Insights into intermetallic phases on pulse welded dissimilar metal joints

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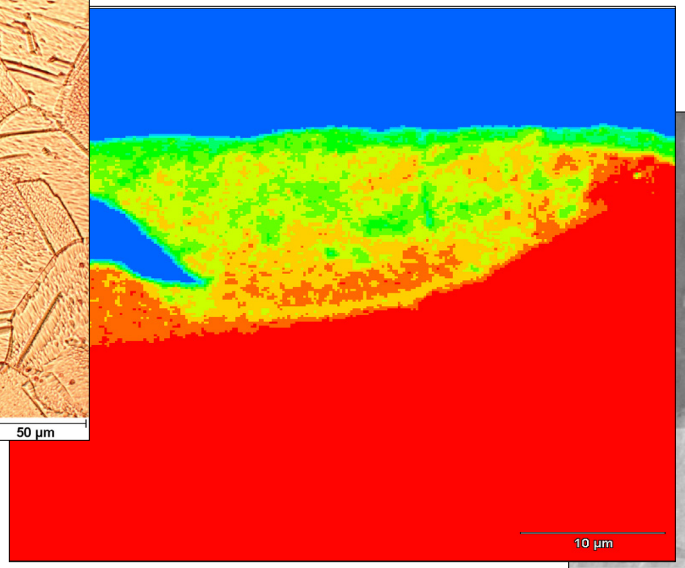

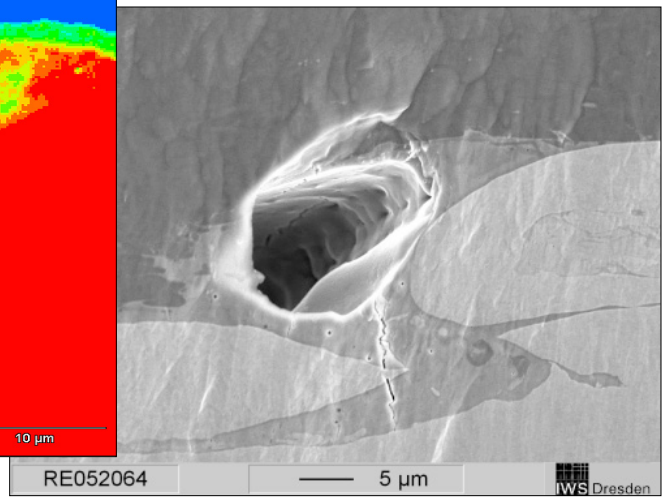

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Introduction

Portrait: Fraunhofer Institute Material and Beam Technology (IWS)

- Part of Fraunhofer Society (57 Institutes, 15.000 Employees)
- IWS Institute: 240 employees
- Scientific Background IWS: material analysis, process technologies, surface technologies
- Important topic: Joining in industrial applications
- Main Joining Technologies:
  - Laser beam welding/brazing
  - Laser-hybrid techniques (+induction, +TIG, +MAG)
  - friction stir welding

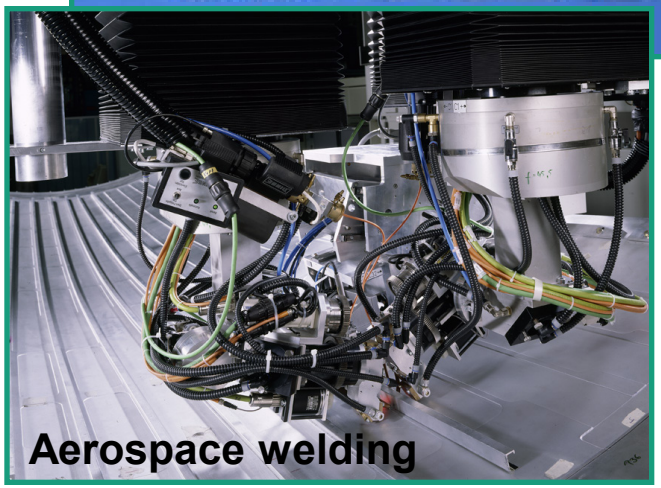
Fraunhofer IWS in Dresden, Germany

Introduction

Portrait: Fraunhofer Institute Material and Beam Technology (IWS)

- Expertise: development and transfer of technologies into production processes
- long term cooperation with major automotive and aerospace companies and SMI
- Strong network in welding community

- **Interest: capabilities of magnetic pulse welding**



Motivation

Pro/Contras for MPW

Pro:

- Many material combination weldable
- (Possible) good joint properties (HAZ, Strength)
- (Possible) low process costs (energy efficient, clean)

Contra:

- Geometry restrictions
- Equipment reliability
- Noise, EM-Noise

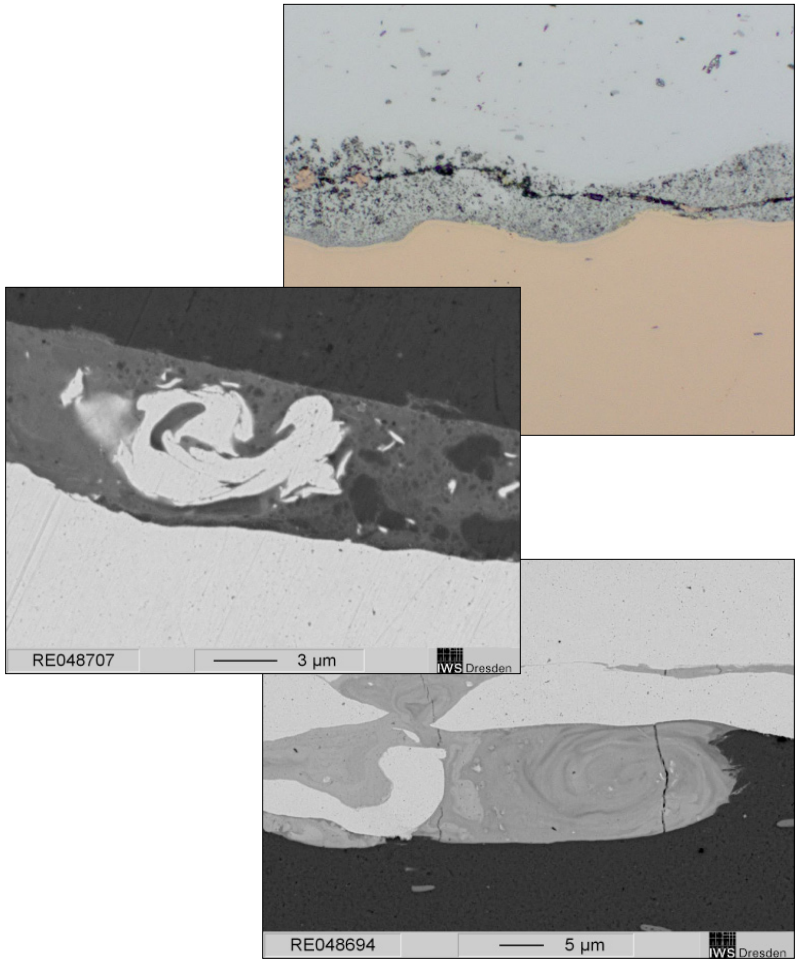
Question:

How is the typical internal weld quality of MPW joints and what factors effect it ?

Detail MPW joint Al+Cu

Technology Background
Possible detrimental effects in MPW

- Geometrical/Mechanical
  - Improper connected zones/spallation
  - Pores
  - Cracks
  - Dislocation/Twinning accumulation
  - Internal tensile stresses
- Metallurgical
  - Intermetallic phases
  - Molten pockets
  - Oxide inclusions



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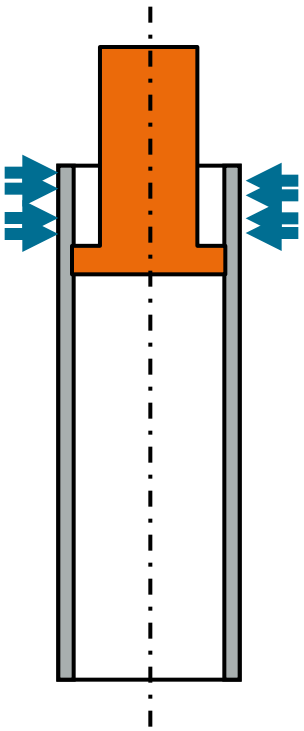
Experimental Tests on Al-Cu Dissimilar Joints

Part details

- Geometry:



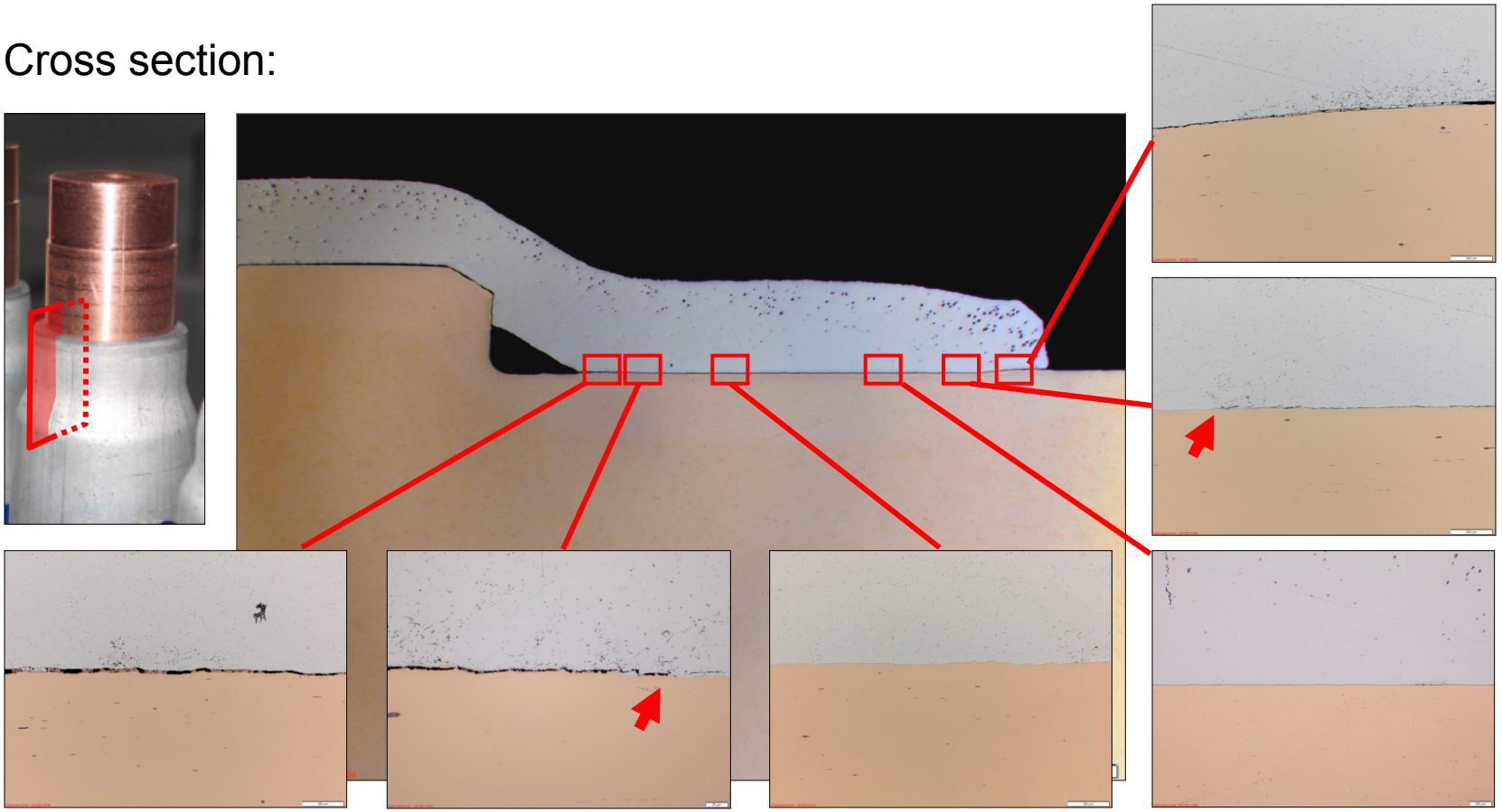
MPW test parts

Parts welded in coop. with the High Magnetic Field Lab of „FZ Dresden-Rossendorf“

Experimental Results, Metallographic Analysis

Overview typical weld geometry

Cross section:

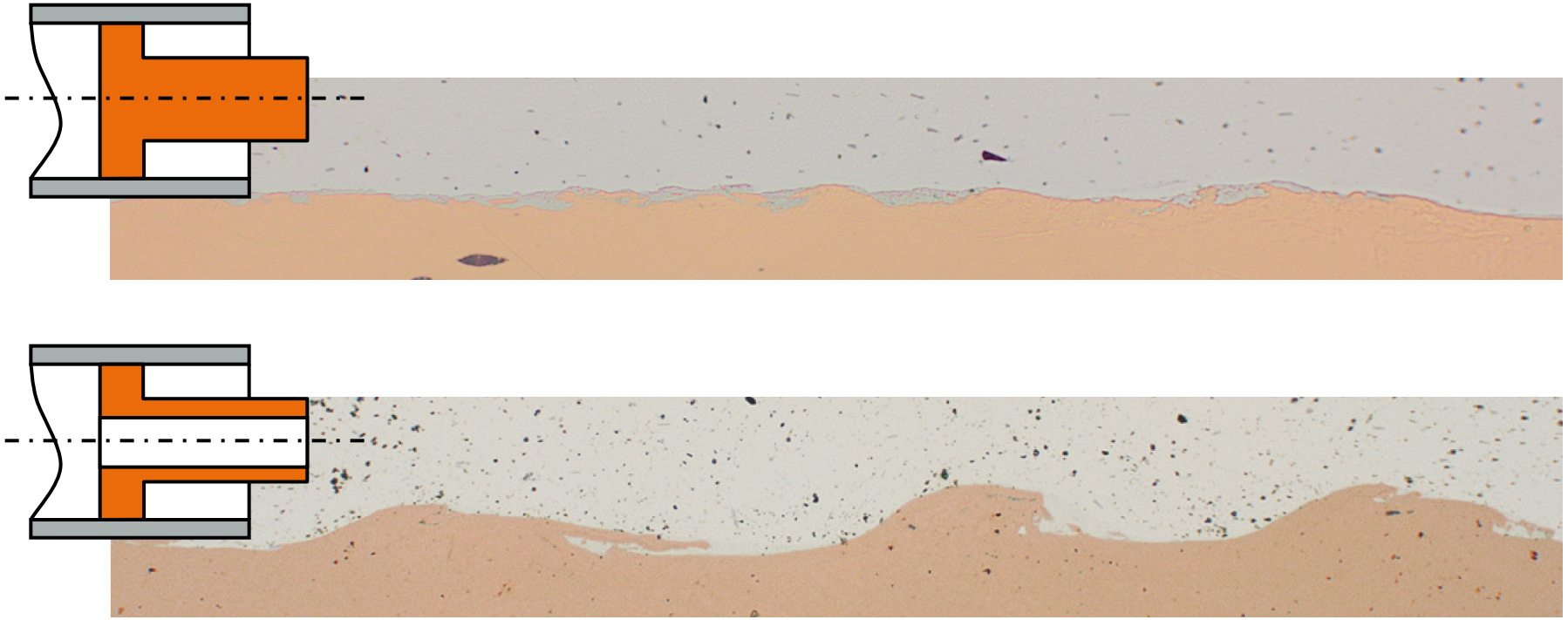


→ Good connection but also residual gap at start/end

→ critical for fatique and crevice corrosion, needs optimization

Experimental Results, Metallographic Analysis

Geometric influence on interface formation

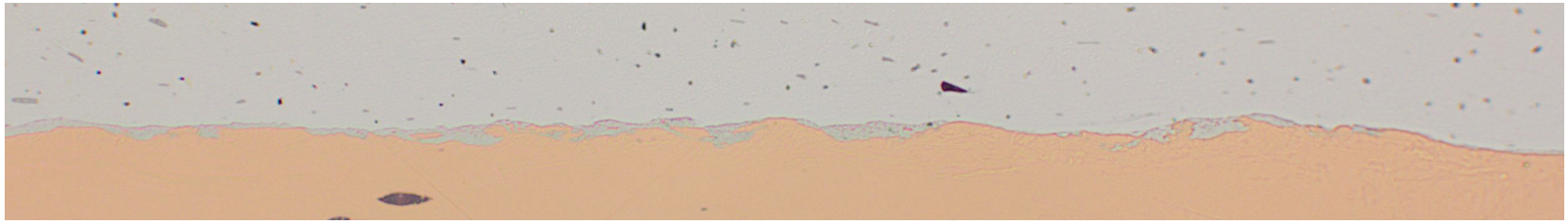


- Geometry influences wave formation for MPW, but not intermetallics

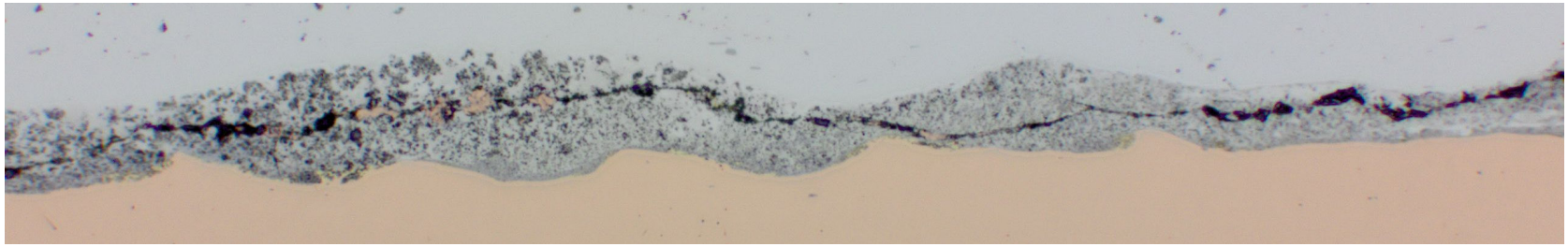
→ Wave formation is not necessary for sound weld

Experimental Results
Influence Pulse Energy

Higher pulse energy (I_{peak}=76kA)



