Soldering Aluminum, A New Look

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Outline

- Introductions by Alan Gickler
  - why solder aluminum
  - what processes are available
  - what materials are used
  - details
- Manufacturing process by F. Larry LePrevost
  - heating method discussion
  - materials and methods
  - results
  - conclusion

General Discussion

- Why solder aluminum
  - less distortion vs. other fusion joining
  - low capital investment
  - ease of assembly
  - low production costs
  - repairable

Typical Applications

- Heat exchangers
- Electronic or electrical capacitors
- Light bulbs

  – note:

    - **none of these applications require high strength, but they do demand NO galvanic corrosion over time**

What Processes are available

- Fluxless
  - mechanical rubbing
  - ultrasonic bath
  - thermal spray
- With flux
  - induction
  - flame
  - infrared
  - hotplate
  - furnace
  - soldering iron
  - laser
  - arc lamp

What makes it difficult

- Oxide layer
  - remove by mechanical means
  - remove by flux
    - organic amine - up to 285°C
    - chloride or fluoride - up to 400°C
    - fluoroaluminate - above 550°C
- Additions to aluminum
  - magnesium
  - vanadium and chromium
- Difficulty of heating the joint
- Flux interferes with alloy wetting

Solders

- Tin/Zinc- soft solder
  - 92Sn/8Zn (eutectic)
  - 91Sn/9Zn, 80Sn/20Zn, 75Sn/25Zn, 70Sn/30Zn, 60Sn/40Zn
  - in literature
    - 90Sn/9.1Zn/0.6Al (eutectic), 76Sn/21Zn/3Al, 71.5Sn/25Zn/3.5Al, 67Sn/27Zn/3Al
    - 55Sn/33Zn/11Al/1Cu, 67Sn/17Zn/15Al/1Cu
- Zinc/Aluminum- hard solder
  - 98Zn/2Al
  - 97Zn/3Al, 95Zn/5Al (eutectic ?), 90Zn/10Al, 85Zn/15Al, 80Zn/20Al
- Tin/lead or cadmium bearing
  - **NOT RECOMMENDED**

Details

- Pre plate aluminum with nickel or zinc
- Solder to steel, copper, brass, stainless, …
  - different thermal expansion during and after soldering
  - how to heat both to correct soldering temperature
  - what flux to use
  - galvanic corrosion issues
- Heat the component not the solder
  - may involve heating the entire component to near soldering temperature and then applying local heat to the joint-
  - flux may expire before components are at soldering temperature- time is of the essence
- Remove flux residue after soldering
  - may still be reactive
  - can cause contamination of surrounding area
  - visual
- What is possible in lab may be difficult in production

It's Always this Complicated

Noted Contributors:

Ford AMTD - Plasma

Ford Norwood - Thermal Spray

Robotron - Induction

Rofin-Sinar - Laser

ORNL / Vortek - Plasma IR Lamp

Mother Nature's Requirements

- Best understood by observation, reason and experiment
- Experiments tests our knowledge, so allow sufficient time for trial & error
- Forces at work: chemical, electrical, mechanical, physical, thermodynamic, gravity and optics (all overlapping)

From a Chemical Viewpoint

- Type of product and Its end use
- Susceptibility to galvanic corrosion
- Using flux, or swaging (fluxless) method of soldering
- Complete removal of flux residue

