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# Wire Bonding & Ultrasonic Smart Welding for Space Applications



- **This paper will outline design guidelines for:**
- **Wire Bonding Batteries for Space**
- **Ultrasonic “Smart Welding” Batteries and Solar Panels for Space**

# Interconnect Technologies

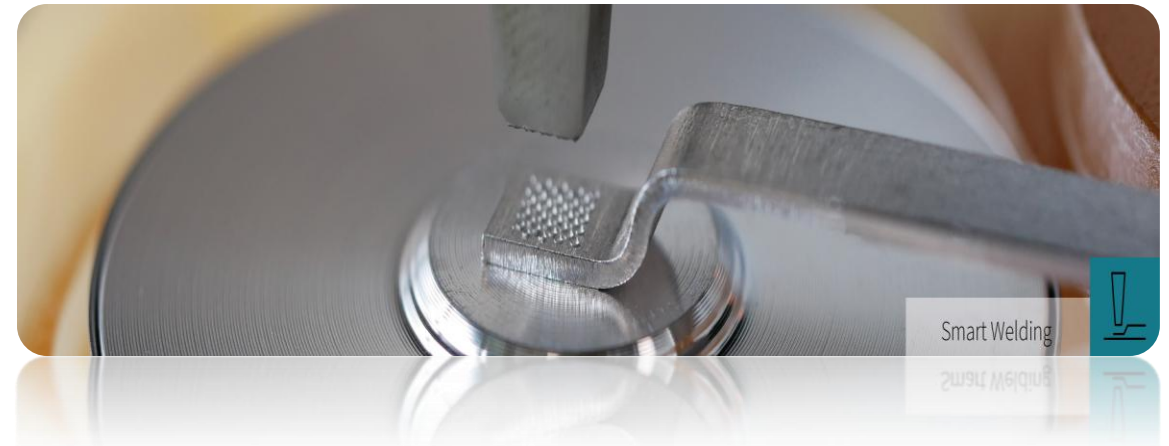
## What is Wire Bonding?

- A solid-state welding process
- Creates a point-to-point electrical connection through a conductive wire or ribbon
- Ideal for small pads and dense layouts



## What is Smart Welding?

- A solid-state welding process
- Joins larger cross-sections (foils, busbars, tabs)
- Ideal for high current paths



# Overall Wire Bonding Guidance

- A simple and repeatable design allows for tighter process control
- Current collectors, cells, and cell housing should be rigid, with coplanarity within each component group (cells and busbars), and fixed as much as possible in XYZ and Theta
- Keeping bonding surfaces clean
- Ample loop profile



*Courtesy of CSULA*

# Current Collector Design Guidelines – Wire bonding

## We recommend PCBs, Aluminum Busbars, or Nickel-Plated Copper Busbars

### ■ PCBs

- A PCB thickness of around 60-93mils is recommended for rigidity.
- ENIG or ENEPIG plating are off the shelf chemistries that are excellent for wire bonding
  - Refer to spec IPC 4452 and IPC 4456, respectively.
  - Request that platers uses a mid-phos chemistry

| Thickness      | ENIG            | ENEPIG              |
|----------------|-----------------|---------------------|
| Electroless Ni | 3-6 micrometers | 3-6 micrometers     |
| Gold           | 0.5 micrometers | 1.0 micrometers     |
| Palladium      | N/A             | .05-.15 micrometers |

### ■ Aluminium

- Half-hard temper is preferred
- 1145 or 3003 are among the best options
- Keep the overall thickness of the busbar between 1-3 mm
- Al surface should be free of scratches, pits, and dents

### ■ Nickel Plating

- Mid Phosphorus content 6-9%
- Zincate process before Ni-plating to improve adhesion, especially for Al Substrates



