Soni-Laser

Ultrasonic assisted laser welding for high volume assembly of automotive battery packs

CARRS
WELDING TECHNOLOGIES LTD

SONI-LASER

Brunel University London

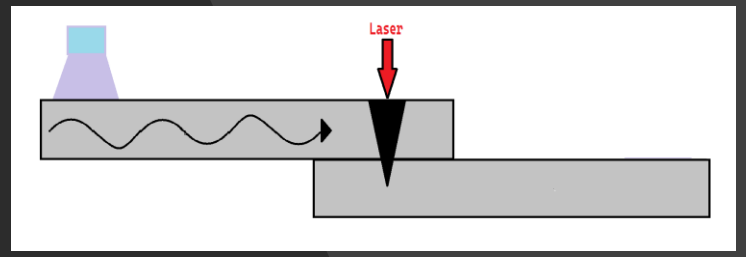
UKRI Innovate UK

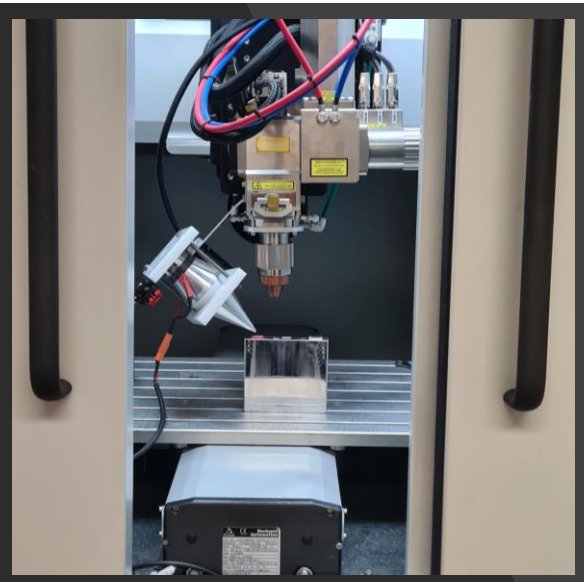
EPIC Laser applications along Battery manufacturing process at ARENA2036.

24th October 2023

Soni-Laser

Innovate Project for Carrs and Brunel University London





Aim:

- Using non-contact Power-Ultrasonic Vibration Treatment subsystem that assists the laser welding process of EV batteries and enhances the integrity and quality of the welds.

- Reduce residual stresses, along with a 10% improvement in mechanical properties (e.g. strength, elasticity) of the battery weld, due to grain refinement and phase distribution

- 30% mitigation of intermetallic compounds reducing brittleness. Improving mechanical strength and impendence

Summary

- Introduction to Soni-Laser
- Contact Ultrasonic Treatment
  - Aluminium Lap weld analysis
  - Copper to Aluminium Analysis
- Contactless Ultrasonic Treatment
  - Aluminium Lap weld analysis
  - Copper to Aluminium Analysis
- Micro/SEM/EDX analysis
- Cell Welding
- Q&A

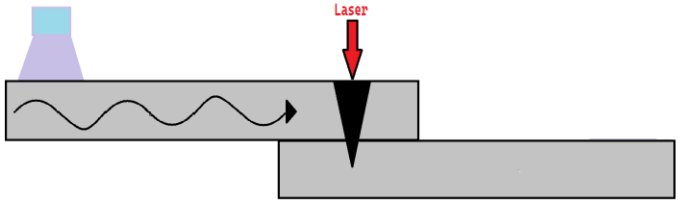
Contact Ultrasonic Treatment - Lap Weld Aluminium

