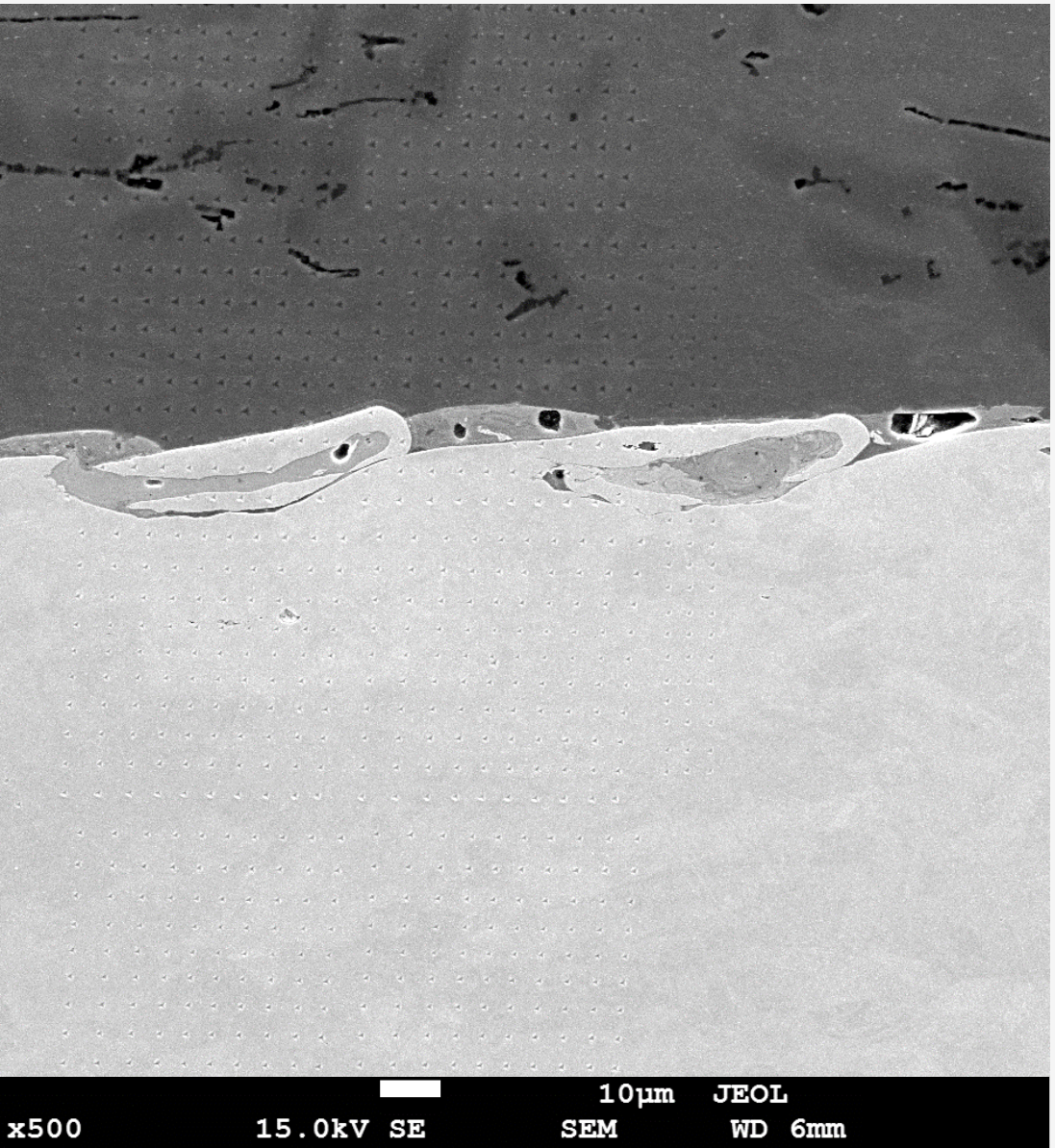

ICHSF21 INTERNATIONAL CONFERENCE ON HIGH SPEED FORMING

A MICRO-MECHANICAL AND MICROSTRUCTURAL ANALYSIS AT THE JOINT INTERFACE BETWEEN DISSIMILAR MATERIALS IN MAGNETIC PULSE WELDING (MPW)