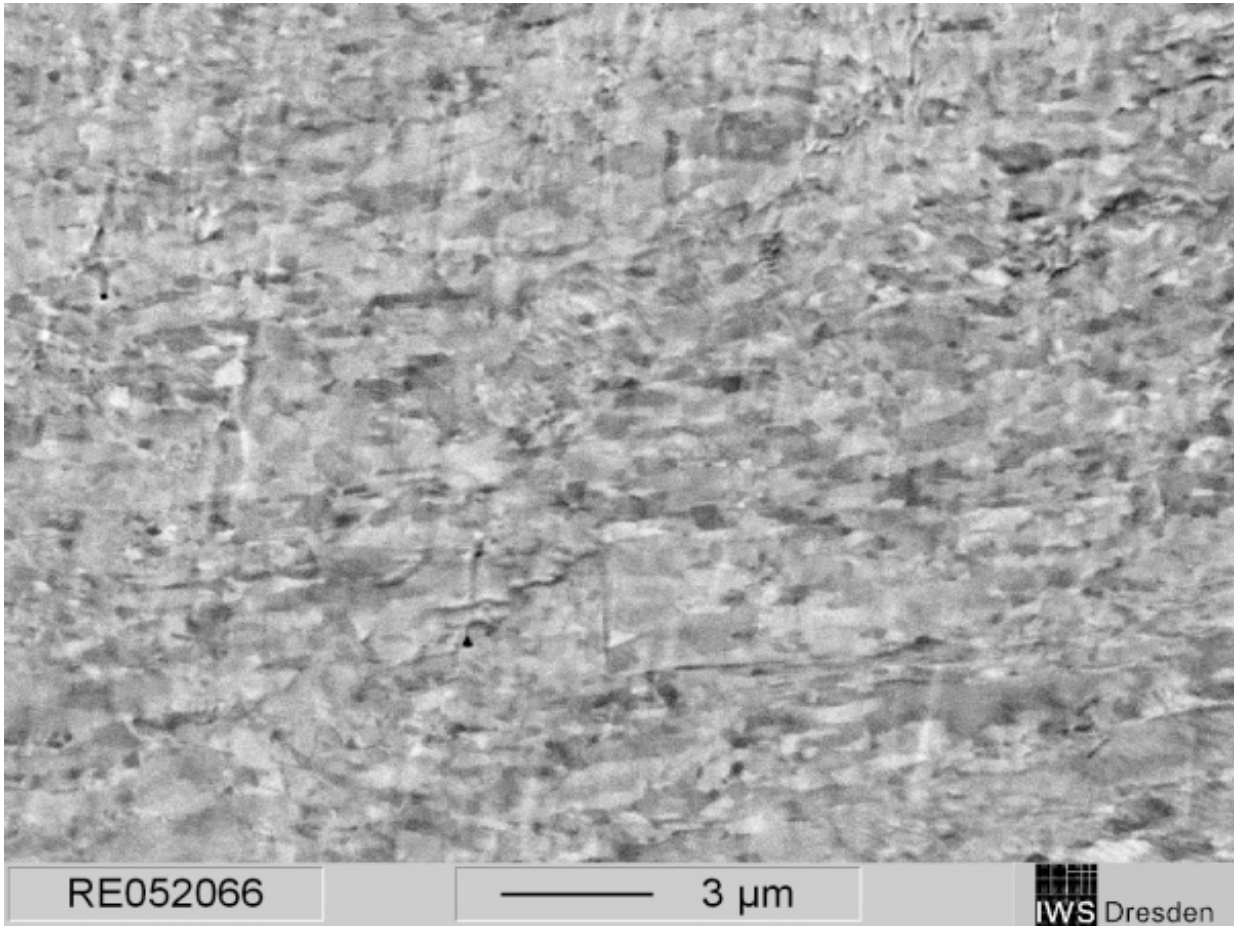
Lower pulse energy (I_{peak}=66kA)



- Strong increase in micro-porosity / intermetallics and cracks with increasing pulse energy