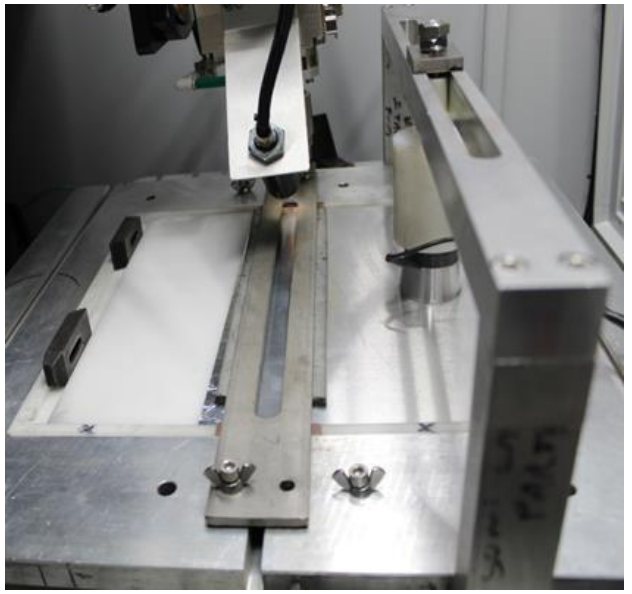
Ultrasound (Contact) Vs Baseline

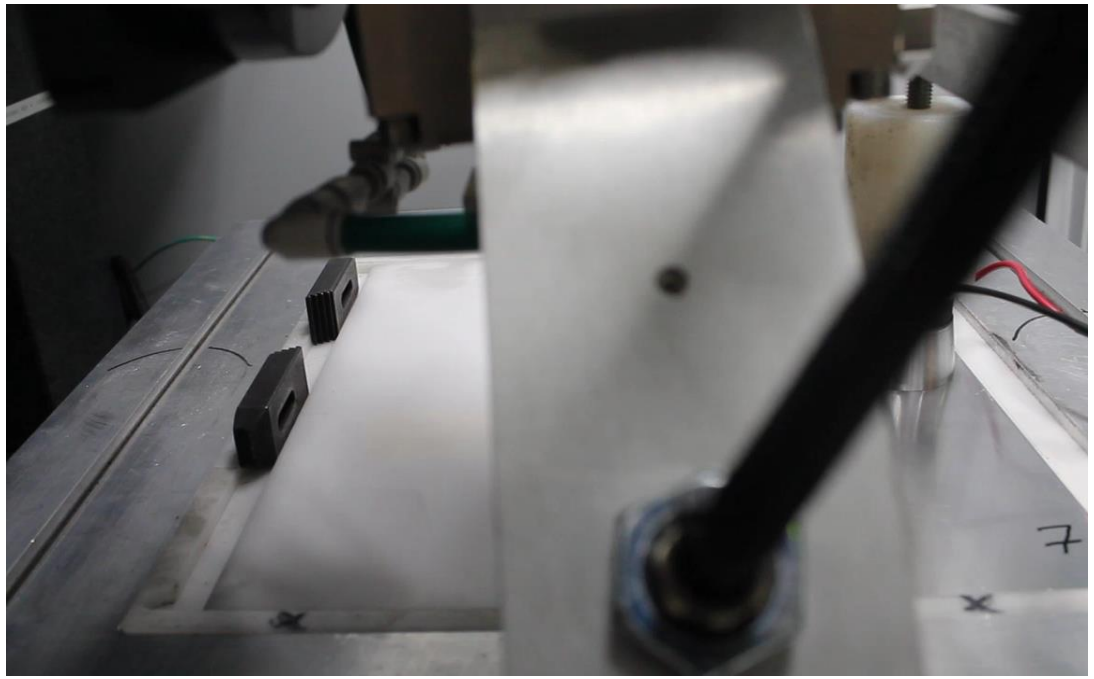
- Al3003 to Al3003
- Al1050 to Al1050

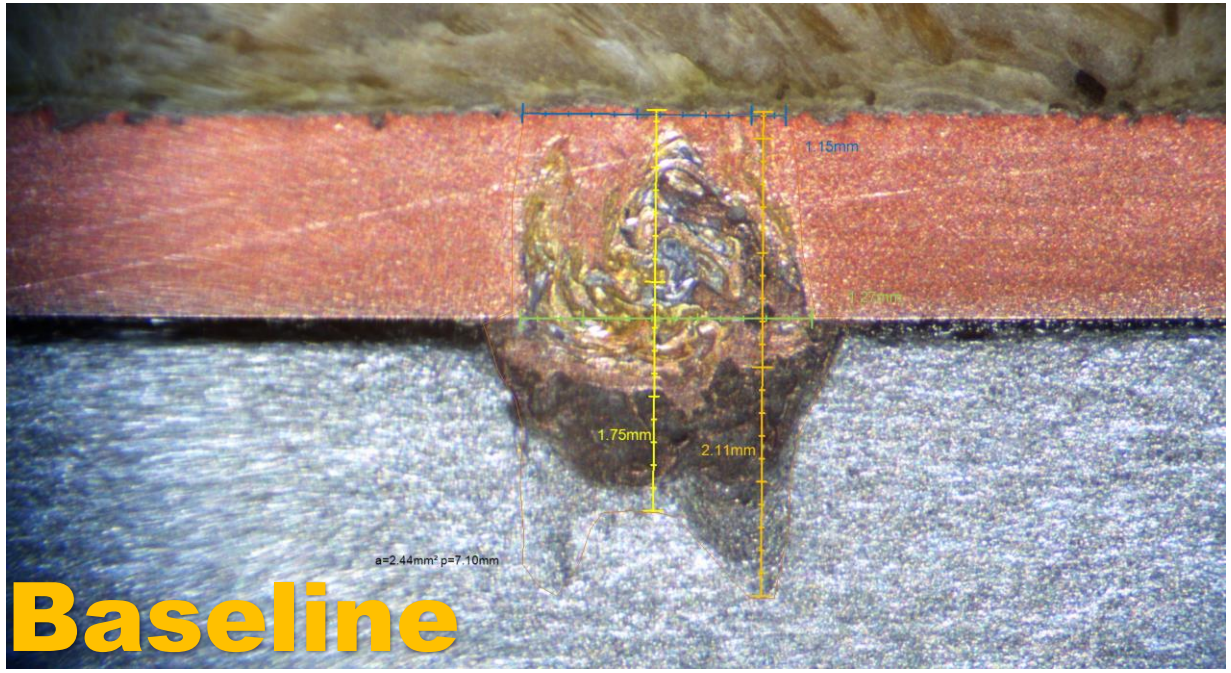
Trials

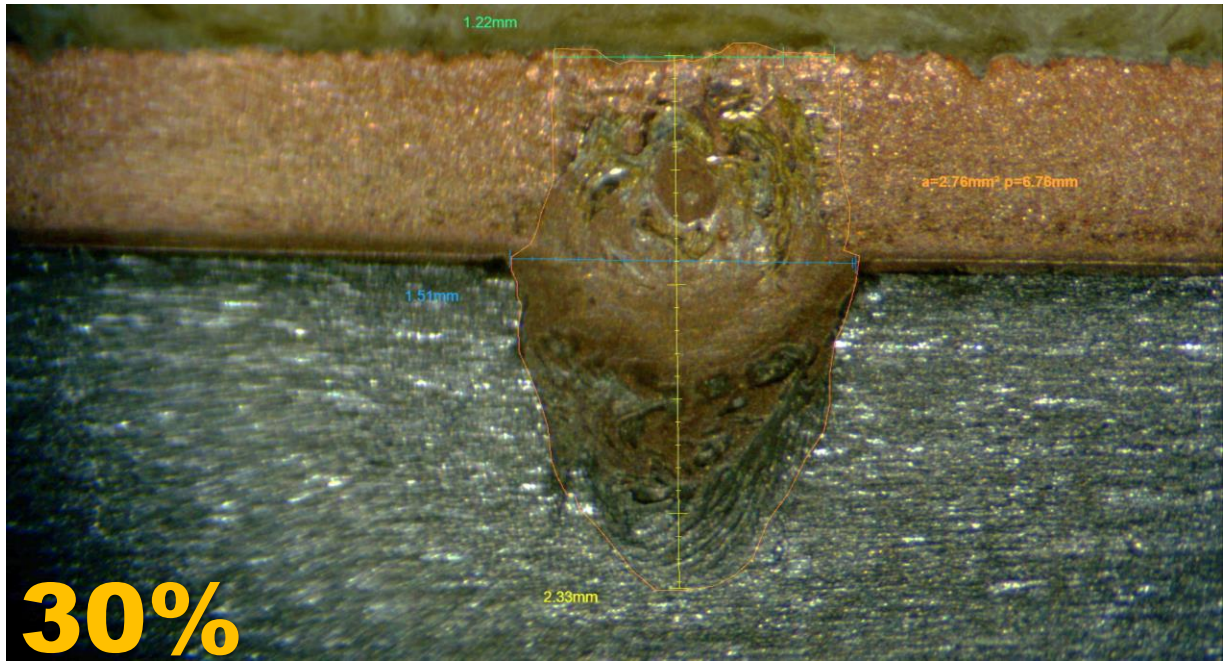
- Two 150x300mm plates overlapped at 25mm
- Trial to compare Baseline vs Ultrasound
- Variables
  - Transducer Power
  - Frequency > 20kHz
  - Heat input

