Dissimilar Metal Joining: Macro- and Microscopic Effects of MPW

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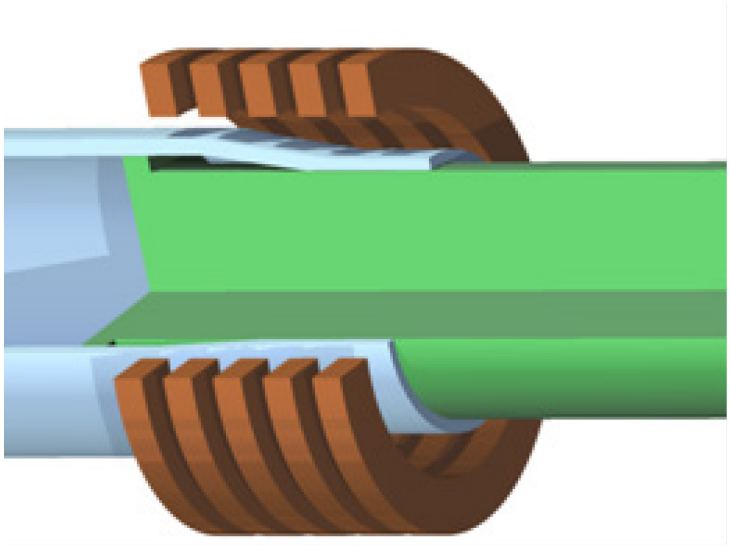
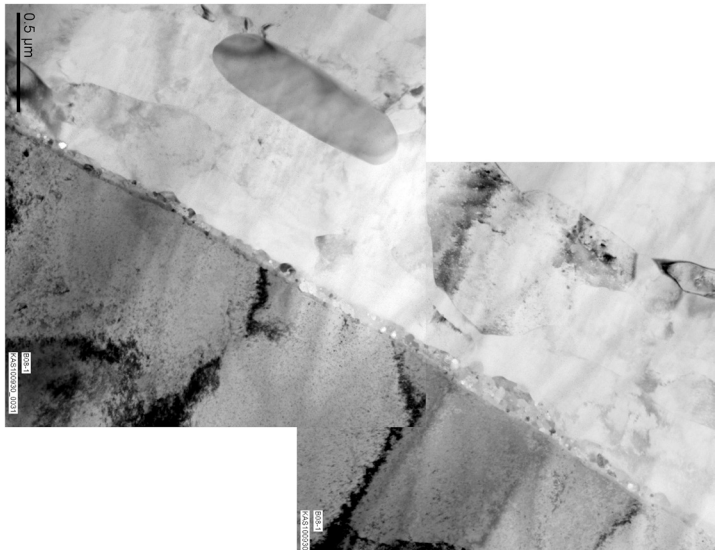
April, 25th 2012





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

Fraunhofer IWS in Dresden, Germany

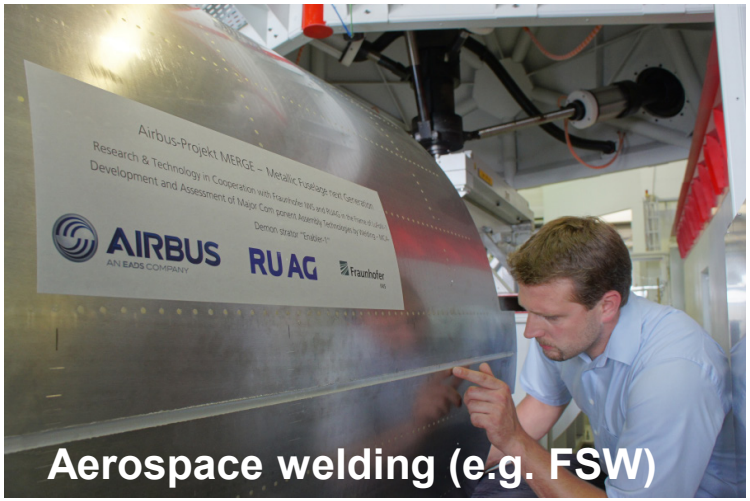
Fraunhofer IWS Dresden

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

- **Magnetic Pulse Welding as a solution for difficult mixed material joining tasks**