The Physical Prospective

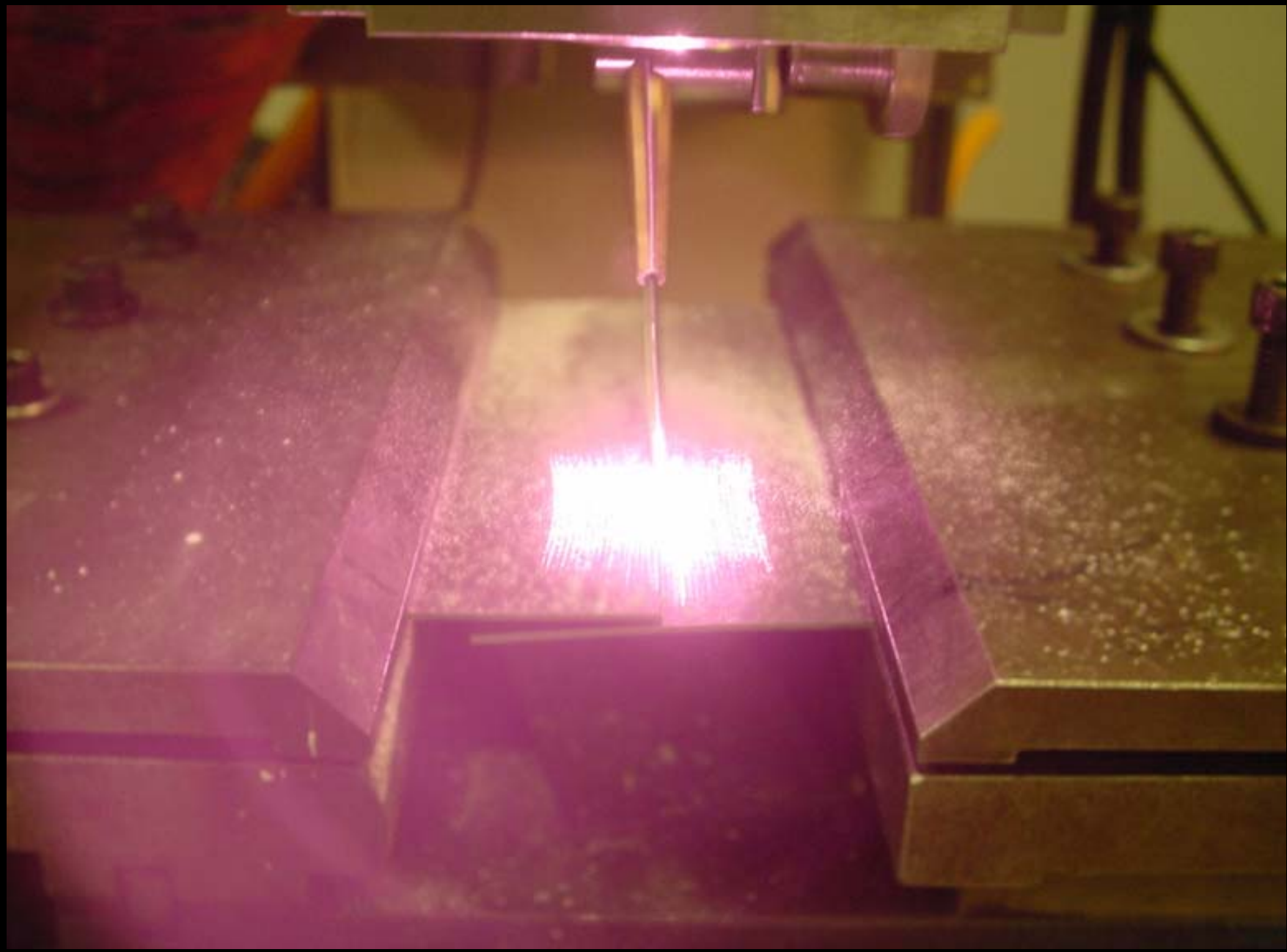
- Alloy of aluminum parts being joined
- How were parts formed, stresses
- Thickness of materials to be soldered
- Joint design and strength requirement
- Does shape permit uniform heating

Thermodynamic Factors

- What type(s) of heat are best suited for production environment
- Adequate VOLUME of heat must be supplied to all parts simultaneously
- Control of heating and cooling rates to minimize, realloying and warping

Heating Methods

- Hot plate, Iron, open-flame, torch
- Oven, vacuum, atmosphere, air
- Heat by induction
- Diode or YAG laser
- Plasma IR lamp
- Plasma arc spray



Over Heating

- Too much time / temperature
- Warping of light gage materials
- Stress relieving, annealing
- Hot cracking
- Re-alloying of parent material
- Dreaded melt down

Hybrid Heating

- Volume of primary heat, to prevent loss
- Specific or localized heat, brings parts and filler metal to soldering temperature in a controlled fashion

Hot Plate & Torch Combo

- Combining the generalized heat of a hot plate with specific heat from a torch is usually very effective in the laboratory.

Plasma IR, Best of Show!