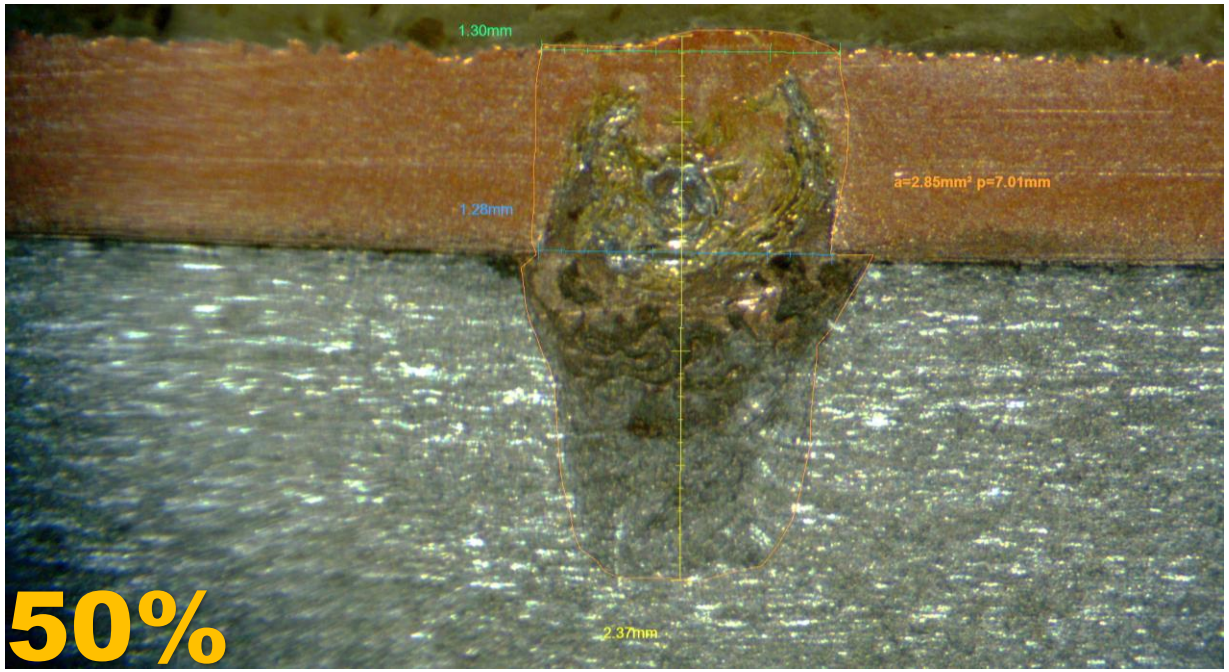


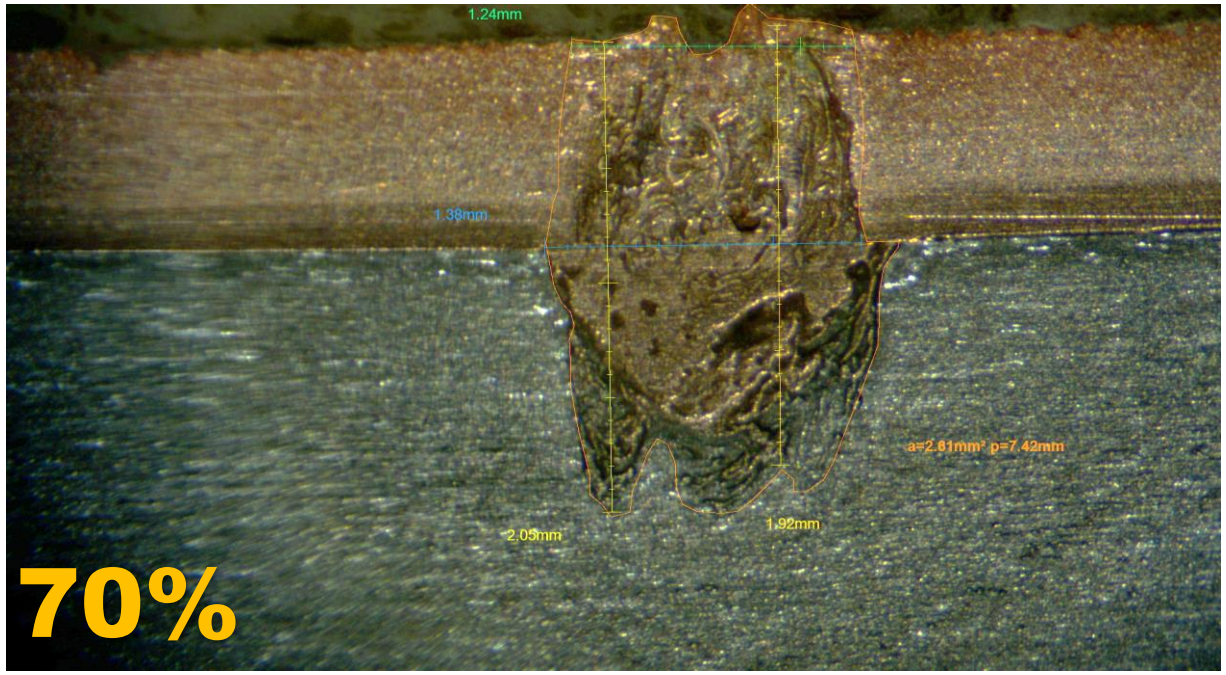





1.15mm
1.27mm
1.75mm
2.11mm
a=2.44mm² p=7.10mm
Baseline

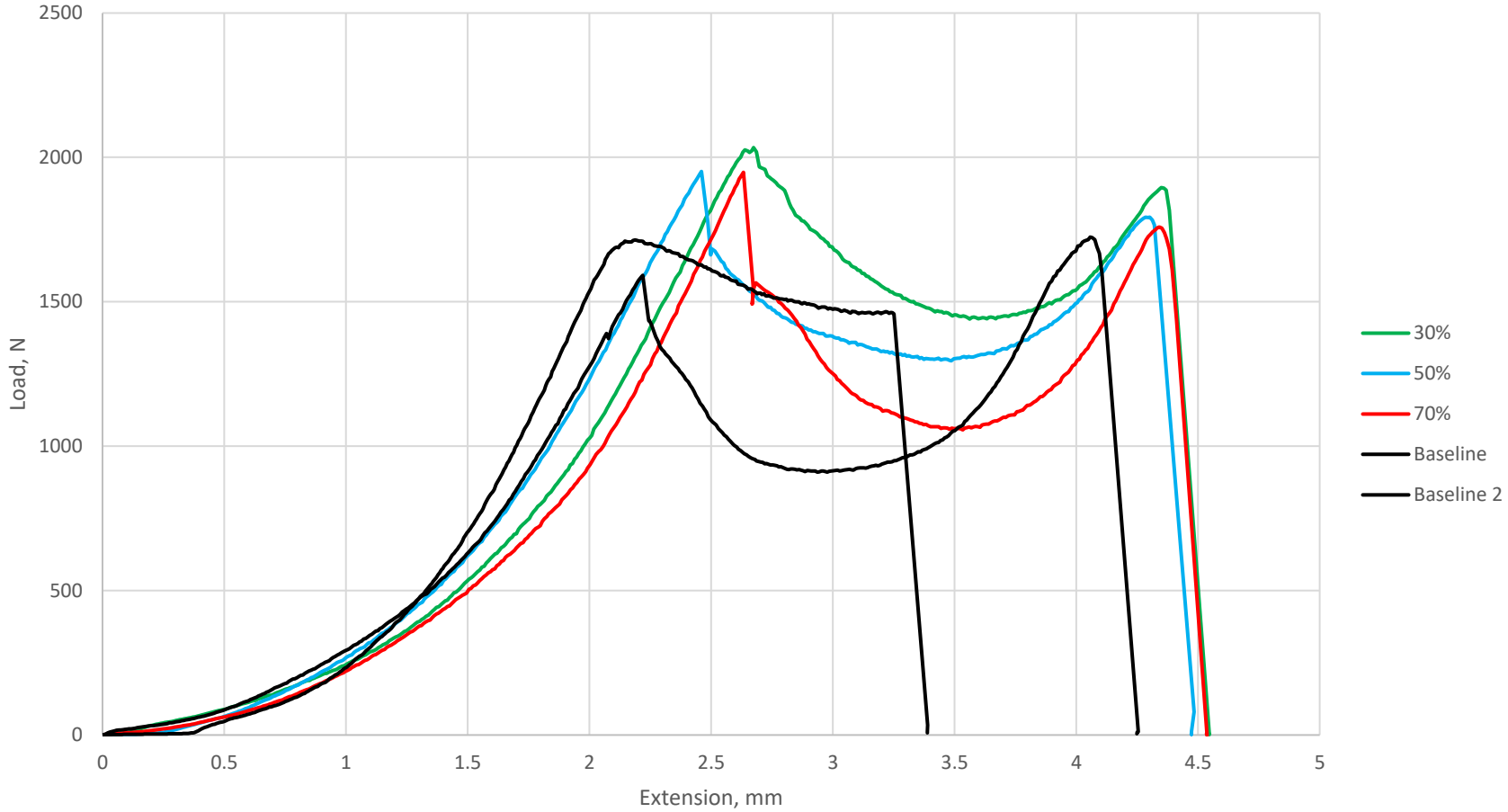

1.22mm
a=2.76mm² p=6.78mm
1.51mm
2.33mm
30%


1.30mm
a=2.85mm² p=7.01mm
1.28mm
2.37mm
50%


1.24mm
1.38mm
a=2.81mm² p=7.42mm
2.05mm
1.92mm
70%

Copper to Aluminium Testing

US Power comparison, Med Freq.		
US Power	Average Load,N	Load Rank
30%	2039	1
50%	1901	3
70%	1931	2
Baseline	1720	4

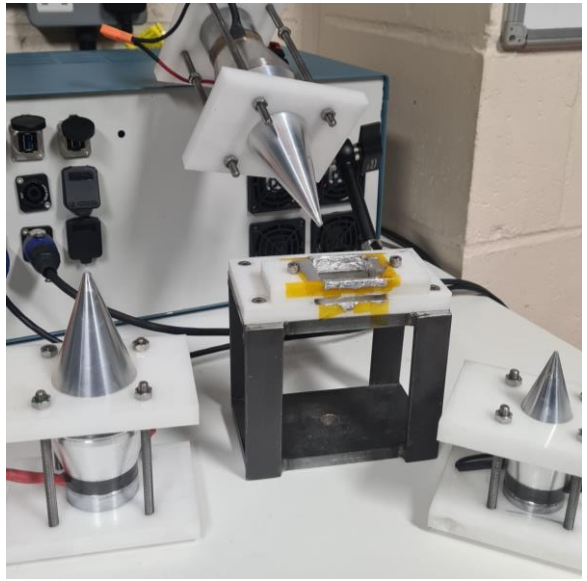


Conclusion

- Pull test shows improvement to the strength and ductility
- Evidence from the macros, shows good conditions for 30% US power at medium frequency
- Evidence of over cavitation in high US power as seen with Al3003 and Al1050