9th International Conference on High-Speed Forming (ICHSF 21)

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Benjamin Zielinski[1)*], Tarik Sadat[1], Denis Jouaffre[2], Rudy Dubois[1], Stephania Kossman[1], Laurent Dubar[1], Eric Markiewicz[1]

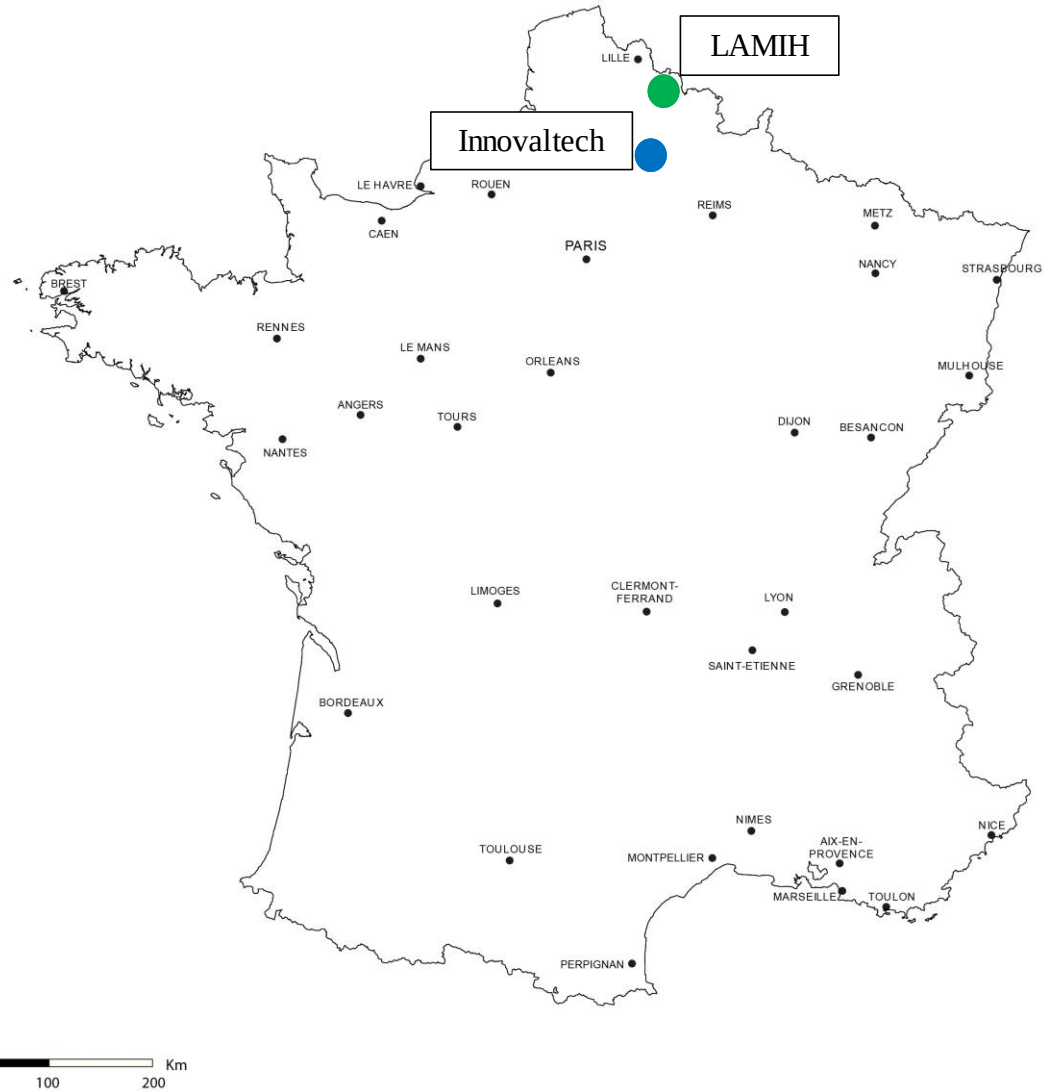
1) Laboratoire d'Automatique, de Mécanique et d'Informatique Industrielles et Humaines, LAMIH, Université Polytechnique Hauts-de-France, UMR CNRS 8201, 59300 Valenciennes, France