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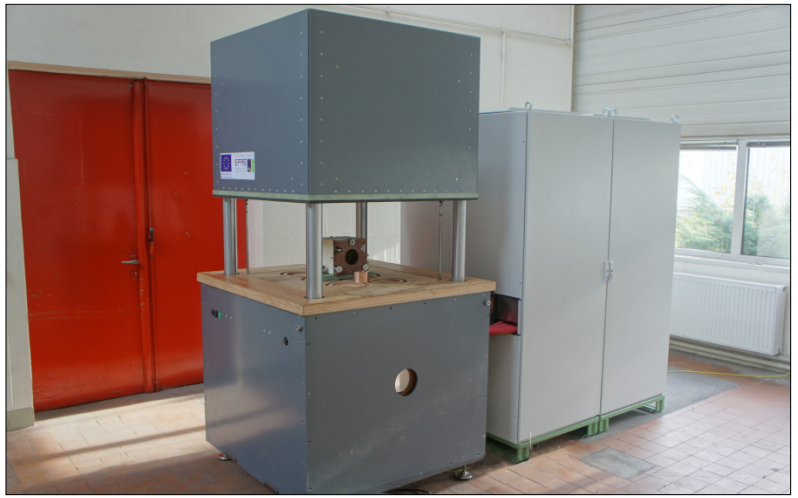
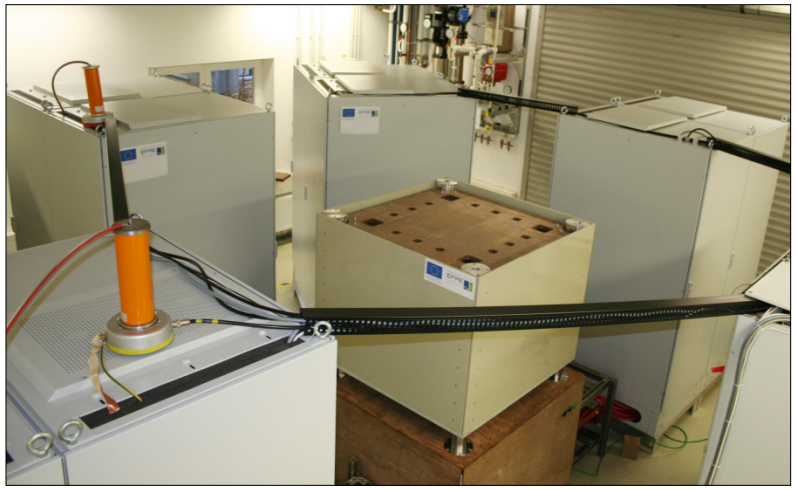
Introduction

Fraunhofer IWS: Special Joining Technologies

- Friction Stir Welding
- Magnetic Pulse Welding
  - Systems:
    - **40 kJ Generator***
    - **160 kJ Generator***
  - Simulation
  - Analysis



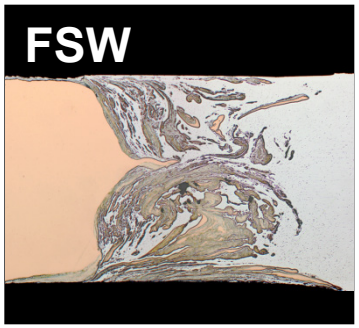


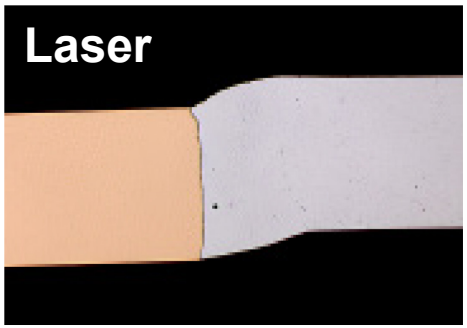
*built by Helmholtz-Zentrum Dresden-Rossendorf

Motivation

Importance of dissimilar metal joints

- Typical Materials involved:
  - Aluminum
  - Copper
  - Steel
  - Nickel
  - Magnesium
  - Titanium
- Many processes could be suitable, established in IWS so far:
  - Laser beam welding
  - Laser induction roll plating
  - Friction Stir Welding
  - Magnetic pulse welding





Joints made using different joining processes for example mix Al+Cu

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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

Details MPW joint Al+Cu

Question:

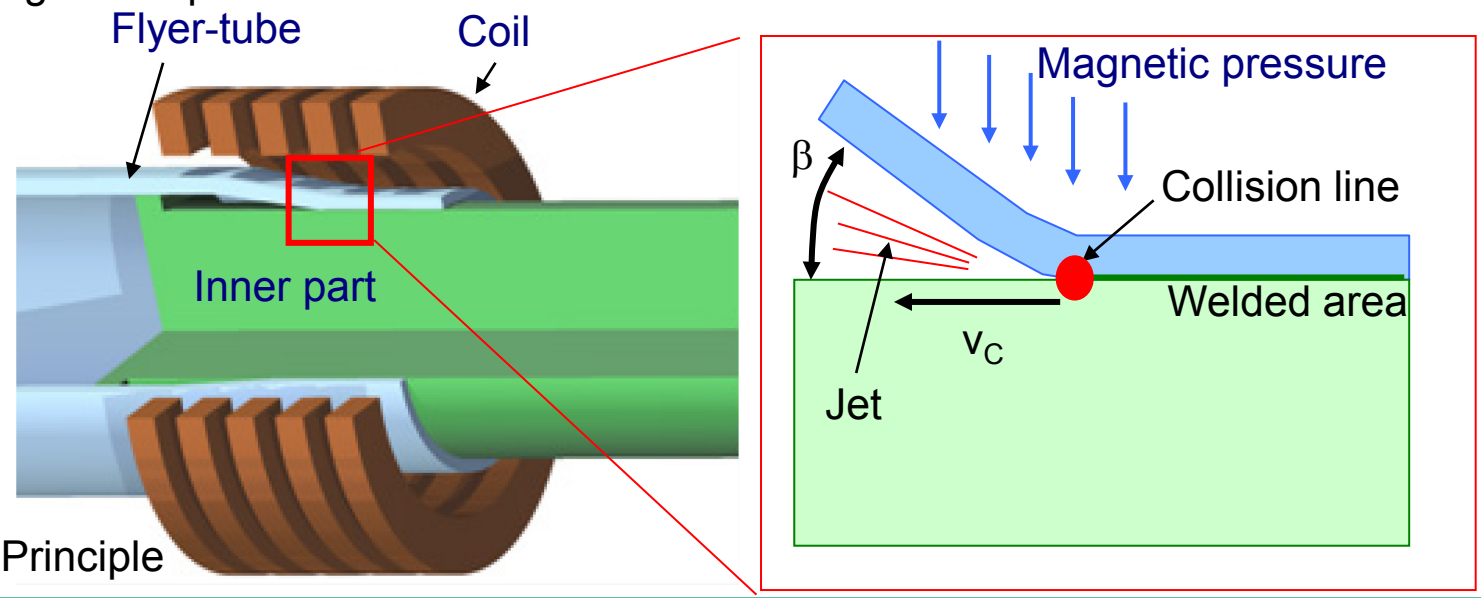
How to reach perfect welds?