*Courtesy of Univ. of Alabama*

# Current Collector Design Guidelines – Smart Welding

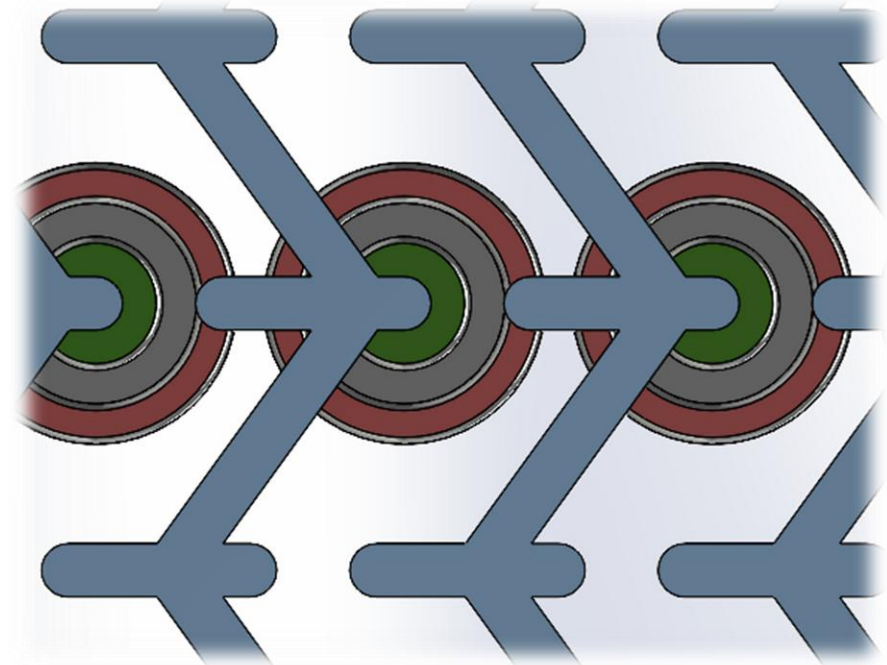
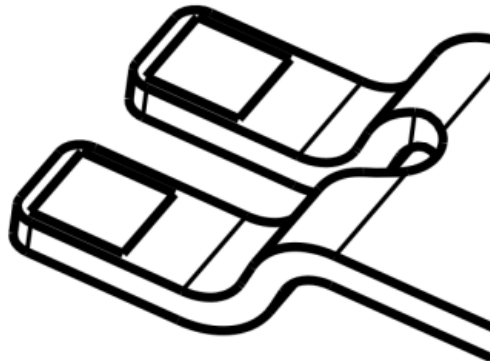
We recommend an aluminum tab overlay or S-shaped Al lead frames

## Thin-film Al (100-400um)

- Half-hard temper is preferred
- 1145 or 3003 are among the best options

## Lead Frame Al (500-1000um)

- Up to 5x5 mm lead area
- Aluminum that is very soft and has high ductility
- 20-45HV



# Plastic housing guide

## Plastics for injection molding

- PTS PBT 30% Glass filled
- Lexan FR resin
- Polypropylene

## Plastics for Machining

- G11/FR5
- Delrin
- Nylon 6 30% glass filled

## Plastics for 3D printing (SLS preferred)

- PEEK
- Nylon 12
- PA6-GF

The base of the module should be flat. This allows the module to be easily fixtured on work holders and prevents it from “rattling” or “rocking unevenly”.



# Adhesives for maintaining a fixed cell

**It is recommended to add adhesive to the top and bottom of the cell for optimal rigidity.**

- Recommend using low-off-gassing adhesives
- Avoid using silicone-based adhesives
- Adhesives that interact well with both plastic and metal

## **Recommended Adhesives**

- Loctite AA 3979 - 1 component, UV light cure acrylic – great option if the battery cell holder is clear
- Loctite AA H3500- 2-component, room temperature mix cure – recommended option if heat cure or UV light cure is not doable
- Loctite EA 9394 – 2-component, room temperature cure, epoxy paste
- Loctite EA E-20HP – 2-component, room temperature cure

## **Adhesive to avoid**

- Super glue with kicker (adhesive activator)