2) PFT Innovaltech – Lycée Condorcet, 02100 Saint-Quentin, France

Contents

Introduction - Presentation

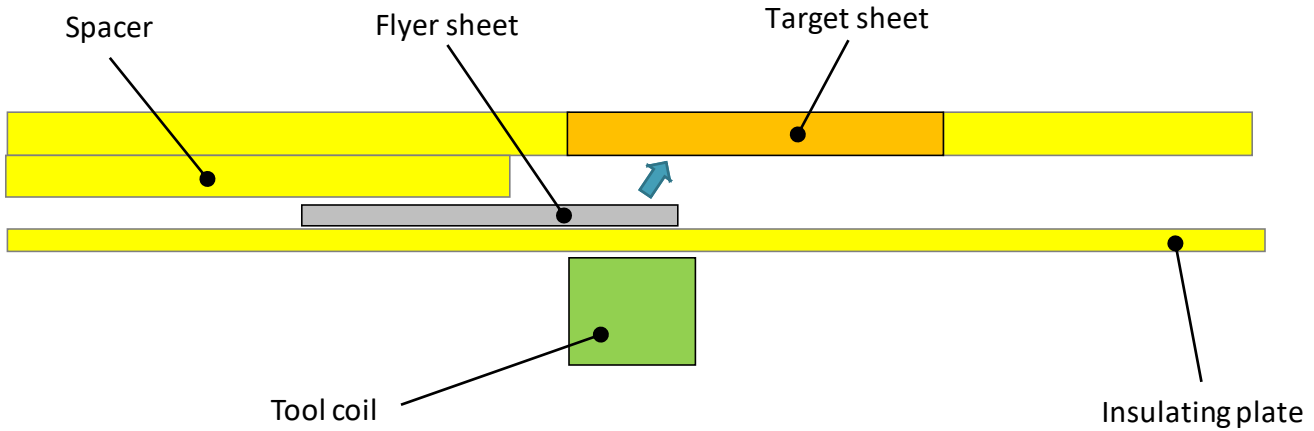
- Laboratory LAMIH
  - 4 departments – Around 250 members
- Location: Valenciennes (Hauts-de-France region)
- Partnership with Innovaltech



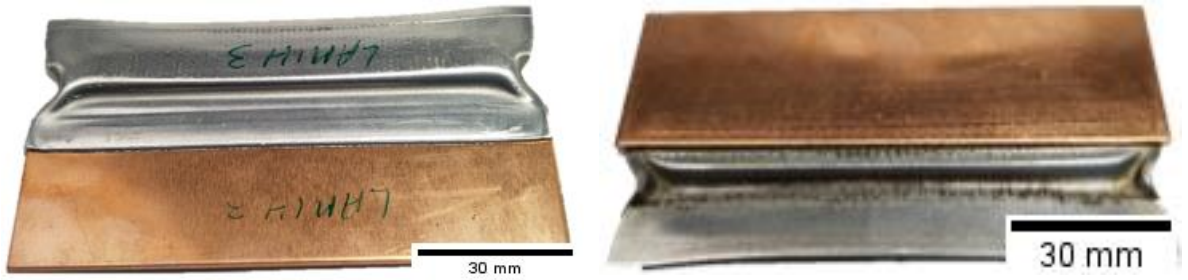
Introduction - Overview

- Target of the presentation:
  - Magnetic Pulse Welding (MPW) interface
  - Microstructural properties
  - Mechanical properties

- MPW parameters:
  - Materials couple:
    - Copper and copper (Cu/Cu)
    - Aluminum and copper (Al/Cu)
  - Process parameters:
    - Flyer: 1 mm - Base: 2 mm
    - Energy: 19.4 kJ
    - Spacing: 2 mm



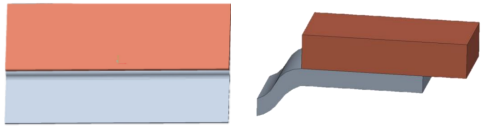
Scheme – Main elements of the MPW process