- The hardness of the alloy produced will render the weld unsuccessful

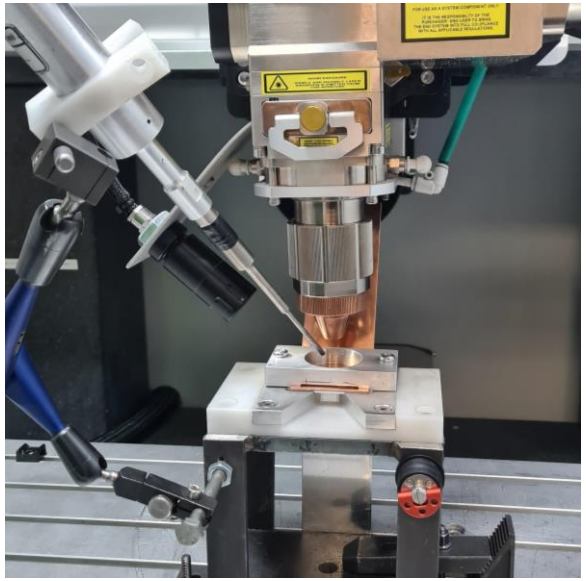
Contactless Ultrasonic Treatment – Lap Weld Peel Test Jig

- Ultrasound (Contactless) Vs Baseline
  - Al1050 to Al1050
  - Cu101 to Al1050
- Trials
  - Positioning Trials
  - Configuration Trials
  - Freq/Power Trials



Focused Horn

Taper Horn



Needle Horn

Al1050 – Al1050 Welding

Welding Assumptions

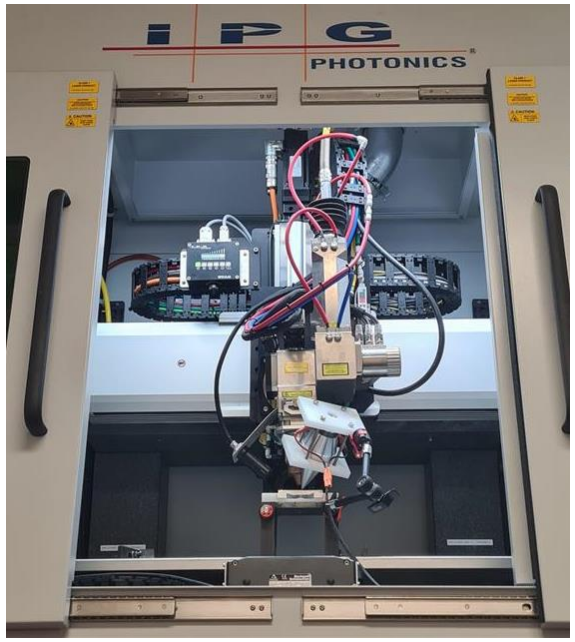
- Material: Aluminium
- Single Plate Dimensions: 50x50
- Laser Type: YLS – 6000 CT
- Laser Used: IPG
- Laser Fibre: 0.1 mm
- Shielding Gas: Argon (99.99% purity) – 86 L/min
- Weld Type: Lap Weld/Stake Weld
- Target Weld Depth: 2mm-4mm
- Wobble: No Wobble