Experimental Results

Grain Structure Analysis

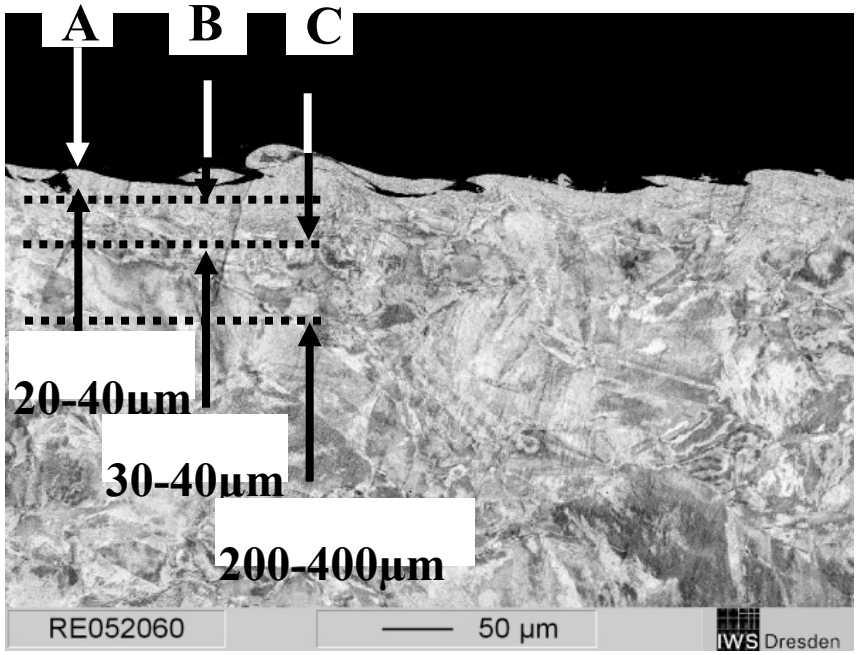


Experimental Results
Grain Structure Analysis

- Recrystallized ultra-fine grains in zone (A) on Copper side
- Dislocation accumulation in (B)
- Distorted grains (C) (both sides)

→ Dislocations potentially negative (less deformability),

→ recrystallized region positive (high ductility and hardness)



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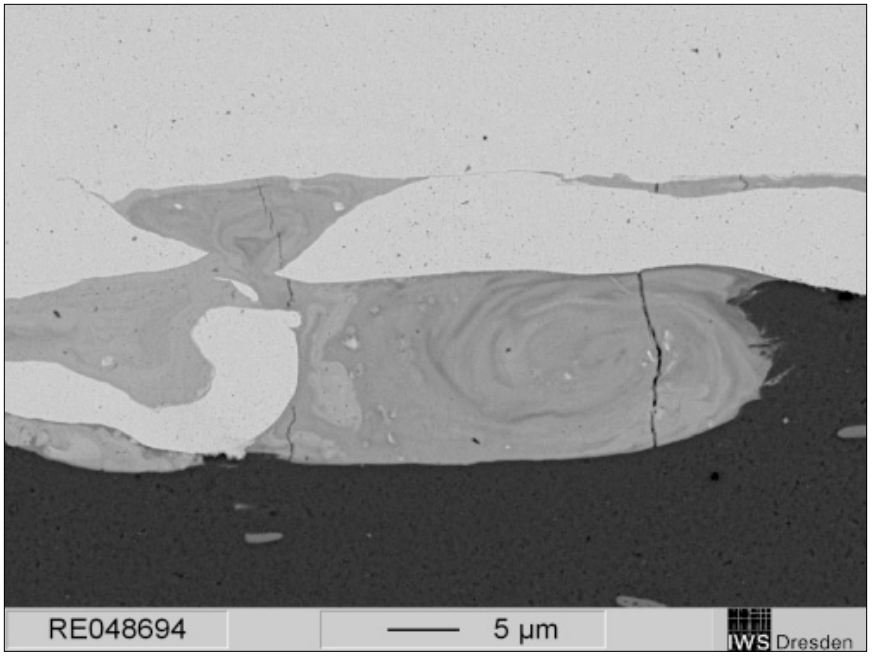
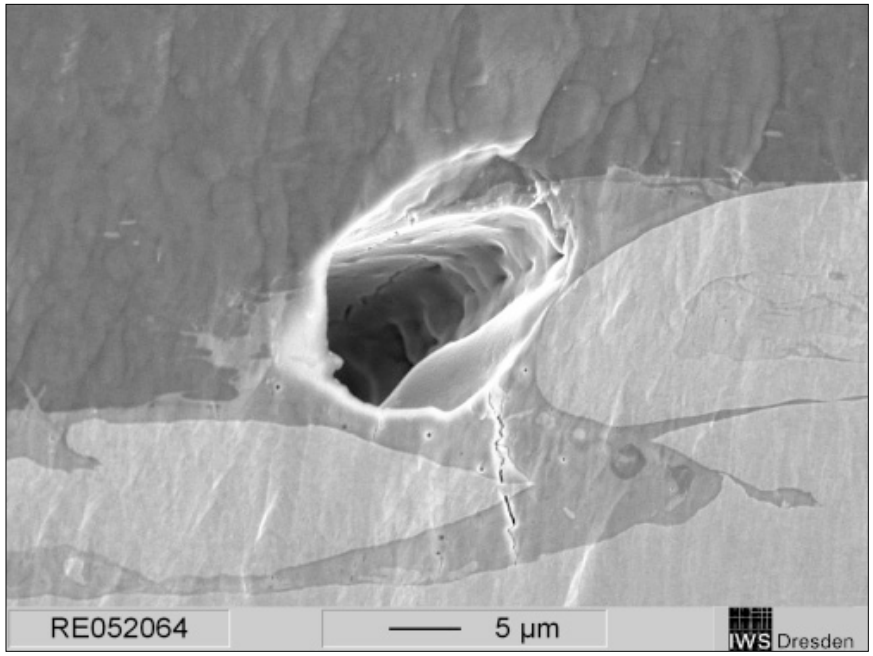
Experimental Results, Metallographic Analysis

SEM Details Interface With Wave Formation





- Thick intermetallic phases present for strong wave formations
- Pores in liquid pockets
- Thickness > 5 µm: Cracks!