Al/Cu plate sample welded by MPW

Introduction - Welding interface

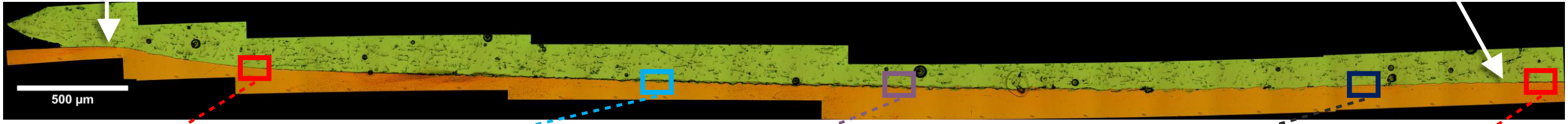
- Several kind of interface along the welding seam (especially for dissimilar materials):
  - IMC: Intermetallic compound (example : Al_2Cu)

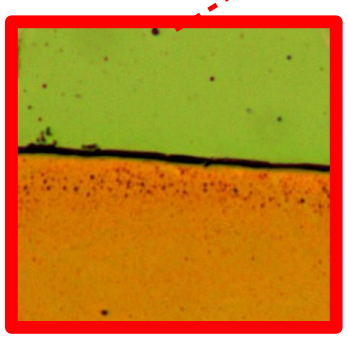


Start of the welding

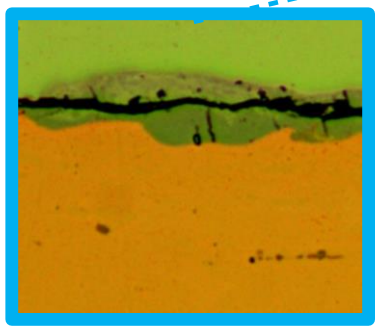
Stitched image from optical miscroscope – Interface Al/Cu plates sample n°3 – D welded by MPW

End of the welding

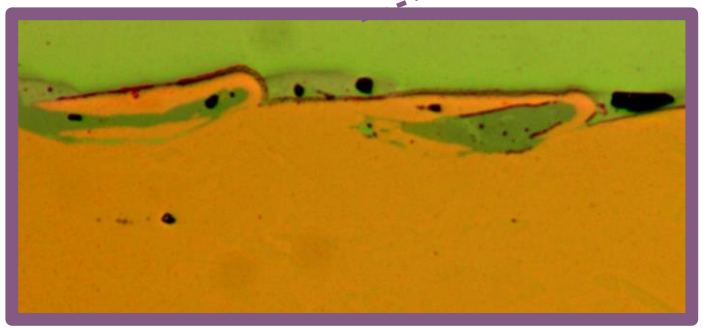




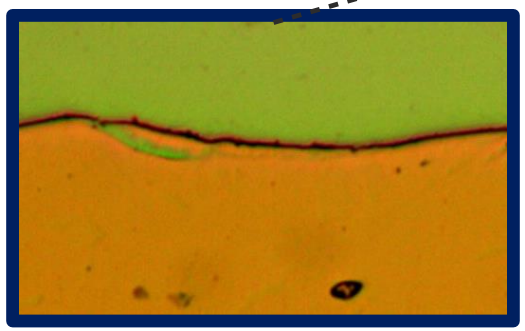
(a) – Unwelded area and no IMC



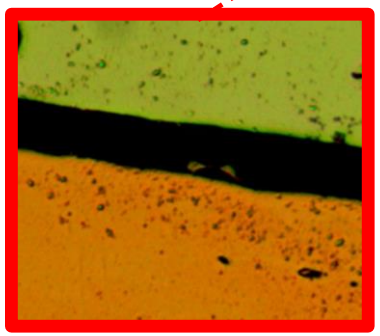
(b) – Unwelded (cracked) area with IMC



(c) – Welded area with IMC



(d) – Welded area without IMC



(e) – Same as (a)