→Some insights concerning parameter windows and interface properties will be presented

Motivation
Principle and Open Questions

Questions

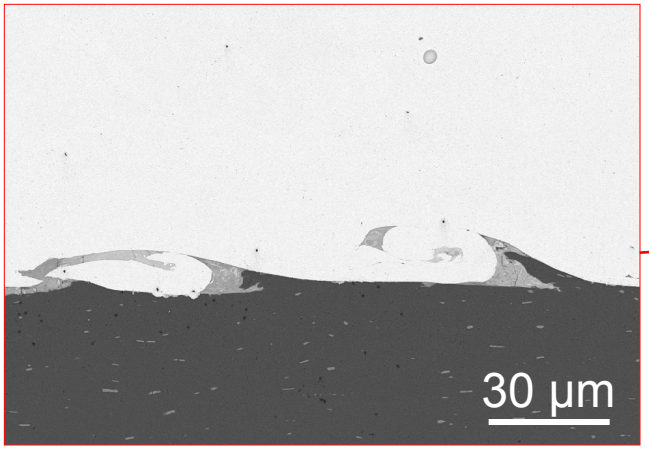
- When is welding possible?
- What is the origin of waves?
- Is MPW comparable to other shock welding techniques?

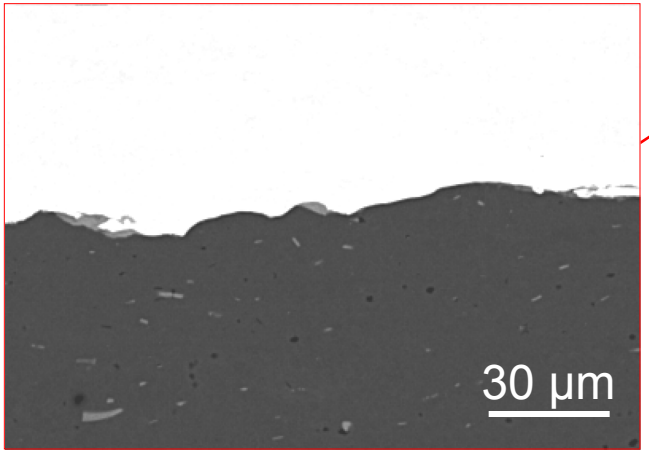


MPW Principle

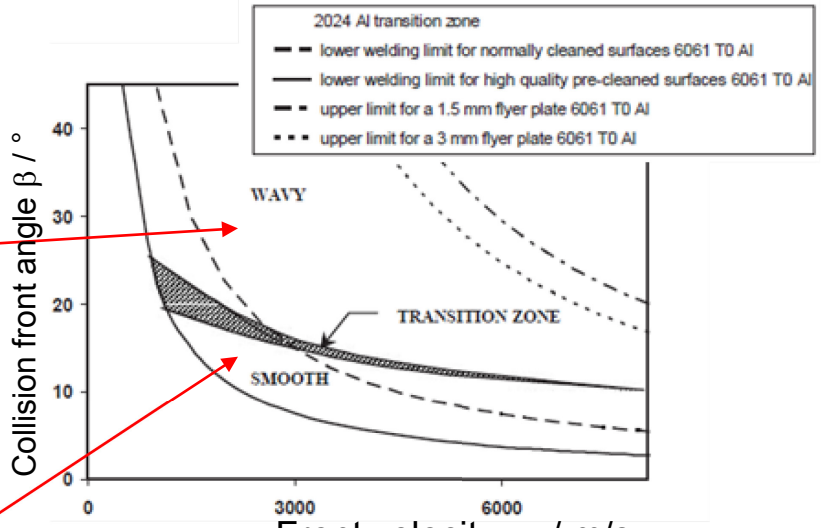
MPW <-> EXW Parameter Comparison

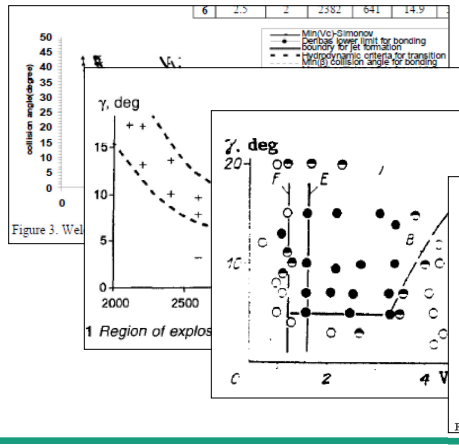
Welding Window Analysis





Grignon et al. 2004:





Sartangi 08

Kuzmin 04

Simonov 91

Zhakareno 83

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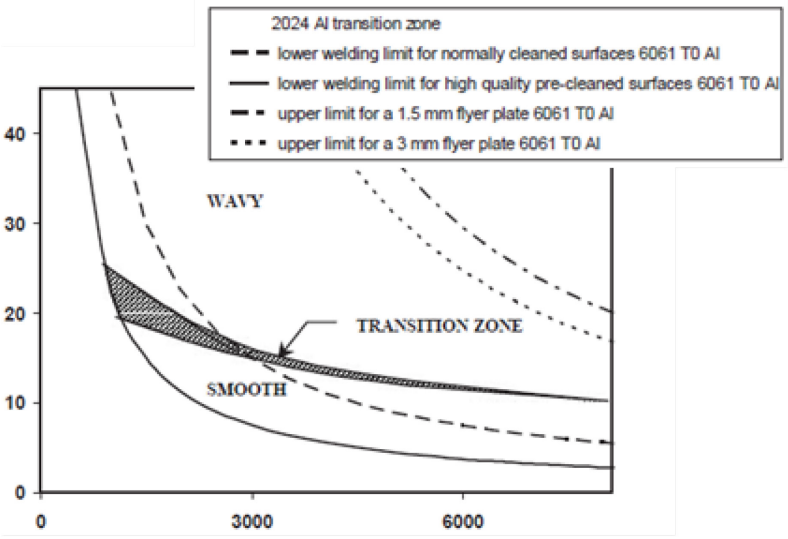
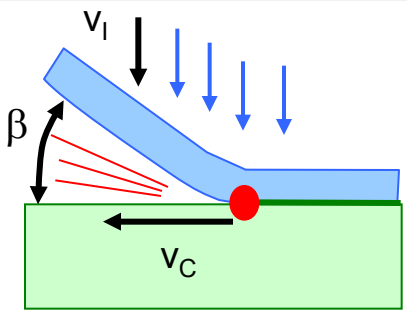
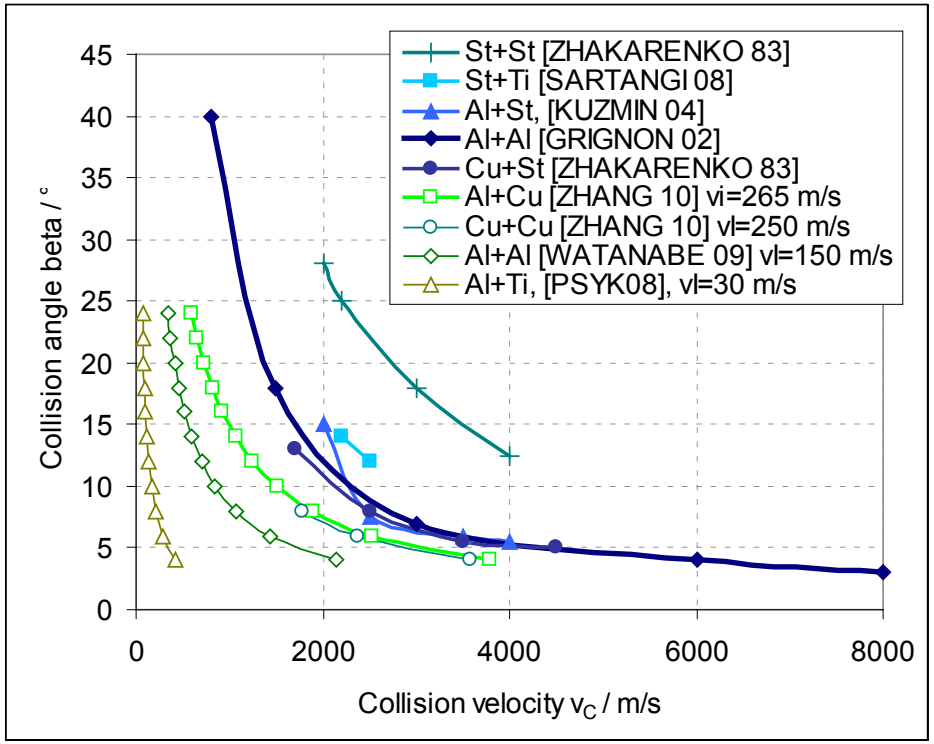
MPW <-> EXW Parameter Comparison

Welding Window Analysis





$$v_C = \frac{v_I}{\tan(\beta)}$$



Welding Windows: Lower EXW-Border + MPW Examples

→ Parameter windows of EXW and MPW differ, especially wave formation in MPW is hard to explain due to lower speeds!

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MPW <-> EXW Parameter Comparison
Welding Window Analysis

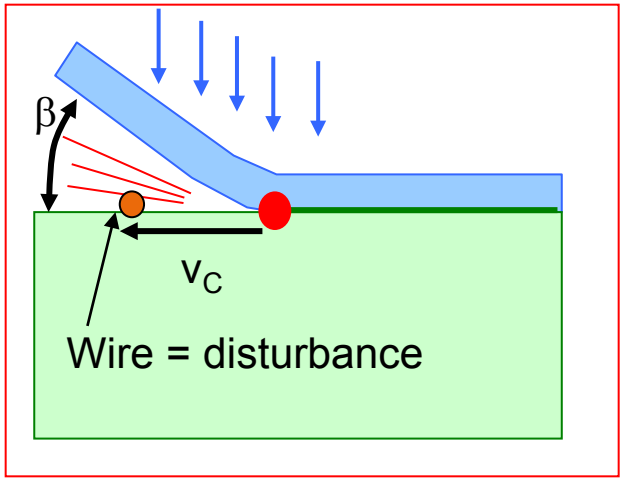
Possible explanation in regard to wave formation:

- According to Pai et al. metastable waves are possible
- Initiation by disturbances (wire idea)

→ Transient nature of MPW tends to metastable wave initiation

→ General disagreement of welding window not clear yet→ further research needed!

