Marking | Cutting | Welding | Micro Machining | Additive Manufacturing
Nanosecond Laser Welding of Dissimilar Metals and Foils

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1. Introduction
2. Lasers for welding
3. Thin metal ns pulsed laser welding
4. Dissimilar metal “welding”
5. Joining of battery cells
6. Summary
Proven industrial tool for:

- Marking
- Engraving
- Cutting
- Surface texturing
- Thin film patterning
- Cleaning

All based on ablative material removal processes
Welding and joining represents a paradigm shift for ns lasers......

Need to think differently....
Micro joining of foils

Problem

Reliable joining avoiding over penetration

Challenge

Avoiding distortion and warping

Solution

Control of heat input by beam mode shaping.
Micro joining of metals

**Problem**

Reliable joining of thin section dissimilar materials

**Challenge**

Overcome the problems of brittle inter-metallics

**Solution**

Novel ns welding process not based on large weld pool
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Lasers for welding

• CW Lasers
  - Laser measured by power – able to provide continuous stable laser output at rated power

• CW/Modulated Lasers
  - Lasers that produce a gated output with the maximum power being the CW limit

• QCW Lasers
  - Able to produce ms pulses at higher peak powers at reduced average power than their continuous duty operation

• Pulsed Lasers (ref FLP Nd:YAG)
  - Producing short high peak power pulses with low average power.
OLD (FLP Nd:YAG)
- 6-10kW peak power
- ms pulse duration
- >J pulse energy
- <1kHz Rep Rate
- <15% DF
- <100W average power

NEW (ns Joining)
- 6-10kW peak power
- ns pulse duration
- <mJ pulse energy
- >100kHz Rep Rate
- <15% DF
- <100W average power
• Flexibility in ns lasers in optimising pulses to match application requirements.

<table>
<thead>
<tr>
<th>Low kHz</th>
<th>High kW</th>
<th>P/E Max</th>
<th>&gt;500 ns</th>
</tr>
</thead>
<tbody>
<tr>
<td>High kHz</td>
<td>Low kW</td>
<td>P/E Min</td>
<td>&lt;10 ns</td>
</tr>
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</table>
• Use pulse waveforms & frequency to tune parameters from vaporisation/melt ejection to melt generation.

(a) WF0 - 70kHz
70W, 1mJ
>10kW peak,
<2% duty.

(b) WF0 - 140kHz
70W, 0.5mJ
>2kW peak,
<4% duty.

(c) WF0 - 500kHz
70W, 0.15mJ
>500W peak,
<15% duty.
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Lap welding in stainless steel

- 304 SST 150µm sheets welded in lap configuration
  - Parameters - 70W  100mm/s - 6mm Ø welds.

Top weld view
no cover gas

Bottom weld view
full penetration

Weld under manual peel stress

Failure mode at weld interface

Similar results were achieved in 250µm sheets at 50% welding speed.
• These welds really strong enough for serious applications.

Tests completed on stainless steel to stainless steel welds show shear strength for two 1mm welds in a full 0.5mm lap weld to be > 224 lbs. In one case with a 180 degree peel test on a linear weld 5mm long and 1mm wide, the part yielded at 241 lbs.
• Stake weld to hold parts + continuous seam with wobble
• Using 70W EP-Z.
Butt Welding

- Can make good butt welds in similar materials
- 70W EP-Z using wobble technique in 200µm stainless steel
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4. **Dissimilar metal „welding“**
5. Joining of battery cells
6. Summary
• Focus on ability to weld bright metals
  • Range of material types and dissimilar combinations
  • Using novel weld configurations..
• Method for making spot welds.

Spatially overlapping spots >98% linear fill separated by 50% the $F_s$ on the rise radius.

$R_1$, Inner Radius, 0.02mm
$R_2$, Outer Radius, 0.5mm
a, Ramp, 3mm
b, Rise, 0.02mm
Grid patterns

- Fast and flexible applicable to multiple material combinations

Copper on Supper Alloy  Aluminium on brass  Aluminium on Copper
• No witness marks on wide variety of material combinations!

Combinations
Left to Right:
SS-Cu
SS-Al
Al-Cu
Ti-Al
Spot welds do not show characteristic form of conventional pulsed spot welds

More closely resembles multi-staking

WF 36, 520ns, 70 KHz
Tensile weld strength

1. .15mm on .15mm Cu - 20 lbs
2. .3mm on .3mm C260 - 61 lbs
3. .3mm on .3mm C510 - 42 lbs
4. .15mm Cu on .4mm Al - 26 lbs
With a cosmetic pass

- Reduced surface porosity with bright finish
- Increased joint strength to 48lbs on 150 um copper.
Different configurations can yield improved results
Weld geometry flexibility

- Opens up the possibilities to design for purpose
  - Electrical conductivity
  - Pull strength
  - Penetration and nugget shape
  - Available space
  - Heat input (witness marks)
• Single pass with 70W HS-H
  • Laser made “Metal Rivet”!
  • Aluminium flows through copper layer – no signs of inter-metallic layer
• Various dissimilar micros

- Cu/Al
- Al/Cu
- SS/Al
- Ti/Cu
• Wobble welding offers width control in lap welding of dissimilar combinations
Welding with ns Pulsed Fiber Lasers

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• Requirement to weld copper/aluminium tabs to cells
• Using scanner + 100W EP-Z
• Basic fixturing
  • Good contact required.
  • Shielding gas as appropriate to material combinations.
• Objective is to produce strong welds with no burn through or witness marks

Nickel plated Cu

Aluminium
Evaluation of joint design

- Single large area spot vs multiple spots
  - Roughly same contact area time to process
  - Multiple spots proved to be stronger + gave more control over penetration depth
Summary

- ns pulsed lasers offer a flexible solution with multi-process capability
- new welding potential particularly for dissimilar metals
- enhanced thermal input control
- new joint design possibilities
- tailored beam quality options offer the right tool for the job

Patent No:
WO2016128704
WO2016128705
Other patents pending
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