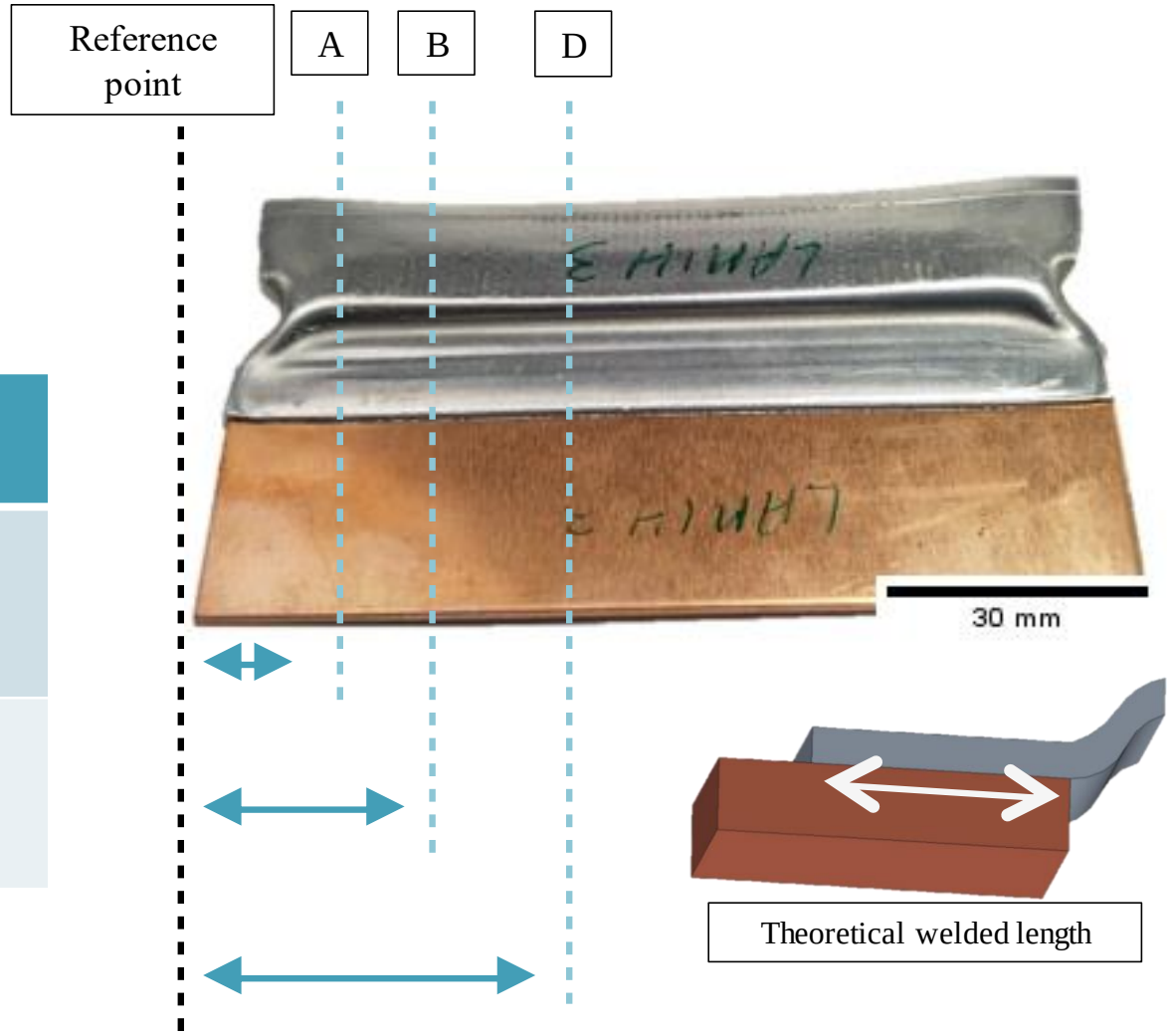
Introduction - Welding interface

- Important to determine the effective area for the welding
- Effective welding "length" is locally varying

$$Effective\ welding\ length = \frac{Welded\ length\ (with\ and\ without\ IMC)}{Length\ of\ the\ theoretical\ welded\ length}$$