→ Also not answered yet: can MPW welds be fully free of intermetallics?

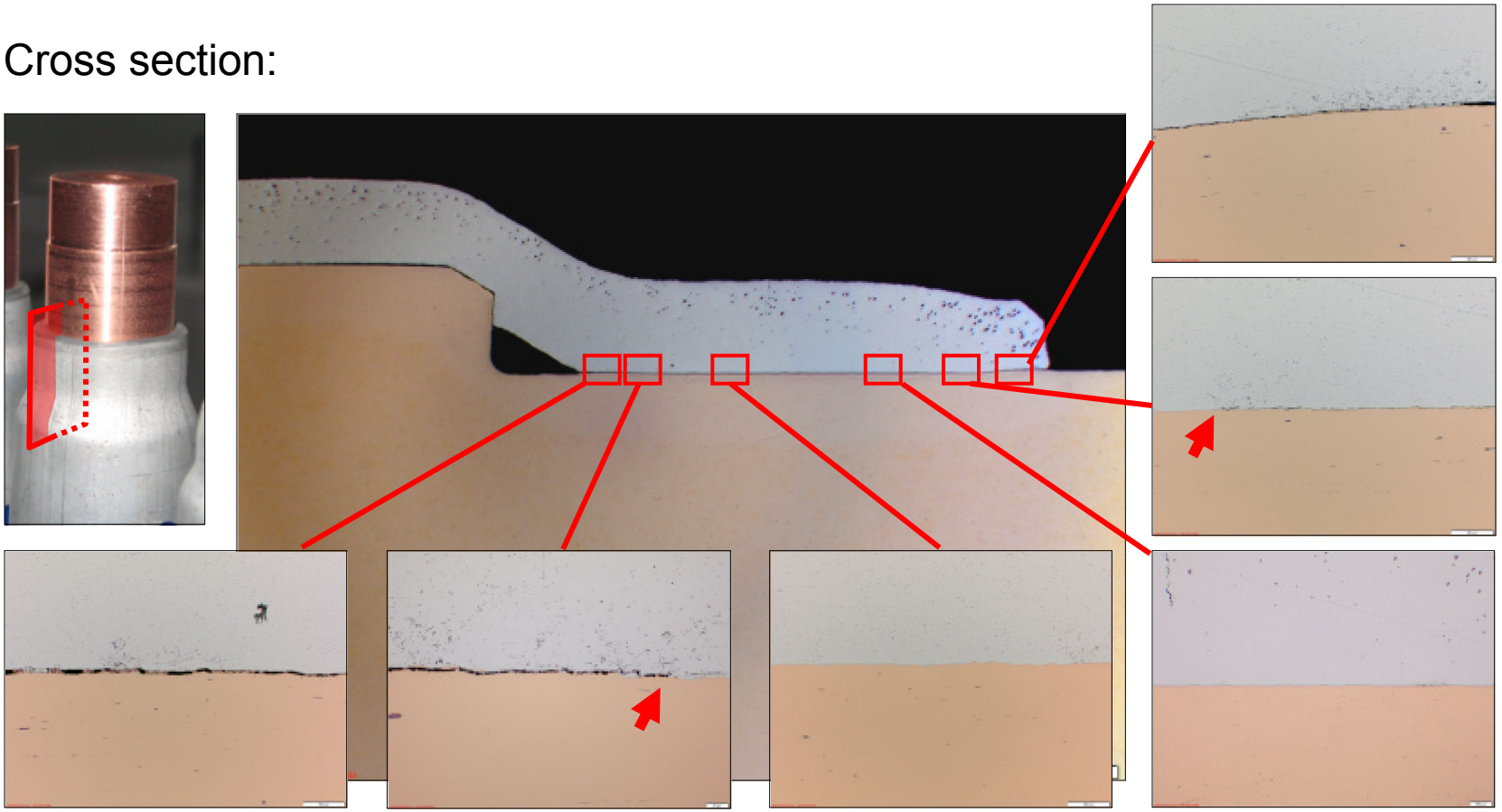


Idea [PAI 06]

Experimental Results, Metallographic Analysis

Overview typical weld geometry

Cross section:



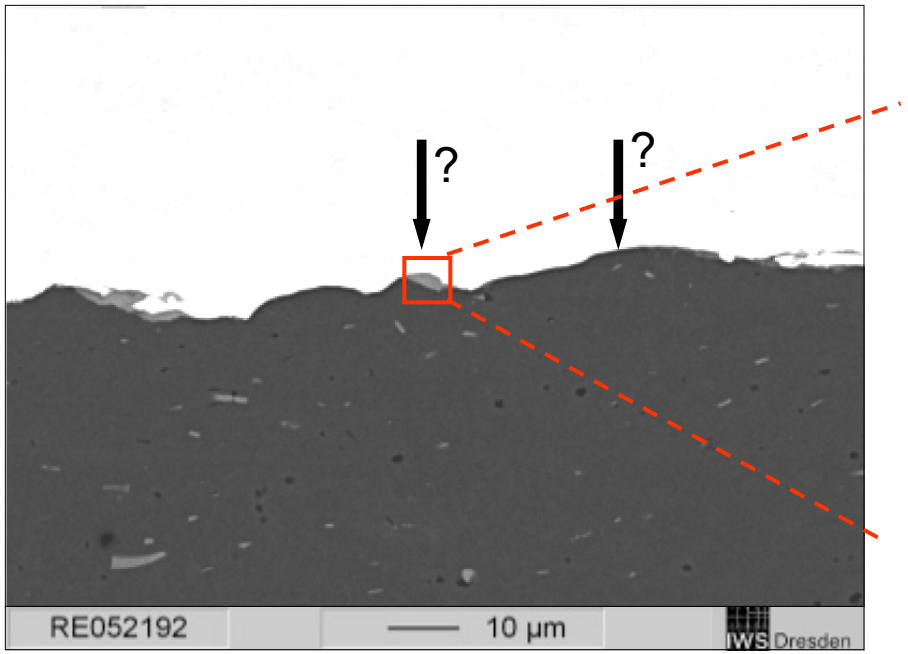
→ Good connection but also residual gap at start/end

→ critical for fatique and crevice corrosion, needs optimization

Experimental Results, Metallographic Analysis
Properties and Influence of Intermetallic Phases

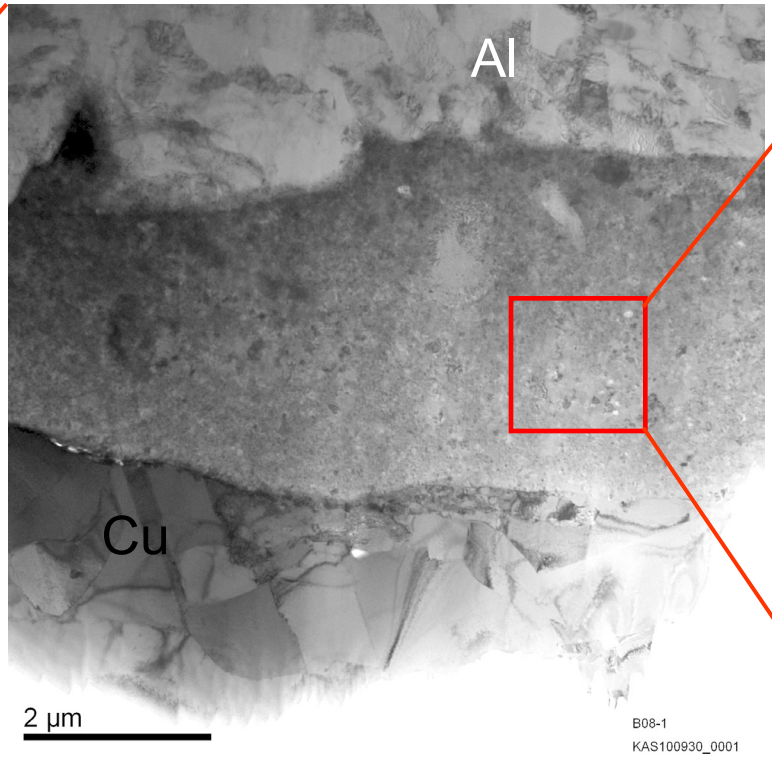
Discussed in ICHSF 2010:

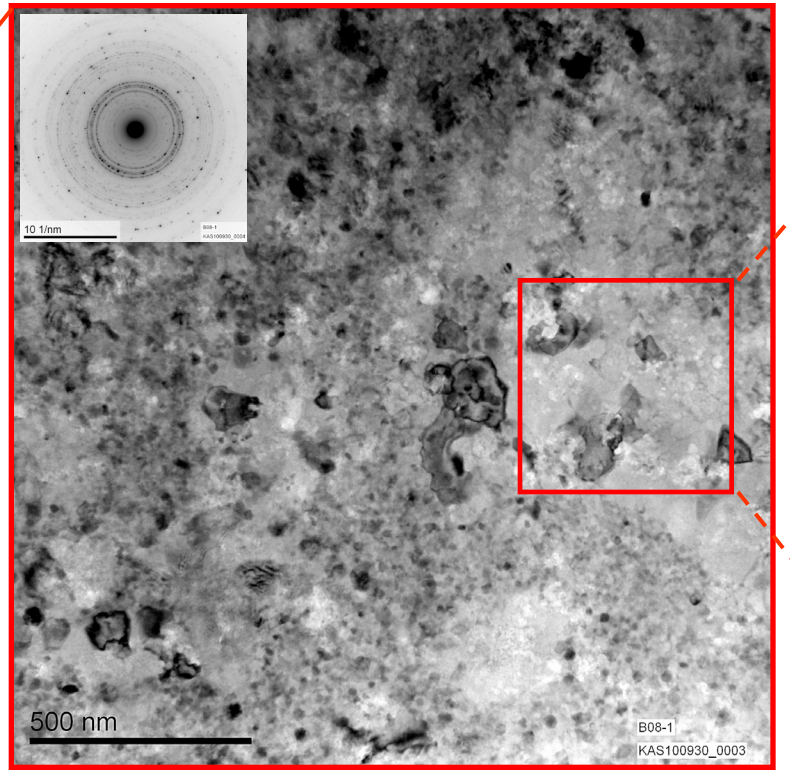
- SEM-visible intermetallic phases can be reduced to pockets in Al+Cu
- Experience/Literature: films with thickness <5µm not detrimental
- Still unclear if intermetallics free interface has been reached even partly