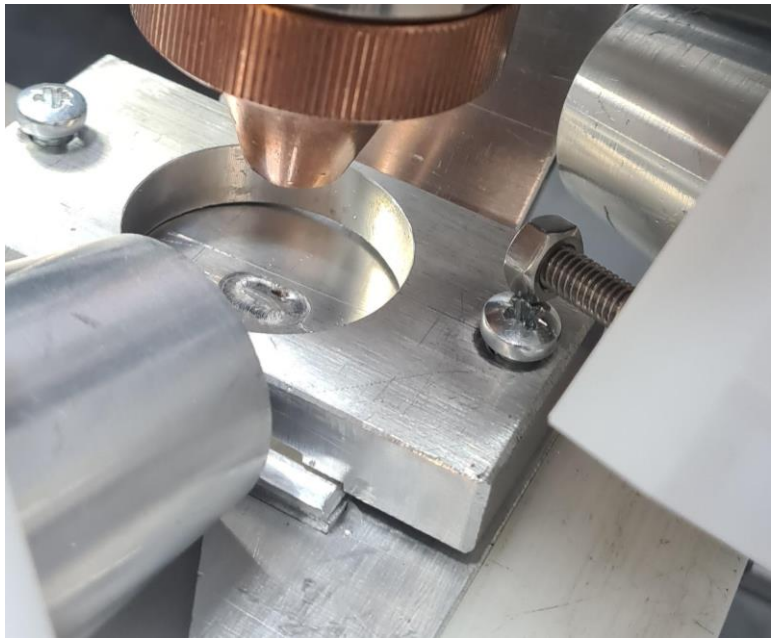
Peel Test Jig

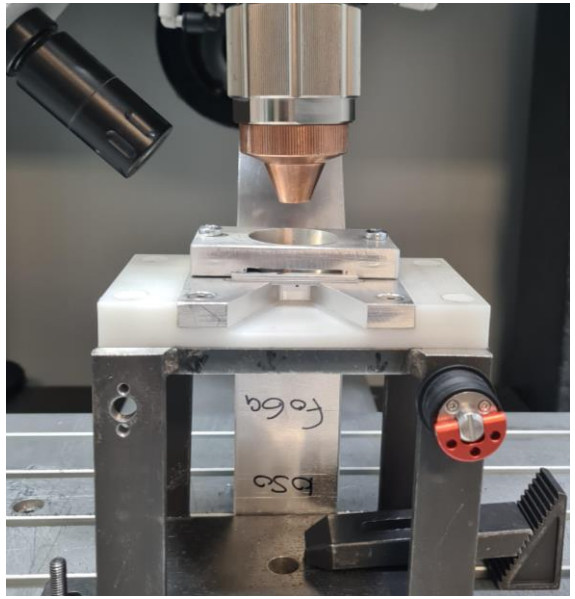
- Steel Base
- Acetal Interface - To minimize wave propagation
- Aluminium Protection with air gap - To protect acetal board from laser radiation

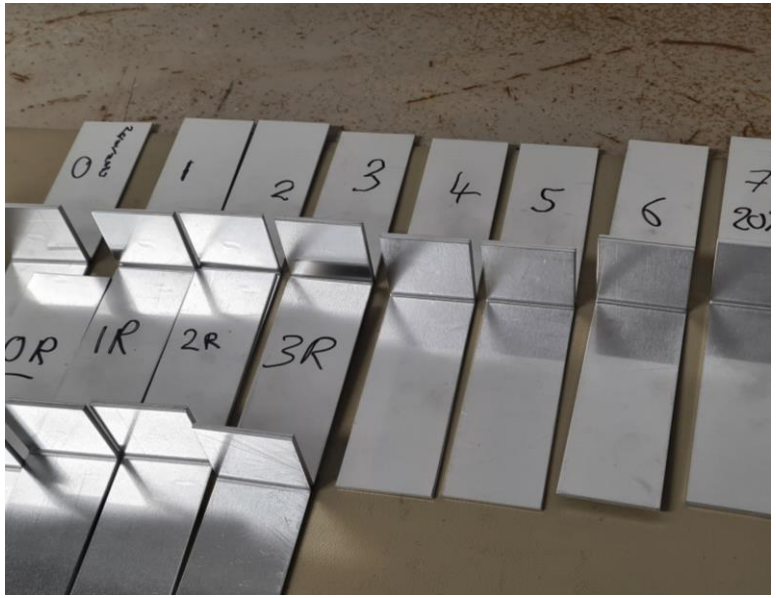
Trials

- Ultrasound (Contact) Vs Baseline
- Testing different variables (Freq., Power, configuration etc.)
- 2 x 2mm L shaped plates
- Oval Weld, 5mm



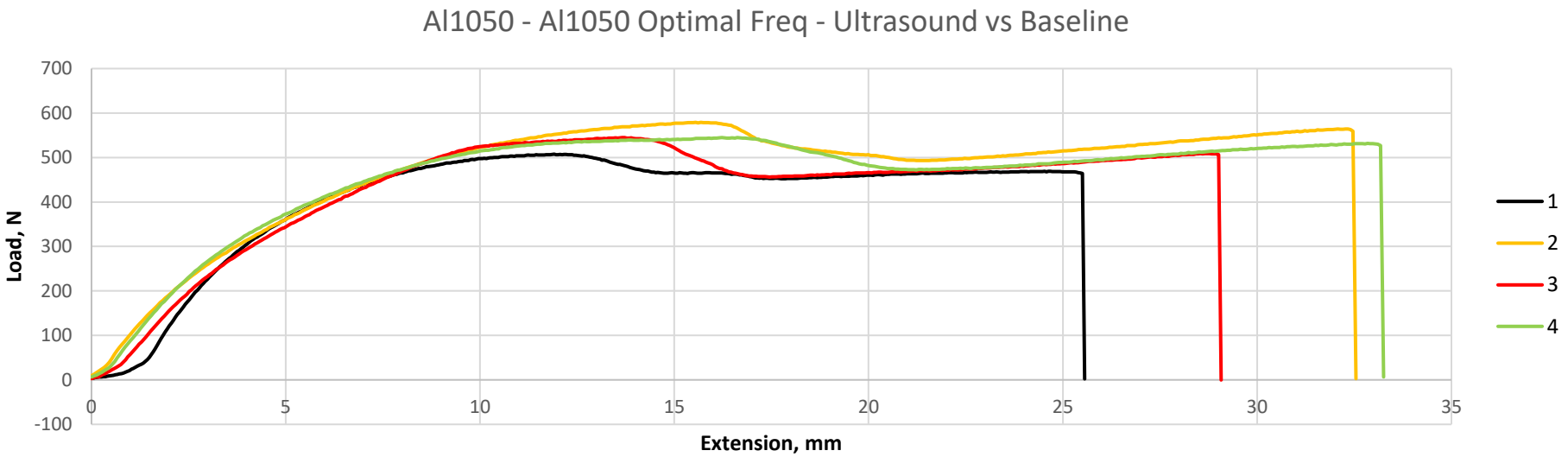






Results Al1050 to Al1050 at Optimal Frequency

Graph Number	Frequency	US Power	Transducer Type	Placement/Angle	Average Load, N	Load Analysis	Load Rank	Average Extension, mm	Extension Analysis	Extension Rank
1	Baseline	N/a	N/a	N/a	509.1	100%	4	11.0	100%	4
2	Low	70	Focused Horn	Contactless on the spot	561.0	110%	2	14.0	127%	2
3	Low	70	Needle 100%	Contactless on the spot	547.0502	107%	3	13.6	124%	3
4	Med	70	Taper Horn	Contact Compressional	584.2	115%	1	18.0	164%	1