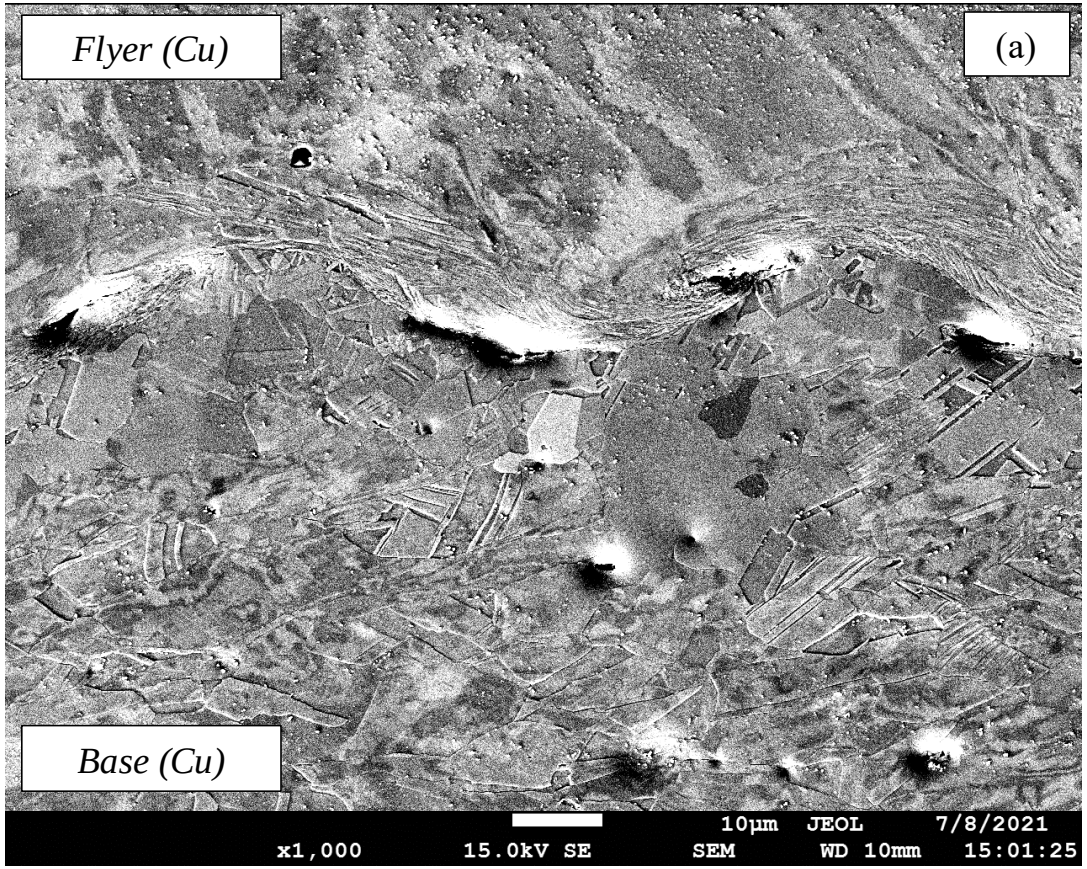
Section localization	A	B	D
Position to reference (mm)	12	20	36
Effetive welding "length"	22%	39%	37%

