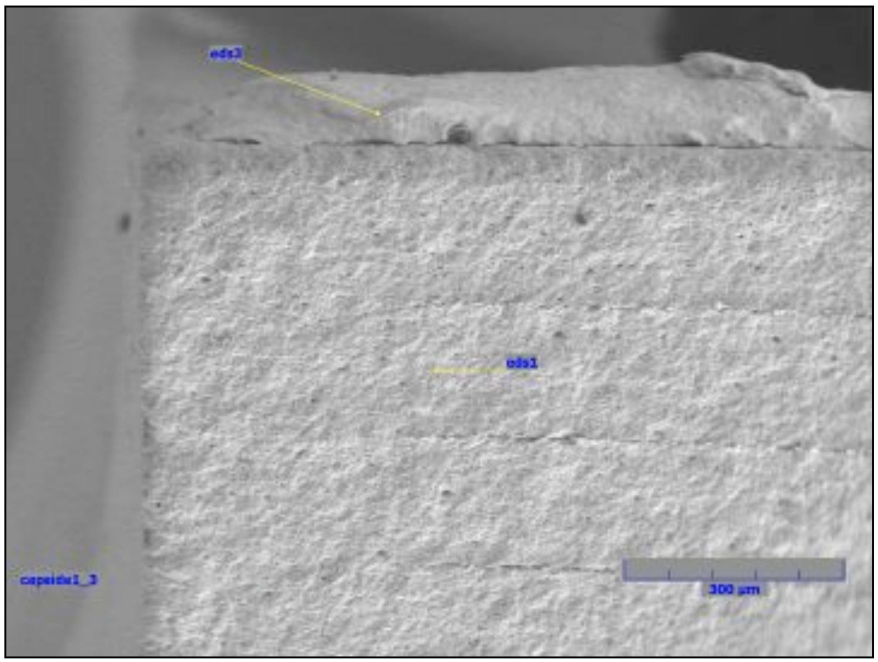
Metallization dissolution was minimized during the process to attach the wire using either of the Pb-based solders.

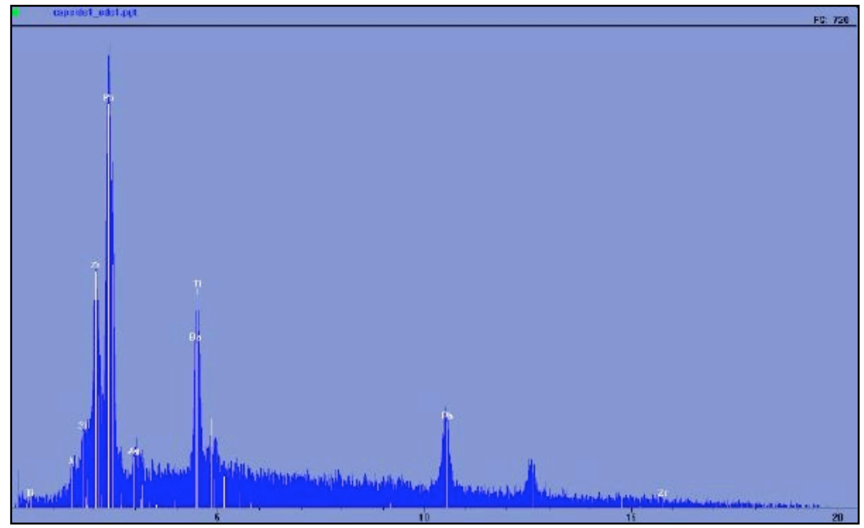




Accomplishments

- The wires easily detached from the capacitor terminations.
- The fracture surfaces were evaluated by SEM/EDXA.