- High density infrared heat source demonstrated successful results with 80Zn/20Al at 490°C
- Joint is stronger than parent material
- Minimum annealing, softening of metal
- No hot cracks in tests with IR heat

Plasma Arc Lamp Hard Solder

- Good penetration of Zn/Al through underside of joint
- Very few voids found in joint
- Dendritic structure of solidified Zn/Al
- Aluminum rich precipitates in Zn-Rich matrix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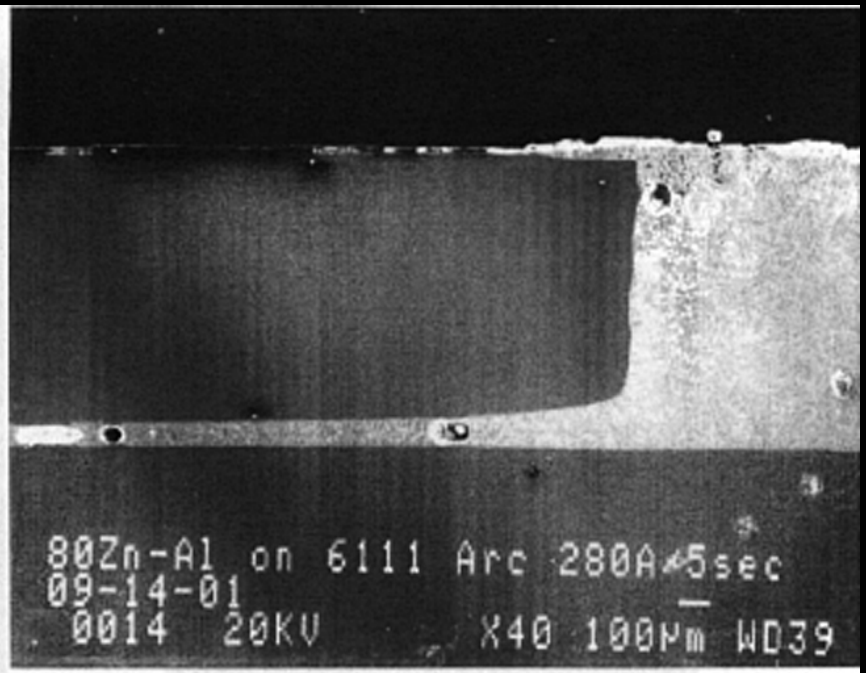
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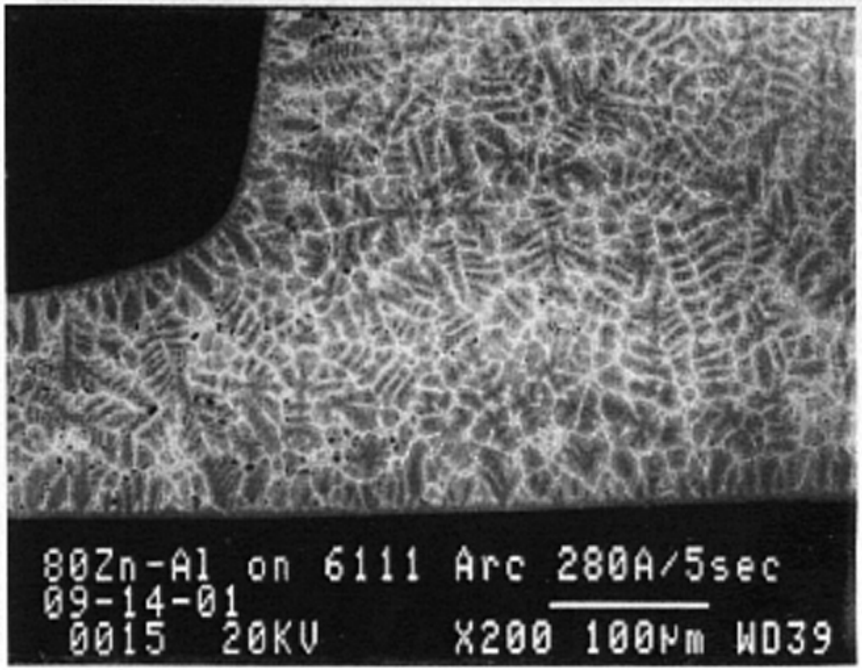
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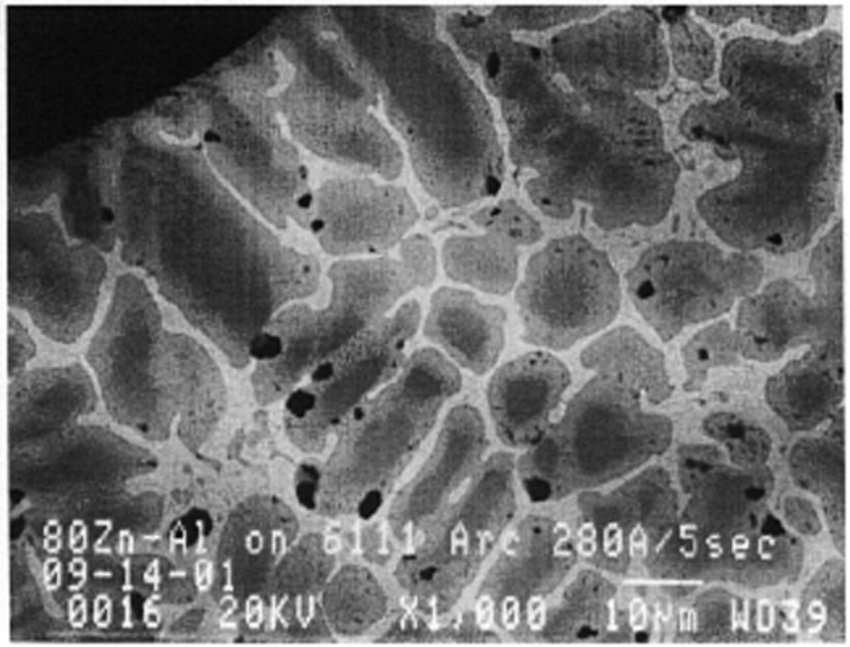
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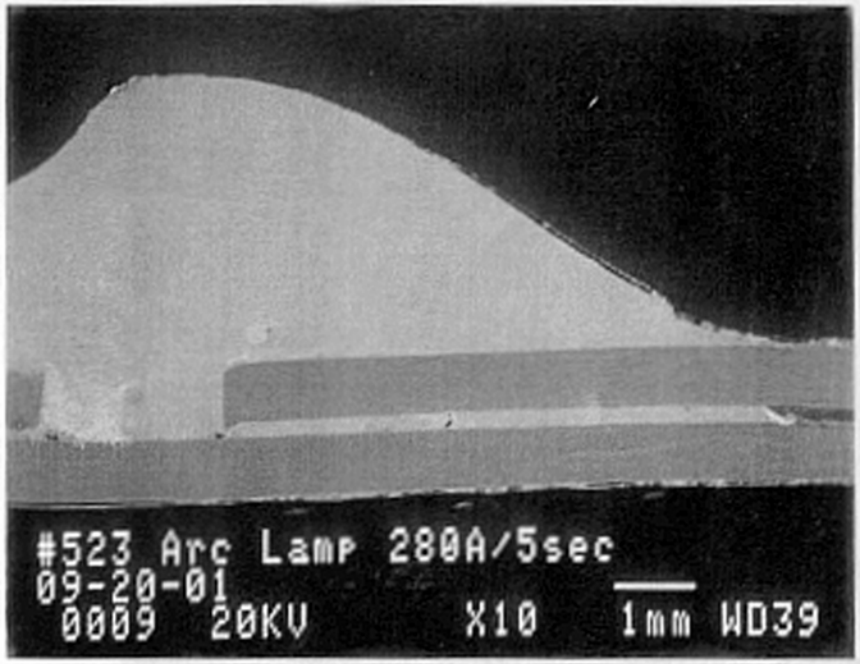
Plasma Arc Lamp Body Solder