→ Best results just above welding threshold

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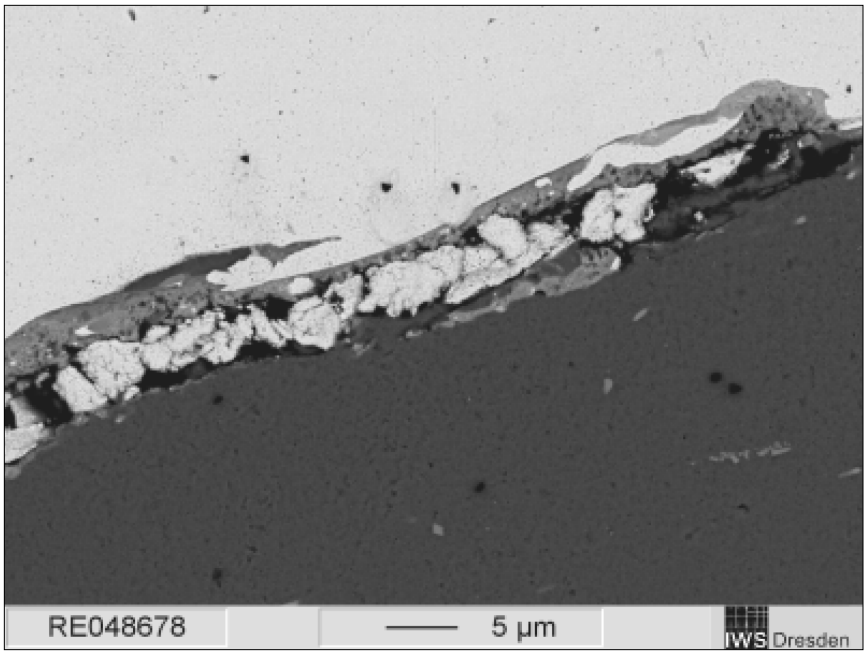
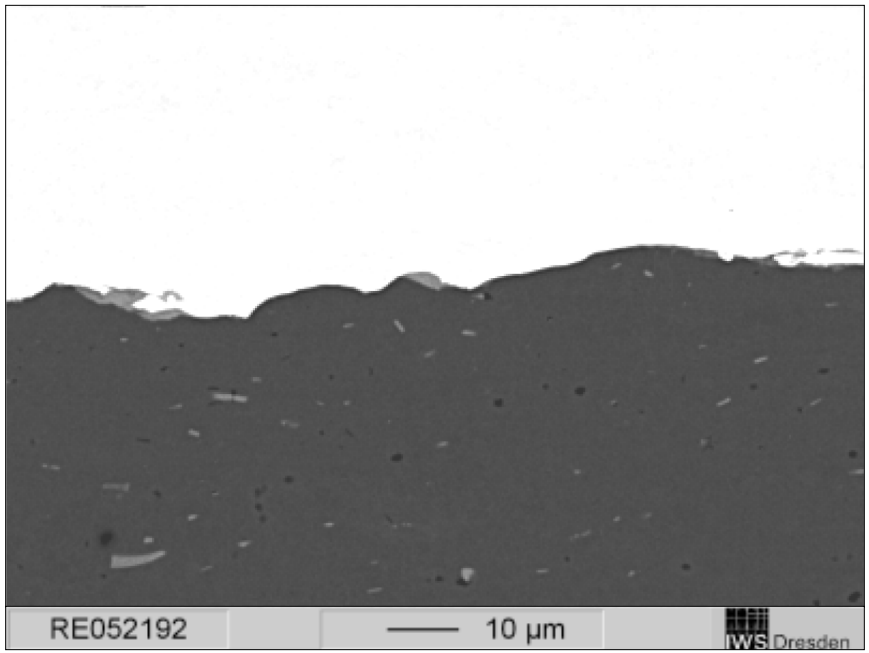
Experimental Results, Metallographic Analysis

Are Intermetallic Phases avoidable ?





- so far no success in creating IP free welds with Al+Cu
- Wave formation/intermetallic phases are not coupled to bonding!
- Experience/Literature: films with limited thickness (<5µm) not detrimental for joint strength