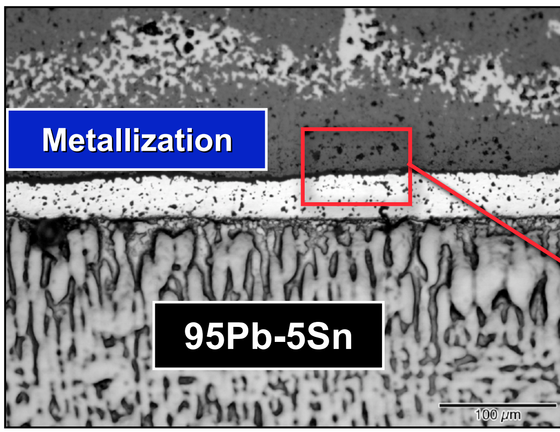


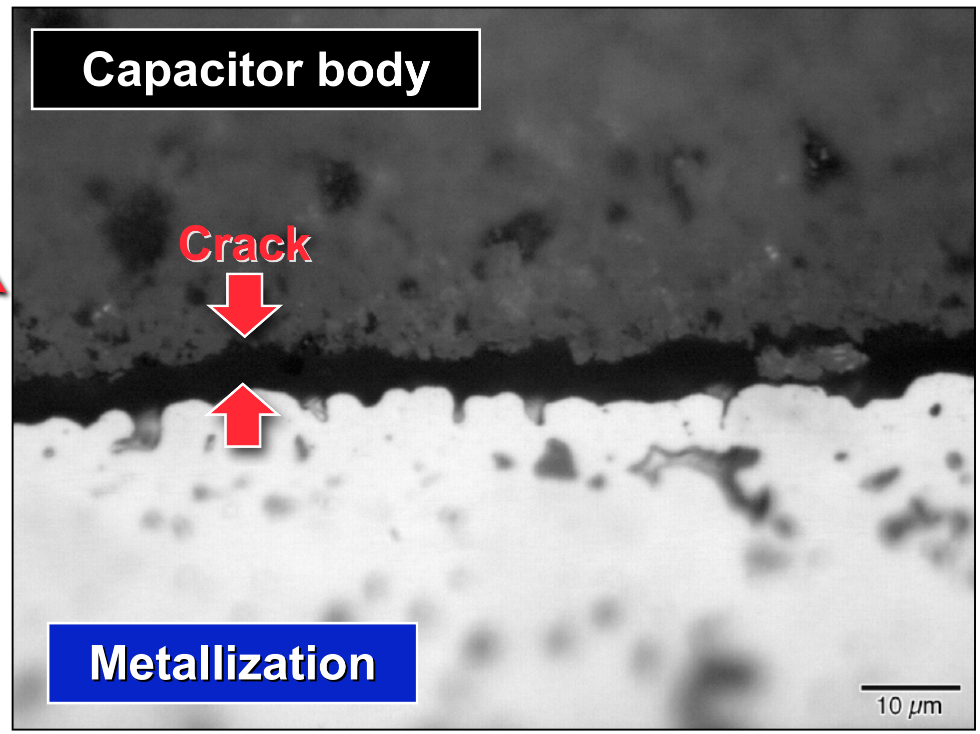
Constituents of the capacitor body: Ag, Ba, Ti, Pb, and Zr.

- Potential fracture locations: (1) metallization/capacitor interface *or* (2) bulk capacitor body

Accomplishments

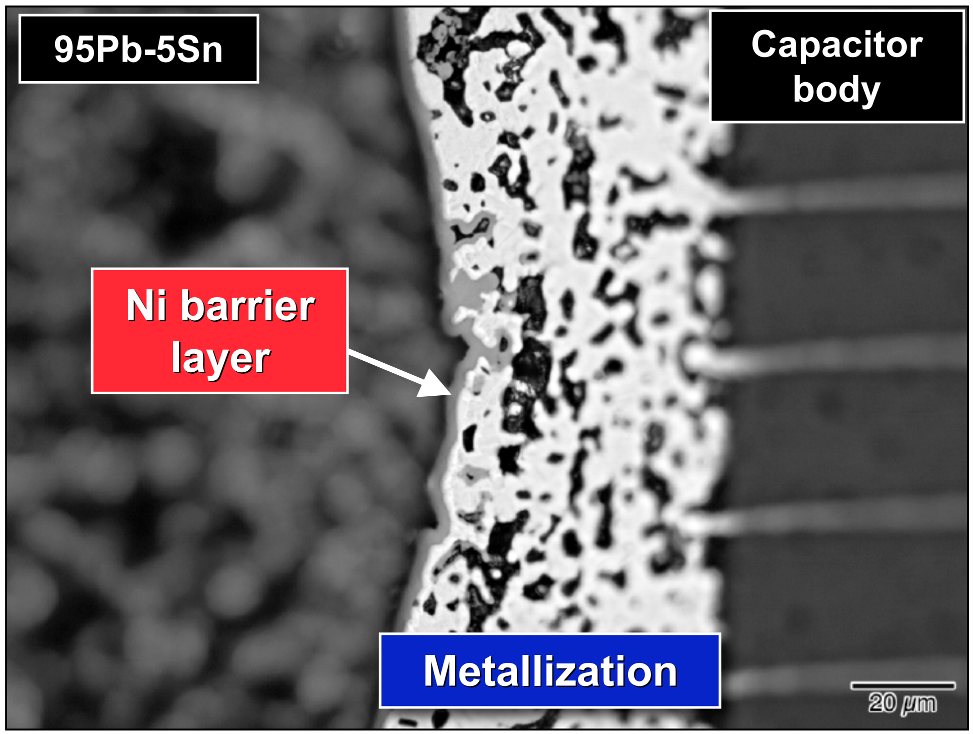
- **Poor adhesion between the metallization and the capacitor body was confirmed - the likely source was thermal shock.**
- **Fracture did *not* occur in the bulk capacitor body.**