## Fixing PCBs and Busbars

### ■ PCB

- Using a strong VHB tape proven to work for PCB to cell housing
- Adhesives can also be used and have shown the best results
- Fasteners are also optimal but require strategic placement to minimize deflection points while accounting for possible collisions with the wire bonding tools



*Courtesy of Ohio State Univ.*

### ■ Busbars

- Adhesive has proven to have the best results
- Finding an adhesive that holds well to metal and plastic is required
- Fasteners should be as flush as possible to busbar height. This allows for optimum bond head clearance



*Courtesy of Clemson Univ.*

# Bonding Wire (be careful with 5 9's Al wire)

- Aluminum bonding wire or ribbon is recommended.
- Wire size will depend on fusing current needed for battery module.
- Hesse Mechatronics typically uses Tanaka or Heraeus wire for battery module bonding. Check in for availability of wires.
  - Refer to Tanaka or Heraeus website for further information.
  - Wires can be provided prior to bonding for conducting fuse studies (recommend).

|                     |                            |                    |       |       |         |        |        |
|---------------------|----------------------------|--------------------|-------|-------|---------|--------|--------|
| Aluminum Al Ribbon  | 4N<br><a href="#">TABR</a> | 750 x 100 um       | -     | -     | 24.0 A  | 16.4 A | 10.6 A |
|                     |                            | 1000 x 100 um      | -     | -     | 32.3 A  | 21.8 A | 14.2 A |
|                     |                            | 1500 x 100 um      | -     | -     | 48.5 A  | 32.7 A | 21.2 A |
|                     |                            | 1500 x 200 um      | -     | -     | 97.0 A  | 65.4 A | 42.5 A |
|                     |                            | 2000 x 200 um      | -     | -     | 129.4 A | 87.3 A | 56.7 A |
| Aluminum Power Wire | 4N<br><a href="#">TANW</a> | Ø100 um            | -     | -     | -       | -      | 2.9 A  |
|                     |                            | Ø200 um            | -     | -     | -       | -      | 7.0 A  |
|                     |                            | Ø300 um            | -     | -     | 22.8 A  | 16.0 A | 12.9 A |
|                     |                            | Ø400 um            | -     | -     | 40.6 A  | 25.8 A | 19.7 A |
|                     |                            | Ø500 um            | -     | -     | 63.5 A  | 40.4 A | 28.9 A |
| Alloy               | Wire Type Type             | Wire Diameter Ø um | 2.0mm | 4.0mm | 6.0mm   | 10mm   | 20mm   |

 **Tanaka**

**Heraeus** 

| Wiretype | Wirelength (mm) | Fusing current (A) |        |        |        |        |                           |                           |
|----------|-----------------|--------------------|--------|--------|--------|--------|---------------------------|---------------------------|
|          |                 | 203 µm             | 254 µm | 304 µm | 380 µm | 500 µm | 2.00x0.20 µm <sup>2</sup> | 2.00x0.30 µm <sup>2</sup> |
| ALW49C   | 5 mm            | 13,9               | 21,2   | 29,8   | 45,9   |        |                           |                           |
| ALW49C   | 10 mm           | 10,7               | 16     | 21,8   | 33,6   |        |                           |                           |
| ALW49C   | 15 mm           | 9                  | 12,7   | 16,8   | 25,4   |        |                           |                           |
| ALW49C   | 20 mm           | 8,5                | 11,9   | 15,5   | 22,4   |        |                           |                           |
| AI-CR    | 5 mm            | 14                 |        |        | 44,6   | 71,6   | 145,0                     | 219,0                     |
| AI-CR    | 10 mm           | 10,7               |        |        | 33,4   | 50,2   | 102,0                     | 153,0                     |
| AI-CR    | 15 mm           | 8,9                |        |        | 25,3   | 40,5   | 82,0                      | 123,0                     |
| AI-CR    | 20 mm           | 8,2                |        |        | 22,1   | 34,4   | 72,0                      | 105,0                     |

## Cleanliness

### All bonding areas must be kept clean for optimal bonding results

- It is recommended wearing gloves during module assembly
- Clean any bonding areas immediately if adhesive seeps into bonding or welding areas.
  - 90%+ Isopropyl works well