- Good flow of solder into overlapped joint region
- Good viscous “bump” of solder above joint for seam filling
- Cu_6Sn_5 intermetallics in Sn matrix in solder (typical)
- Almost no separate layer near interface with Zn/Cu in Sn matrix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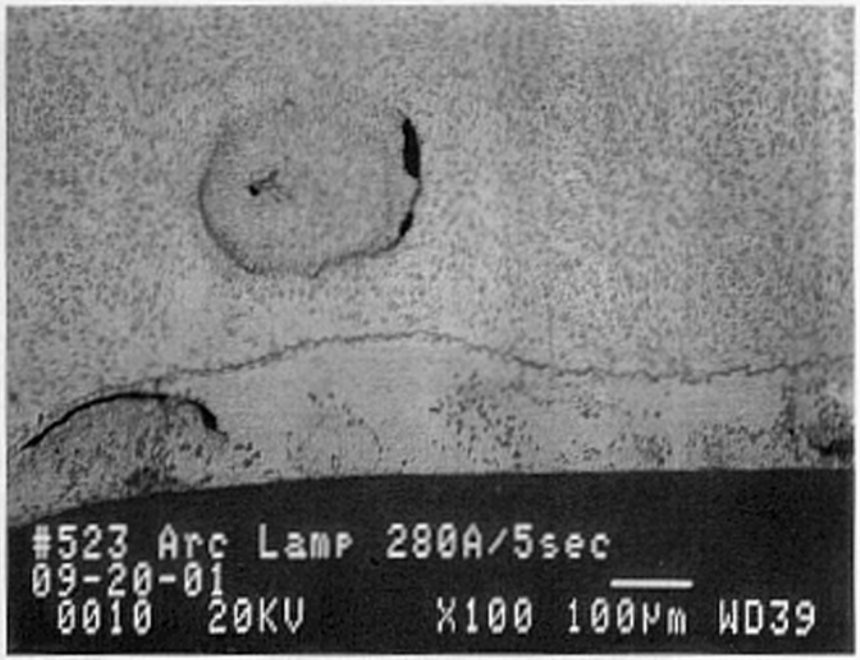
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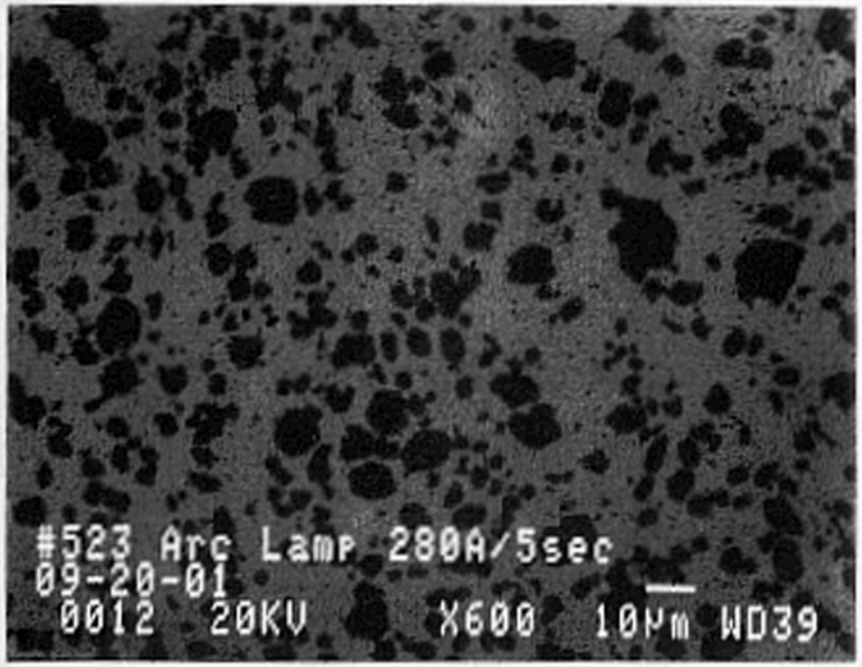
528 Alloy
280/5sec