Accomplishments

- **A second set of capacitors having a Ni barrier layer exhibited no significant metallization dissolution and … *fortuitously* … good adhesion of the metallization layer.**



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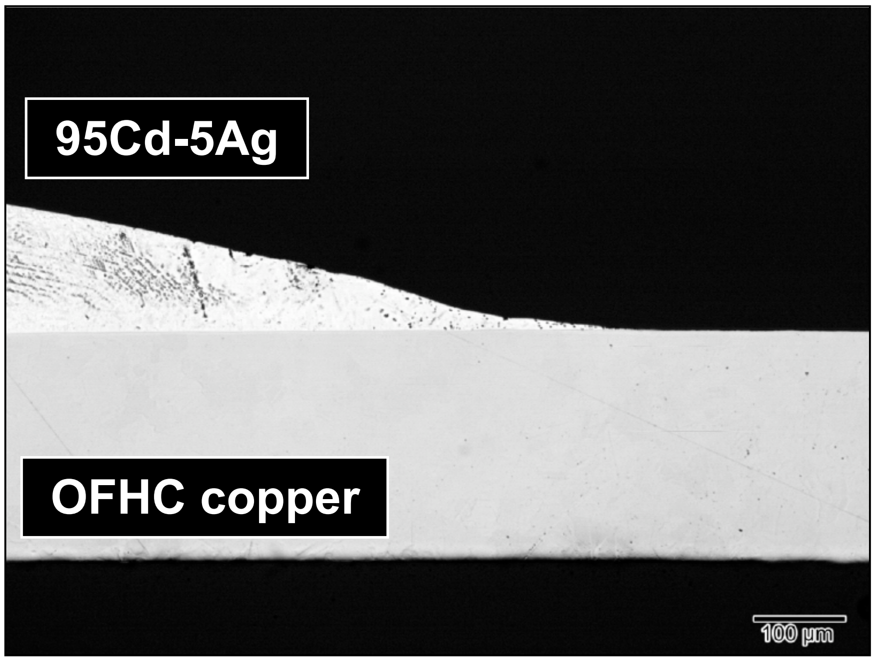
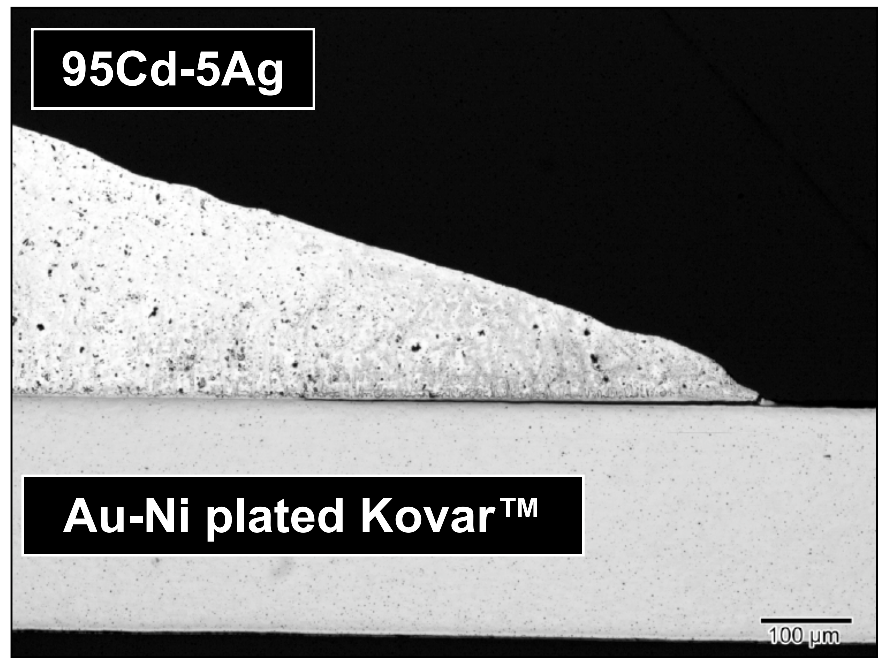
Accomplishments