Experimental Results, Metallographic Analysis
Properties and Influence of Intermetallic Phases

TEM Analysis, 3 µm phase seam, Al+Cu weld





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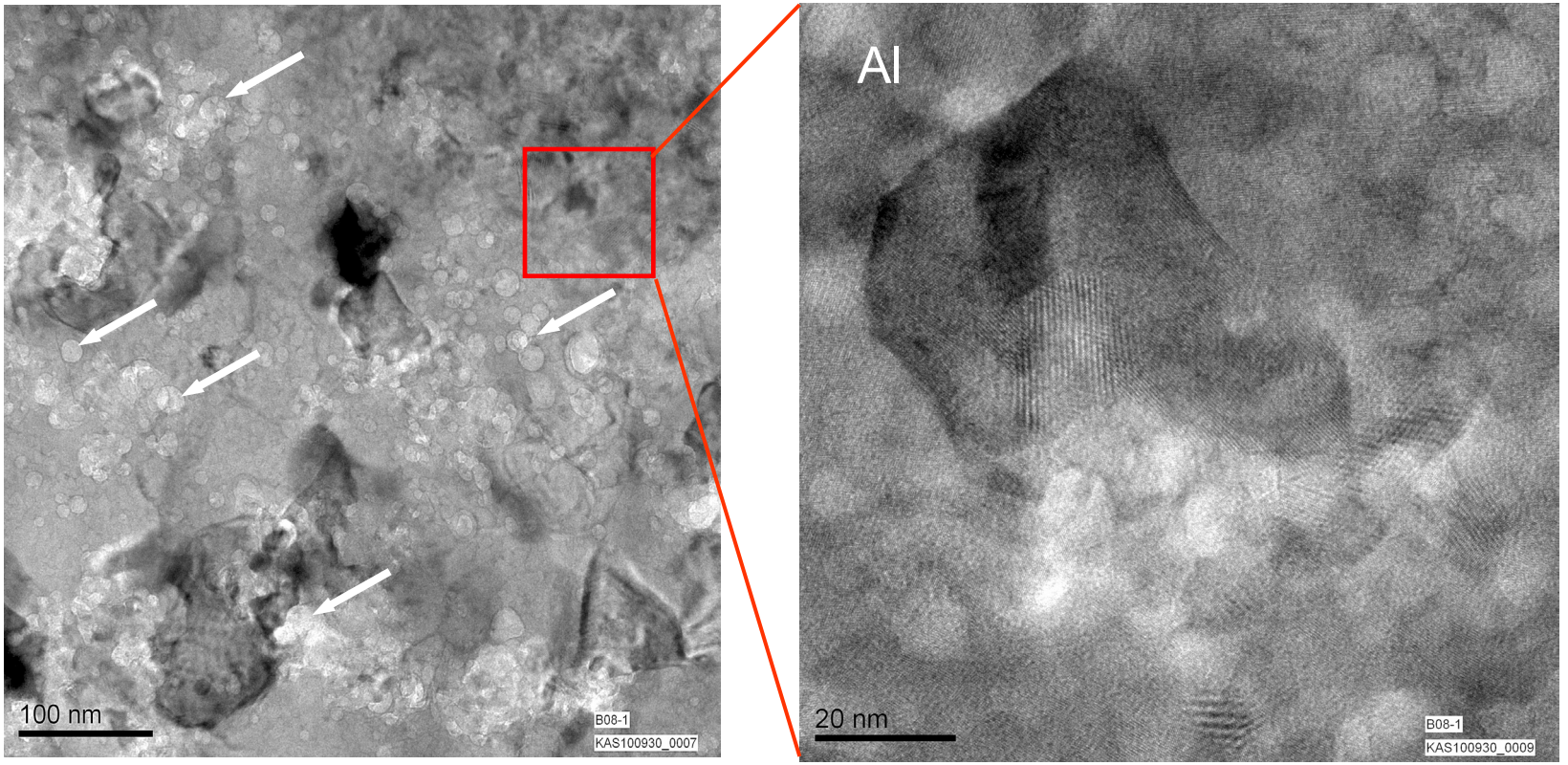
Experimental Results, Metallographic Analysis

Properties and Influence of Intermetallic Phases

TEM Analysis, 3 µm phase seam



- Extreme fine grained structure, no preferred crystal alignment
- Unusually high nano-porosity (diameter 10-20 nm)