Cu101 – Al1050 Welding

Welding Assumptions

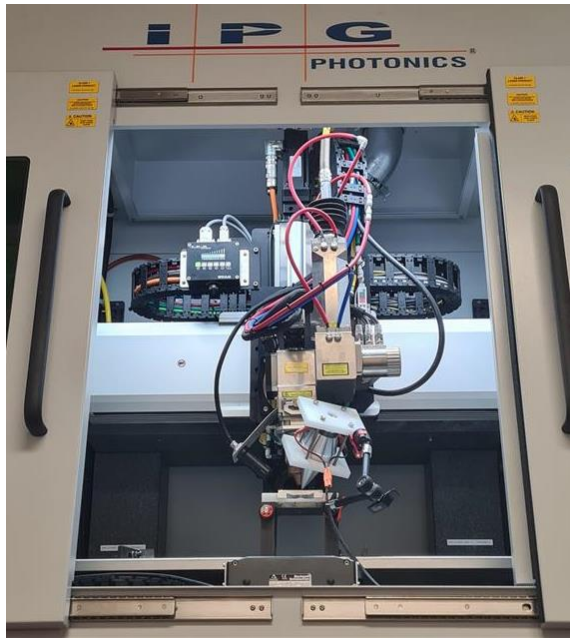
- Material: Copper
- Single Plate Dimensions: 50x50
- Laser Type: YLS – 6000 CT
- Laser Used: IPG
- Laser Fibre: 0.1 mm
- Shielding Gas: Argon (99.99% purity) – 86 L/min
- Weld Type: Lap Weld/Stake Weld
- Target Weld Depth: 0.9mm-2.9mm
- Wobble: 0.7mm/250Hz, circle

Peel Test Jig

- Steel Base
- Acetal Interface - To minimize wave propagation
- Aluminium Protection with air gap - To protect acetal board from laser radiation
- 2 Transducer Arms

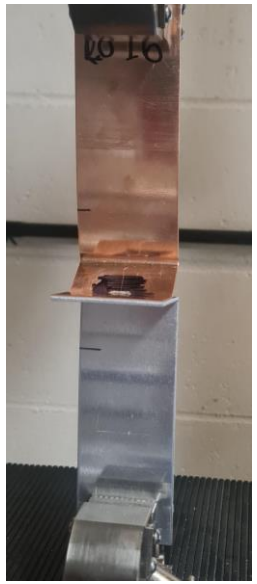
Trials

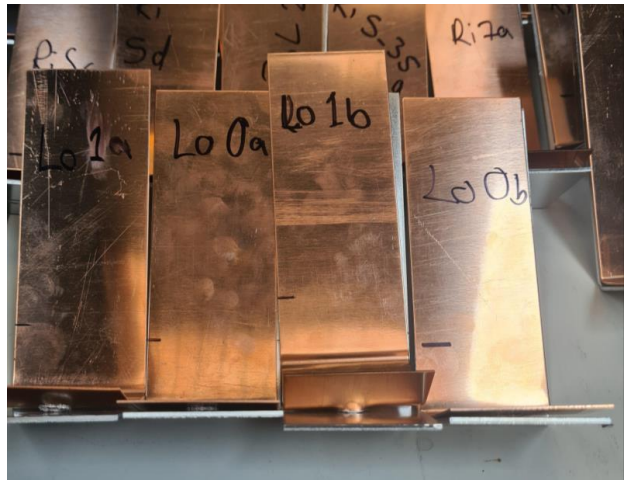
- Ultrasound (Contact) Vs Baseline
- Testing different variables (Freq., Power, configuration etc.)
- Cu101 – 0.9mm and Al1050 – 2mm
- Oval Weld, 5mm