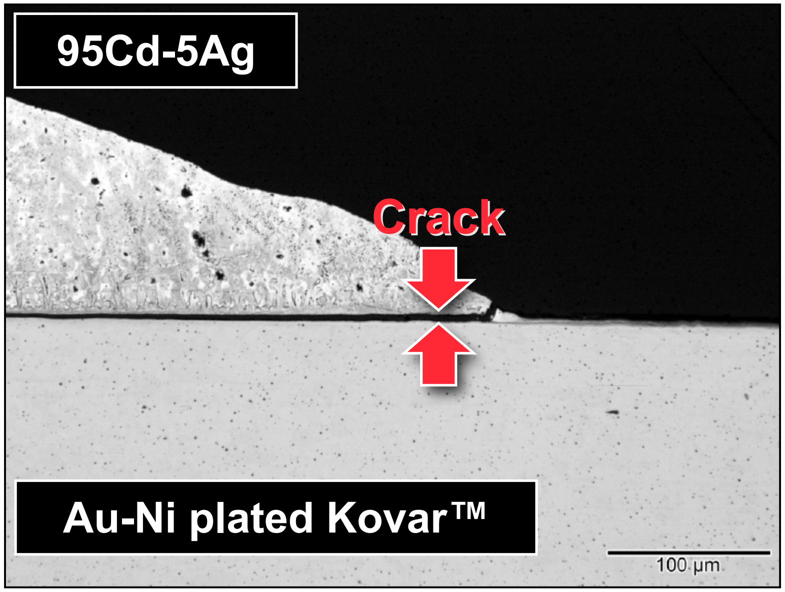
- **The 95Cd-5Ag solder exhibited excellent solderability on both OFHC copper and Au-Ni plated Kovar™ base materials.**