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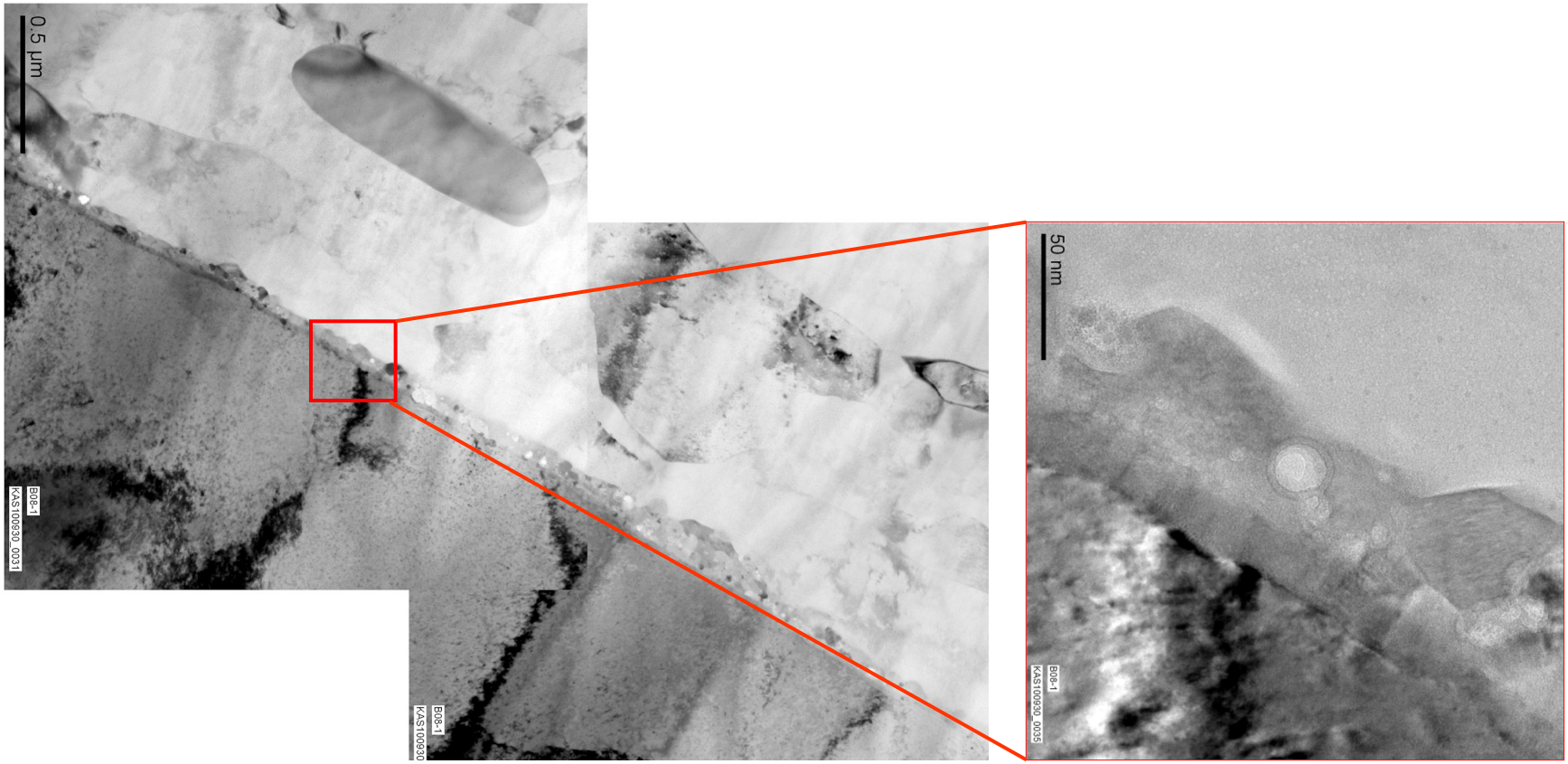
Experimental Results, TEM Analysis

Analysis of pocket-free sections



→ **Continuous films were found throughout all analysed specimen!**

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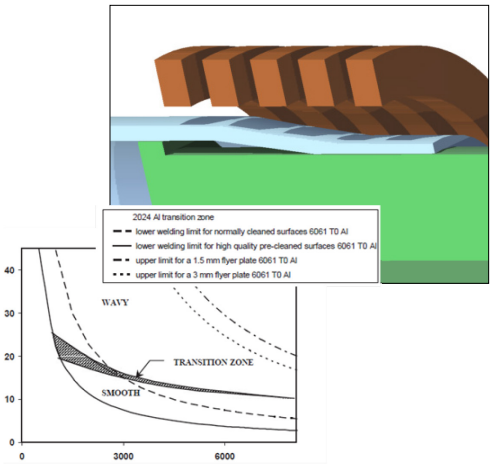
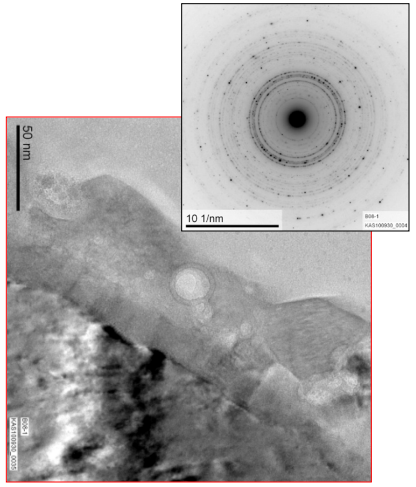
Conclusions

- Although MPW is also a shock welding process, it seems to differ significantly from EXW behaviour
- By discussing a metastable wave initiation, wave formation for MPW could be explained
- MPW can be used to create mixed material joints with extremely low intermetallic phases
- Seen from TEM Analysis, at least for Al+Cu joints fully intermetallics free joints do not seem feasible





Acknowledgements

The authors would like to thank the European Regional Development Fund (ERDF) and the State of Saxony for its financial support.

We also thank the team of the High Magnetic Field Laboratory of the Helmholtz Center Dresden-Rossendorf for the design and manufacturing of the pulse generators.