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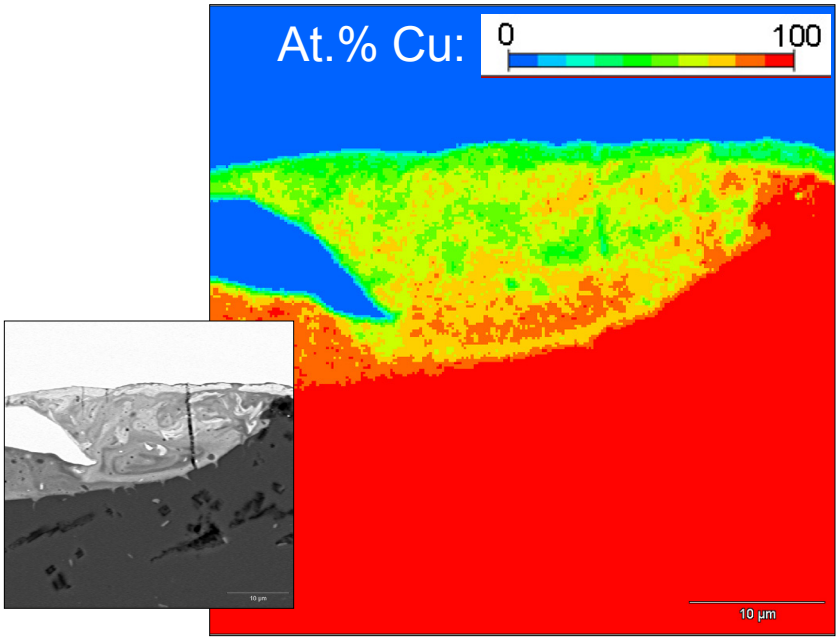
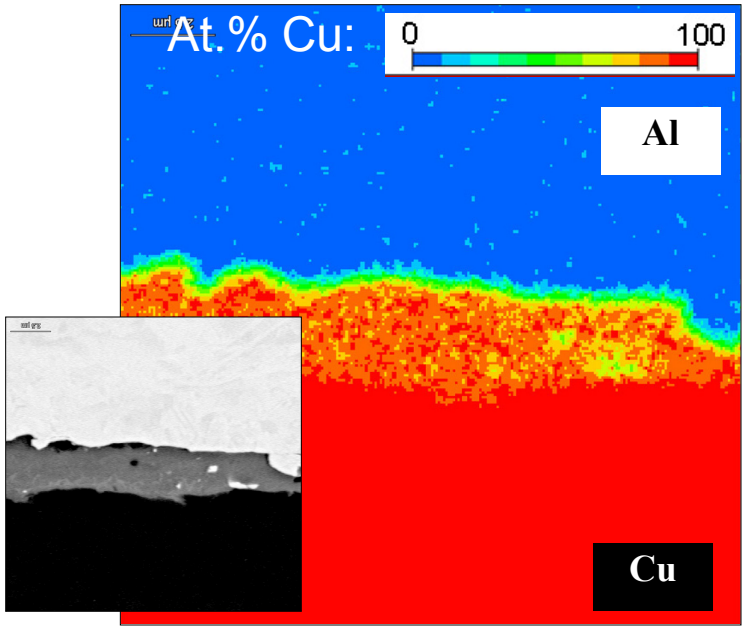
Experimental Results, Chemical Analysis
Composition Comparison

High pulse energy (I_{peak}=76kA)



Lower pulse energy (I_{peak}=66kA)



- Stepwise composition change from base metal to IP
- Gradual changes within IP
- Distinct differences in possible ranges for different pulse energies

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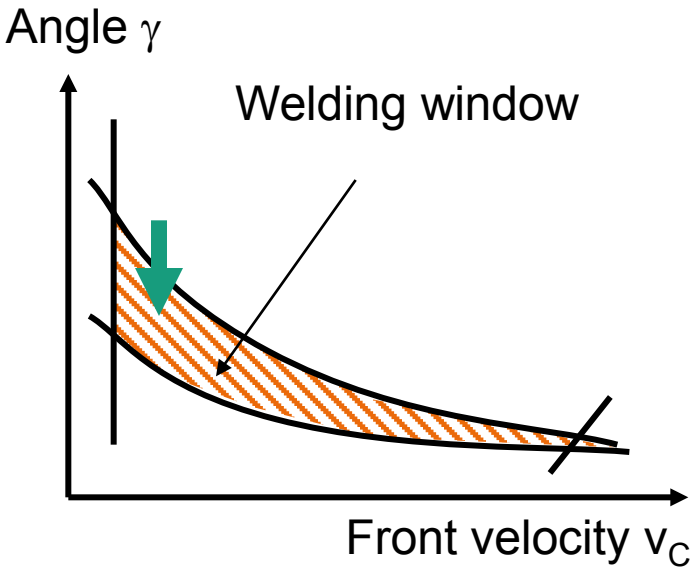
Summary and Conclusion

- Intermetallic phases (IP) are usually formed in magnetic pulse welds
- The IP composition, thickness and geometry is influenced by the pulse energy
- Interface near zones are strongly deformed with re-crystallized seams
- Wave formation in the interface is coupled to the geometry
- Wave formation is not necessary for a sound weld
- To reduce intermetallic phases, porosity and melt pockets, pulse energy should be minimized



Welding window theory