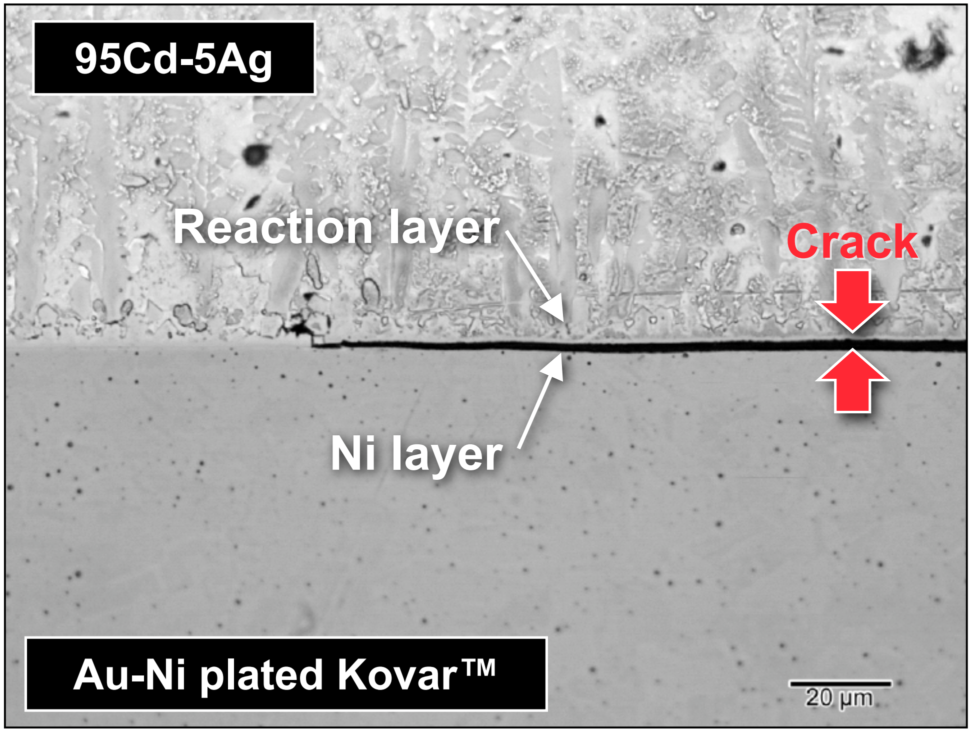




Accomplishments

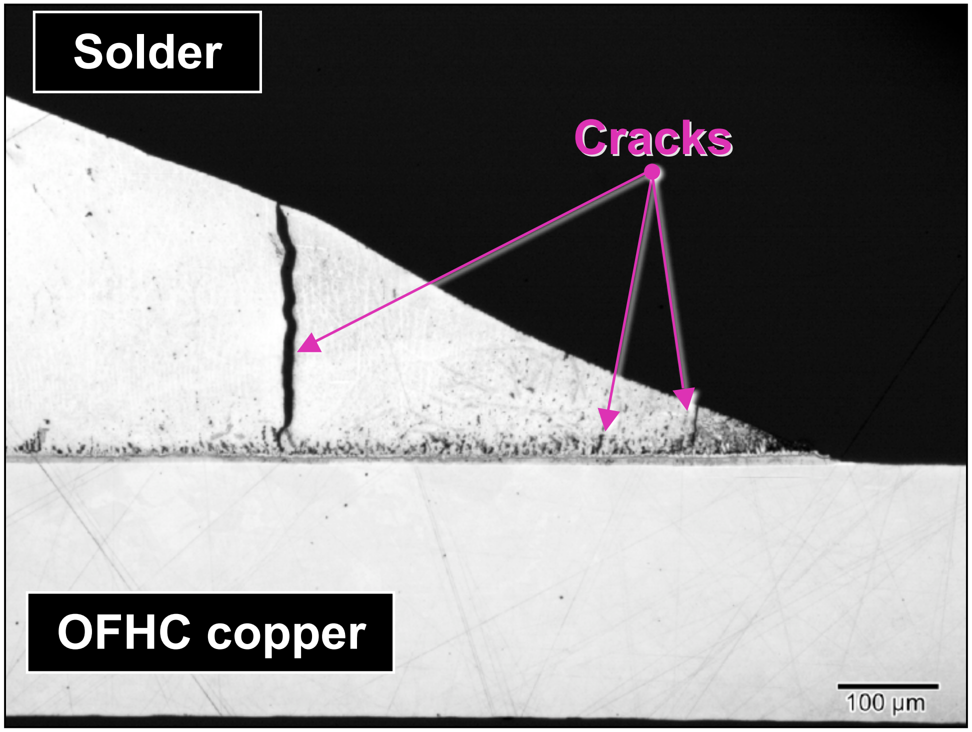
- Good integrity was observed at the 95Cd-5Sn/OFHC copper interface; however, cracking occurred at the 95Cd-5Ag/Ni interface of the Au-Ni plated Kovar™ base material.





Accomplishments

- **Similar interface cracks have been observed between Zn-based solders and Au-Ni plated Kovar™ base material.**
- **The Zn-based solders also exhibited “hot-cracking” due to the formation of low-melting, grain boundary phases.**



Accomplishments

- **Advanced interconnection technologies that are being explored, include transient liquid phase (TLP) bonding as well as nano-particle-based filler metals that allow ...**

- **Low melting temperature solder *alloys* for assembly process to limit thermal degradation of heat sensitive components**

- **High melting temperature solder *joints* to provide the long-term reliability needed at elevated service temperatures.**

Nano-particle-based solders may provide this capability at reasonable, per-unit cost.

Nano-sized particles melt at considerably lower temperatures than the bulk material.

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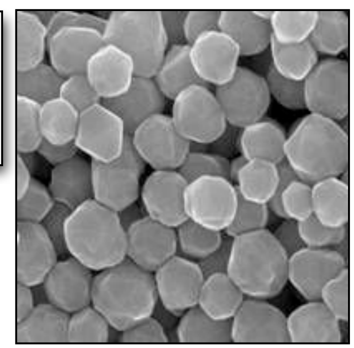
NDMaterials



200 nm Ni powder