#523 Arc Lamp 280A/5sec
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0012 20KV X600 10µm WD39

JOHNSON'S #523 LEAD-FREE SEMI SOLID BODY SOLDER ALLOY 82Sn/15Cu/3Zn, MELTING TEMPERATURE 428 - 940 F as determined by DTA at Ford Research Lab USED BY FORD AND OTHER AUTO ASSEMBLY PLANTS

#524 EXPERIMENTAL SEMI SOLID BODY SOLDER ALLOY 85Sn/12.5Cu/2.5Zn, NARROWER MELTING RANGE Estimated 428 -880 F EXHIBITED MOST SLUMP OF THE SOLDERS TESTED

#527 FORD BODY SOLDER ALLOY 80.3Sn/16.7Cu/3Zn, WIDER MELTING RANGE Estimated 428 - 980 F USED BY FORD DEARBORN EXHIBITED LEAST AMOUNT OF SLUMP OF SOLDERS TESTED

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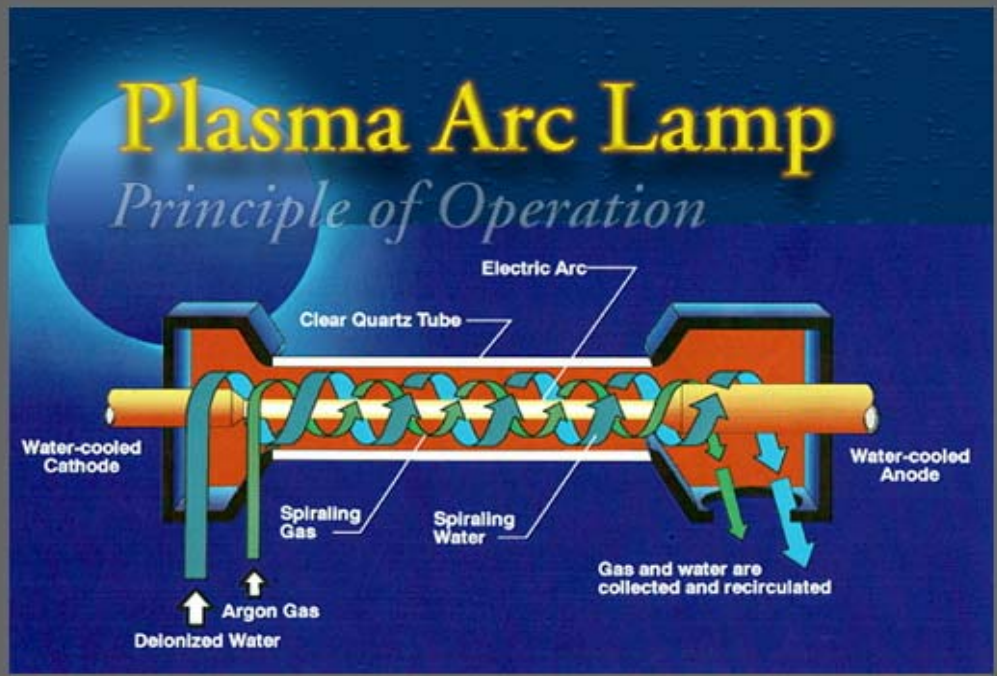
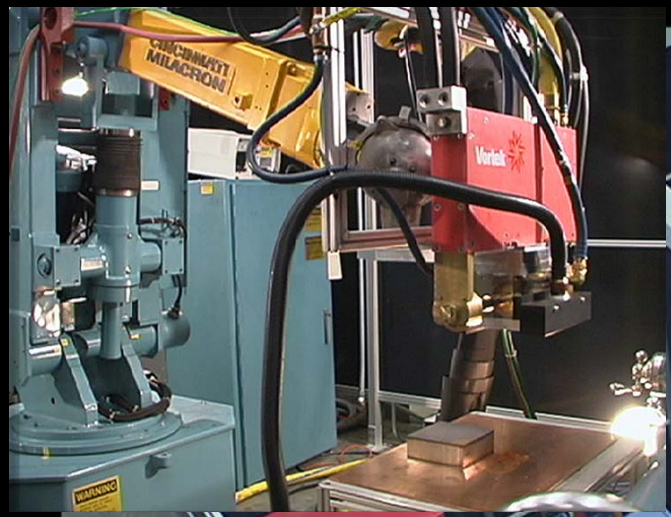
Plasma Arc Lamp Operation