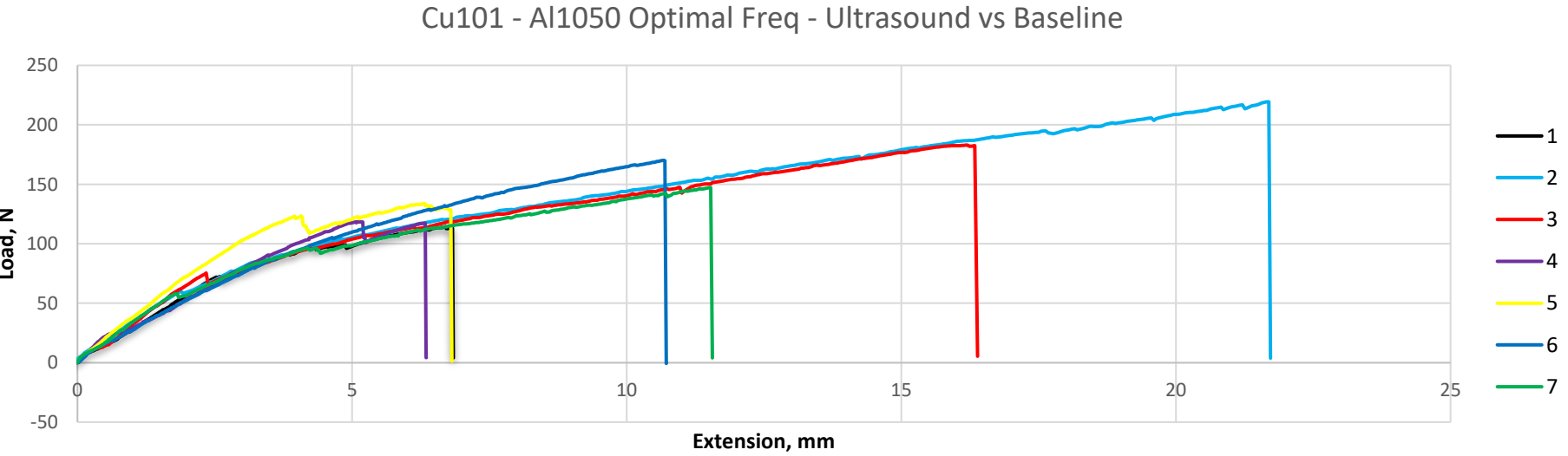


Results Cu101 to Al1050 at Optimal Frequency

	Frequency	Transducer Type	Placement/Angle	Average Extension, mm	Extension Analysis	Extension Rank	Average Load, N	Load Analysis	Load Rank
1	Baseline	N/a	N/a	4.8	100.00%	6	110.0	100.00%	7
2	Low	Taper Horn	Contactless on the spot	20.8	431.61%	1	246.8	224.37%	1
3	Low	Needle 20%	Contactless on the spot	11.9	246.52%	2	170.8	155.27%	2
4	Med	Focused	Contactless on the Spot/45Deg	6.5	135.11%	5	112.2	102.06%	6
5	Med	Taper	Contactless on the Spot/45Deg	4.7	98.27%	7	124.3	113.00%	5
6	High	Focused	Contactless on the Spot/45Deg	10.7	221.03%	3	170.1	154.69%	3
7	High	Taper	Contactless on the Spot/45Deg	7.1	147.36%	4	137.8	125.26%	4





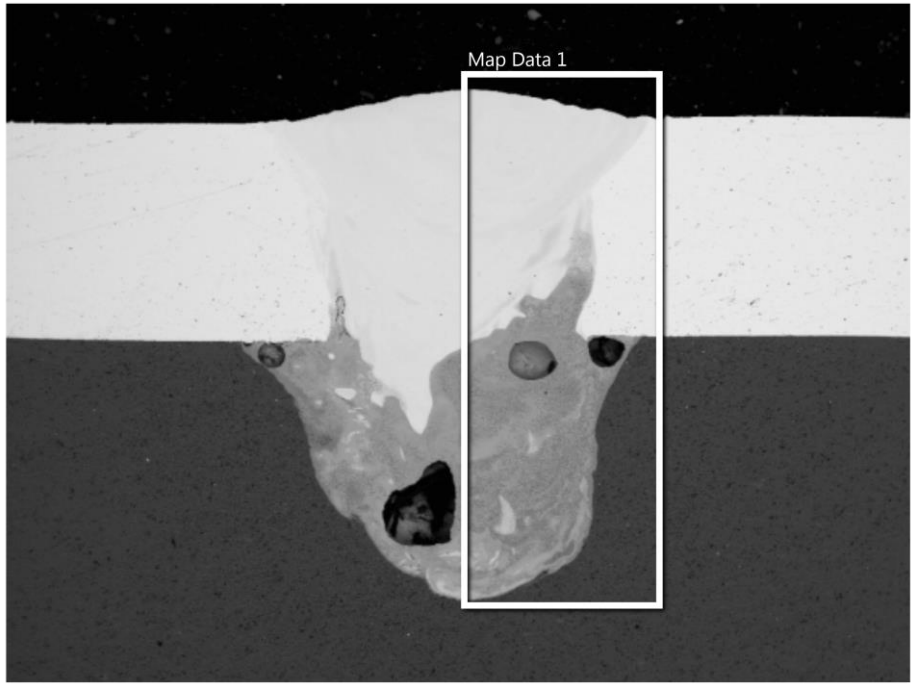


Evaluation Cu-Al

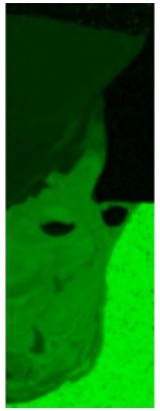
- Load analysis overall improvements when US is applied
- Key performers
  - + Taper Horn Contactless on the spot, Low Frequency
  - + Focused Horn vs Taper Contactless on the spot, Medium and high frequency
    - Due to the different wavelength associated with the different transducers horn
  - - Medium overall not showing the best improvements