### Hesse has laser ablation capabilities. This has proven to be the optimal approach for cleaning cylindrical cells.

- Please note that laser ablation is meant to clean light contamination. It cannot remove cured adhesives
- See UCI-Hesse paper regarding laser ablation on cylindrical cells



# General Guidelines – Bond Quality Guidelines

- Hesse recommends using the JEDEC wire bond standards as your wire bond quality document for pull, shear, and visual requirements
  - <https://www.jedec.org/standards-documents/docs/jesd-22-b116a> Shear Test
  - <https://www.jedec.org/standards-documents/docs/jesd22-b12001> Pull Test
- In Germany, there is the DVS-2811 German Welding Specification
  - We use this standard for smart welding quality verification
- We recommend building 1 module solely for developing parameters
- The development module can be a partial module if it is built the same way as a full-sized module

# Smart Welding of Batteries and Solar Panels

Smart Welding can be done for battery or solar panels for Space.

The welding of batteries will follow the guidelines for wire bonding.

However, Smart Welding of solar panels is an entirely different challenge. Material selection on the solar cell and busbar is extremely critical.



# Shipping Lithium-Ion Batteries (within the U.S.)

Shipping modules are extremely nuanced and should be reviewed

- We recommended reviewing the following regulations and rules:
  - UN3480
  - 49 CFR (Department of Transportation)
  - IATA
- UPS/FedEx normally requires approval or certifications to ship Dangerous Goods
- Freight shipments tend to be more lenient

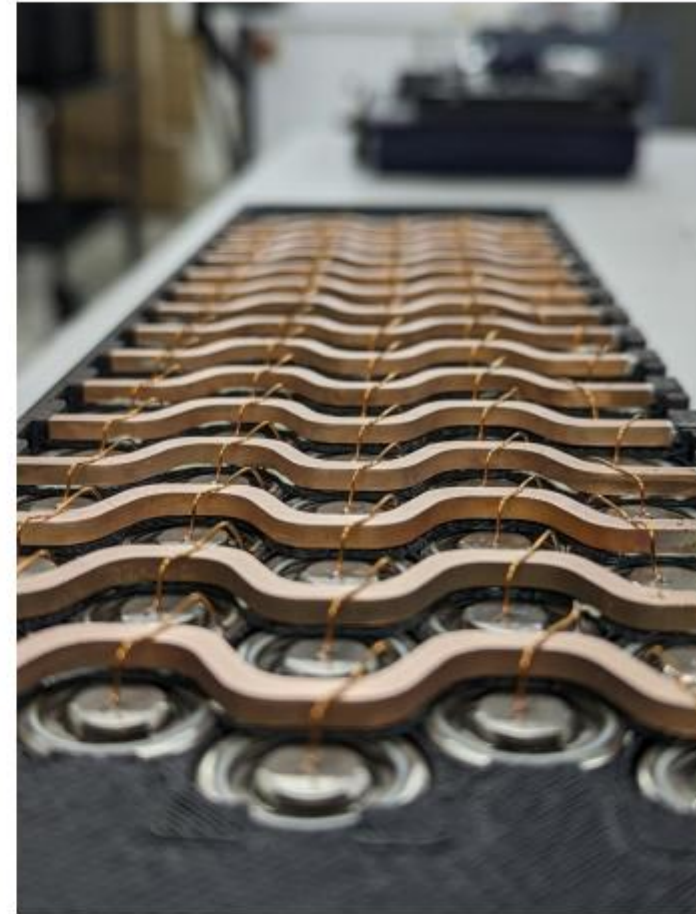


# Conclusions

Shipping batteries is a challenge. Make sure your Shipping Department is certified.

Wire bonding for batteries for Space is done everyday. Al ribbon is now gaining popularity.

Smart Welding solar panels for Space is not as common as wire bonding batteries. Each application is unique.



*Courtesy of Uni CA Riverside*

**Thanks for your kind attention!**

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