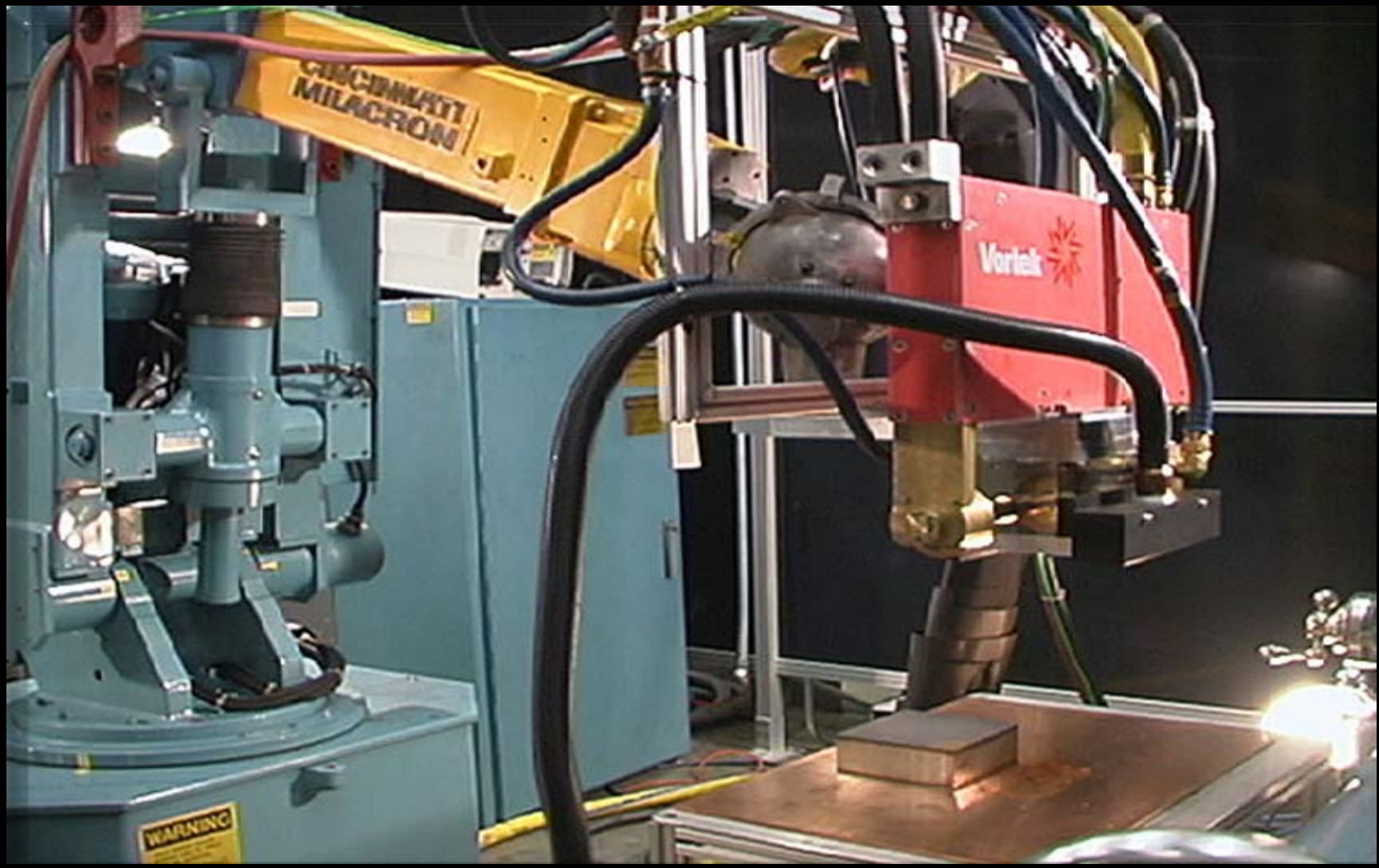
Plasma Arc Lamp Facility



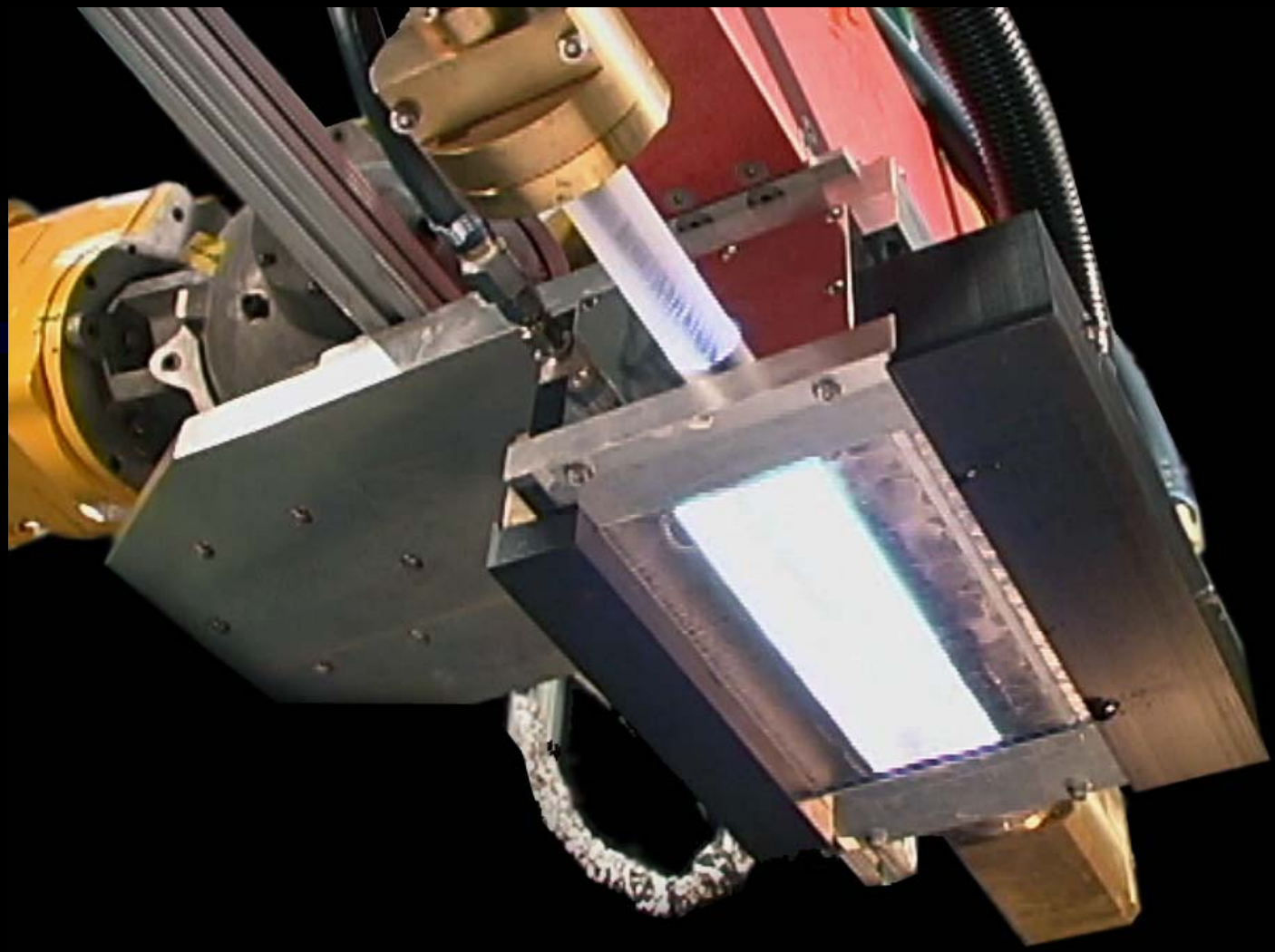
Plasma Radiant Source

- Single source is 300,000 watts.
- Radiant output is short wavelength, 0.2 – 1.4 microns.
- Wavelength constant and independent of power level and anode/cathode wear.
- Lamp can run from 2% to 100% of available radiant output.
- Able to change power levels in less than 20 milliseconds.
- Conversion of electrical into radiant energy in excess of 55% efficient.
- Power can be delivered in a scan mode as wide as 35 cm, presently.
- Ability to tailor reflector design to specific processing needs.
- Three separate plasma heads are available at ORNL, 10, 20 and 35 cm arcs.

Manipulation of the Plasma Arc Lamp



Water Window Technology for Lamp Survivability



Summary

- A new high density infrared processing facility has been installed at ORNL
- The facility is state of the art and fully instrumented
- This is the most powerful Lamp in the world and has been designed for materials processing research.
- ORNL is looking for new applications

For More Information

- “Aluminum Soldering, A New Look” IBSC 2003 Conference CD
- “High Density Infrared Processing: Opportunities in Aluminum,” by Dr. Craig A. Blue - The Aluminum Association, Inc. www.aluminum.org