SEM/EDX - Cu101 to Al1050 Baseline

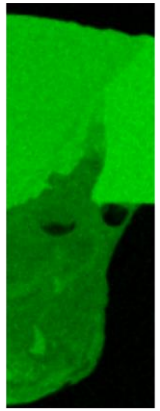
Electron Image 2



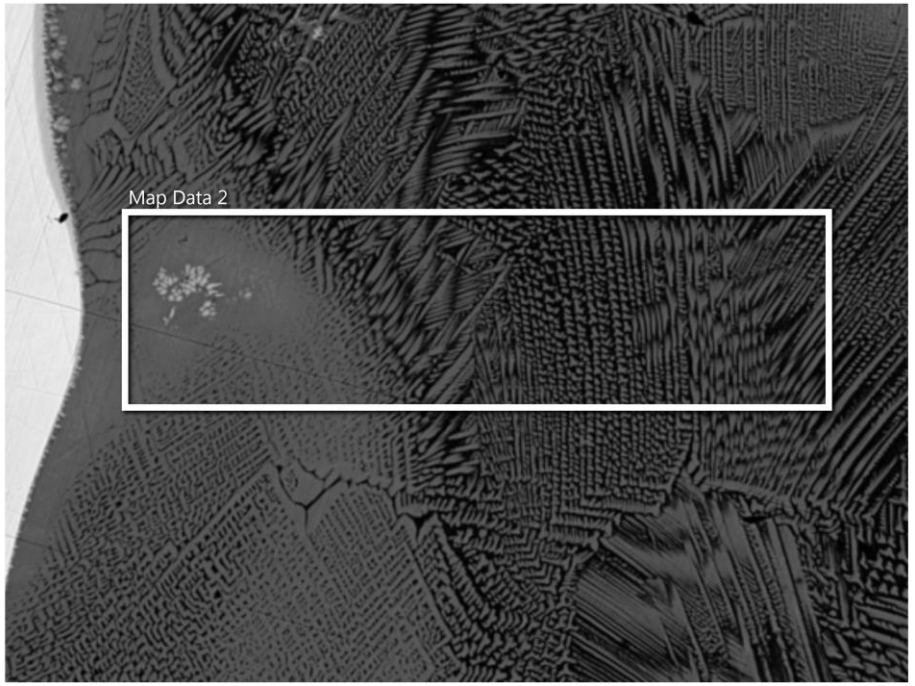
Al K series



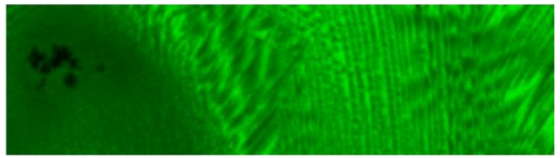
Cu K series



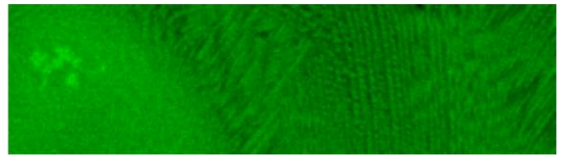
Electron Image 4



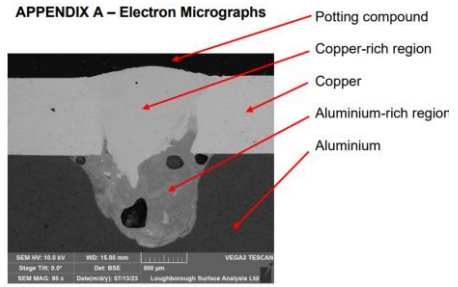
Al K series



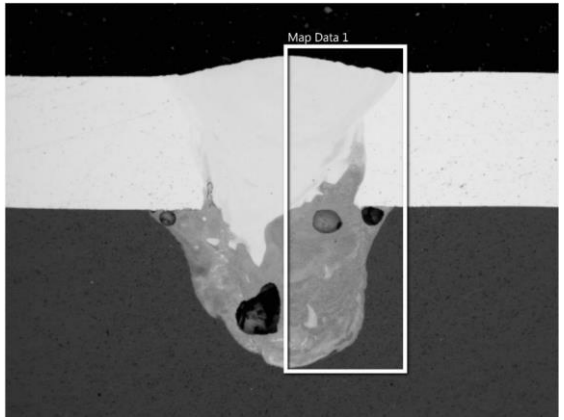
Cu K series

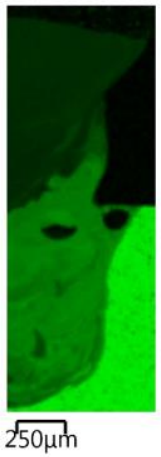


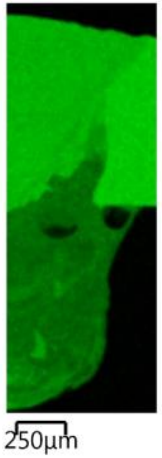
SEM/EDX Microanalysis

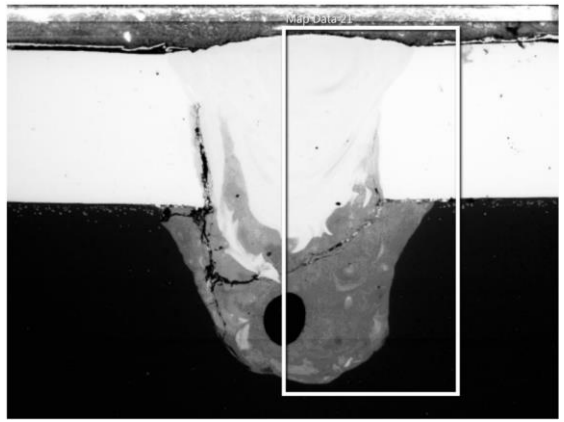


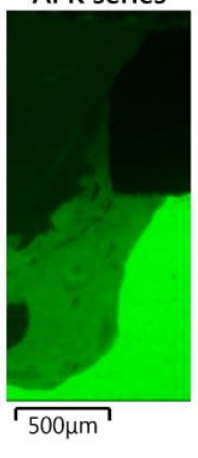
Baseline

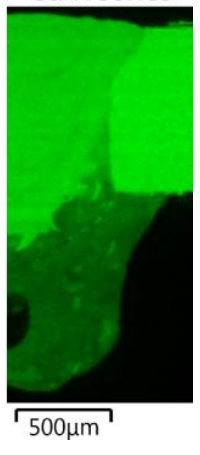




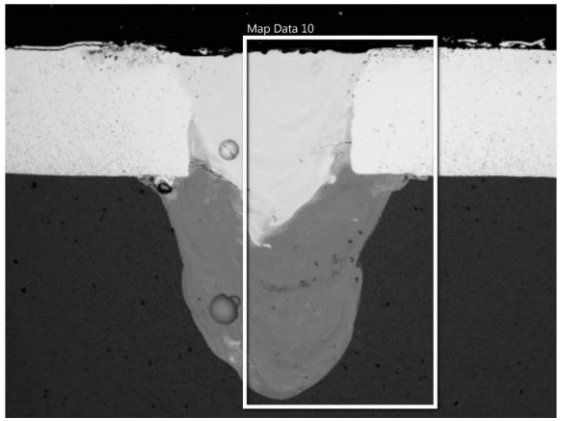


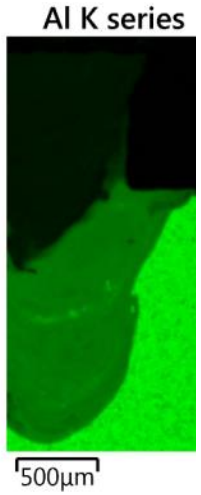


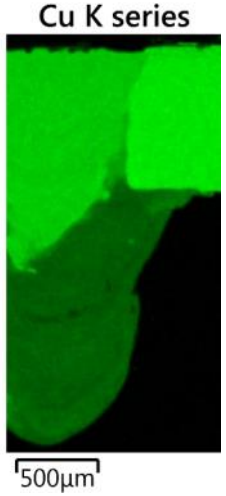




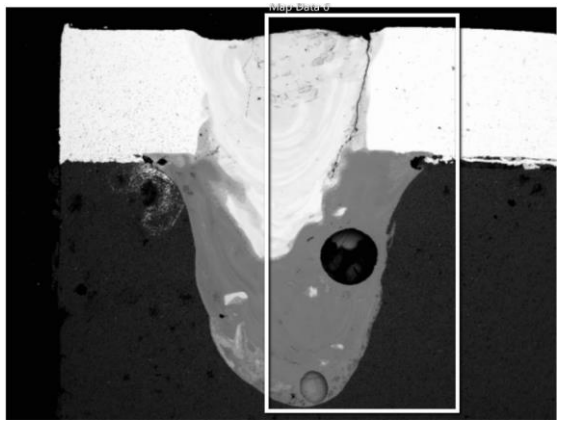
20kHz

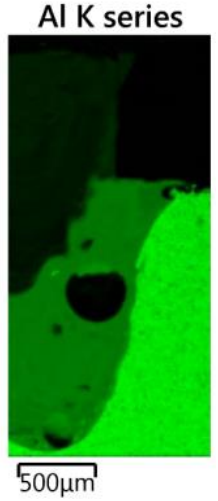


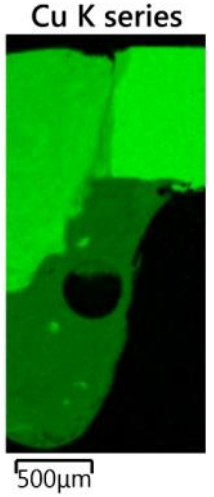




40kHz







Cell Welding Cu-Al

Soni-Laser Project - Ultrasonic assisted laser welding for high volume assembly of automotive battery packs.

Thank You

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