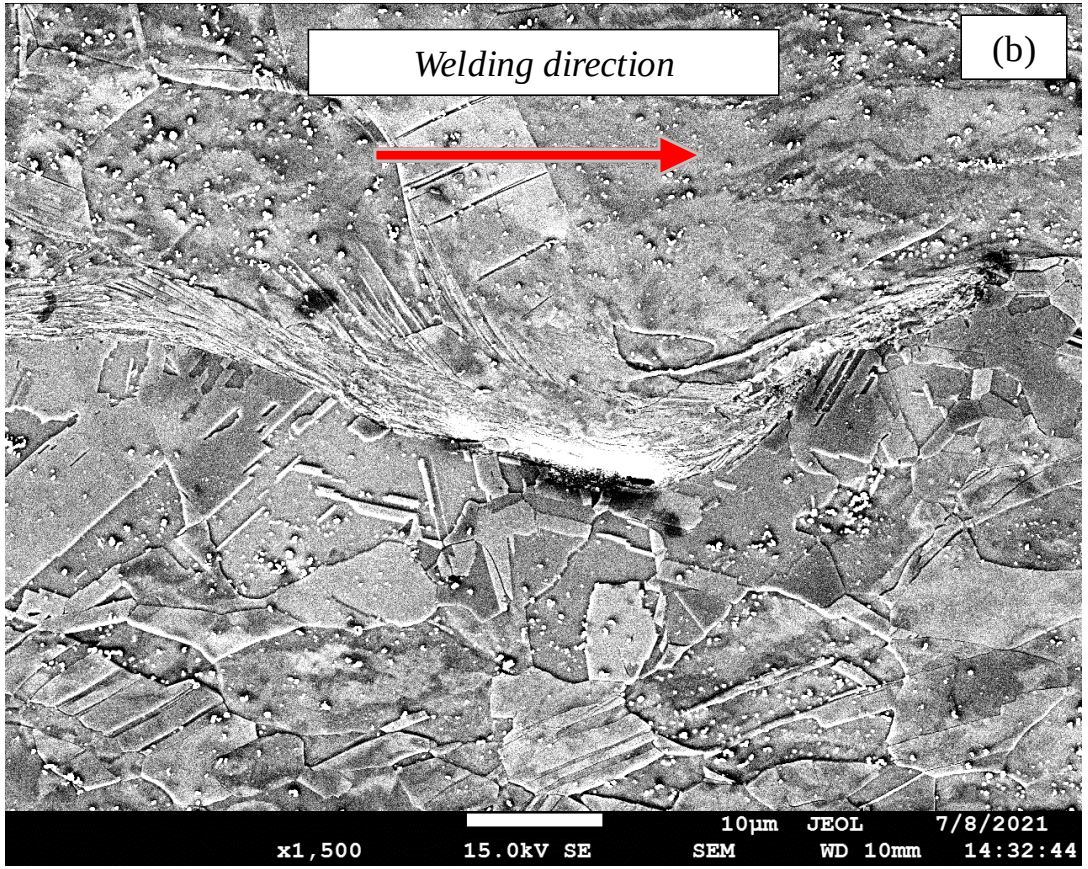
Scheme – Position of the sections on a Al/Cu welded sample



Microstructure - SEM

- Microstructure is modified by the MPW

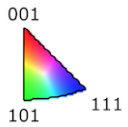




SEM images on JSM-7100F (Jeol) – (a) and (b) - Cu/Cu plates welded by MPW – Interface revealed after electro-polishing

Microstructure - EBSD

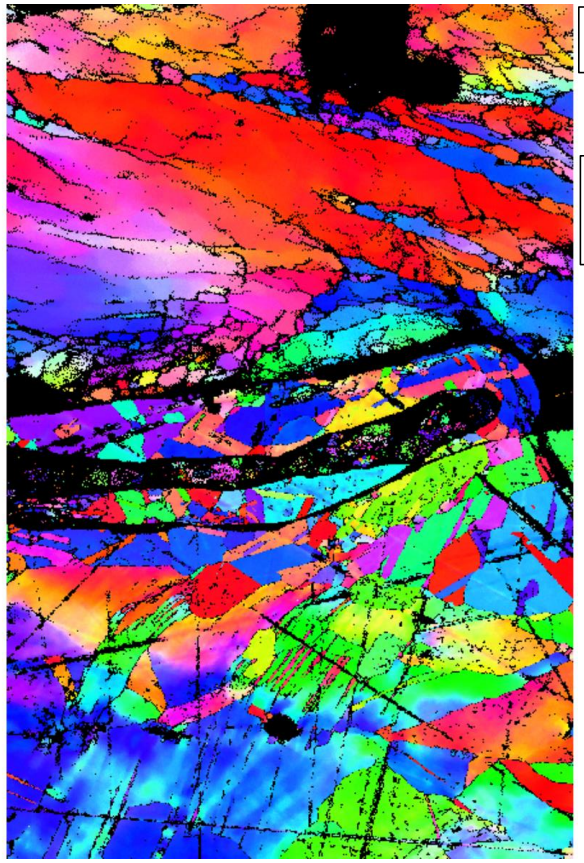
(a)



Flyer (Al)

Welding direction

Base (Cu)

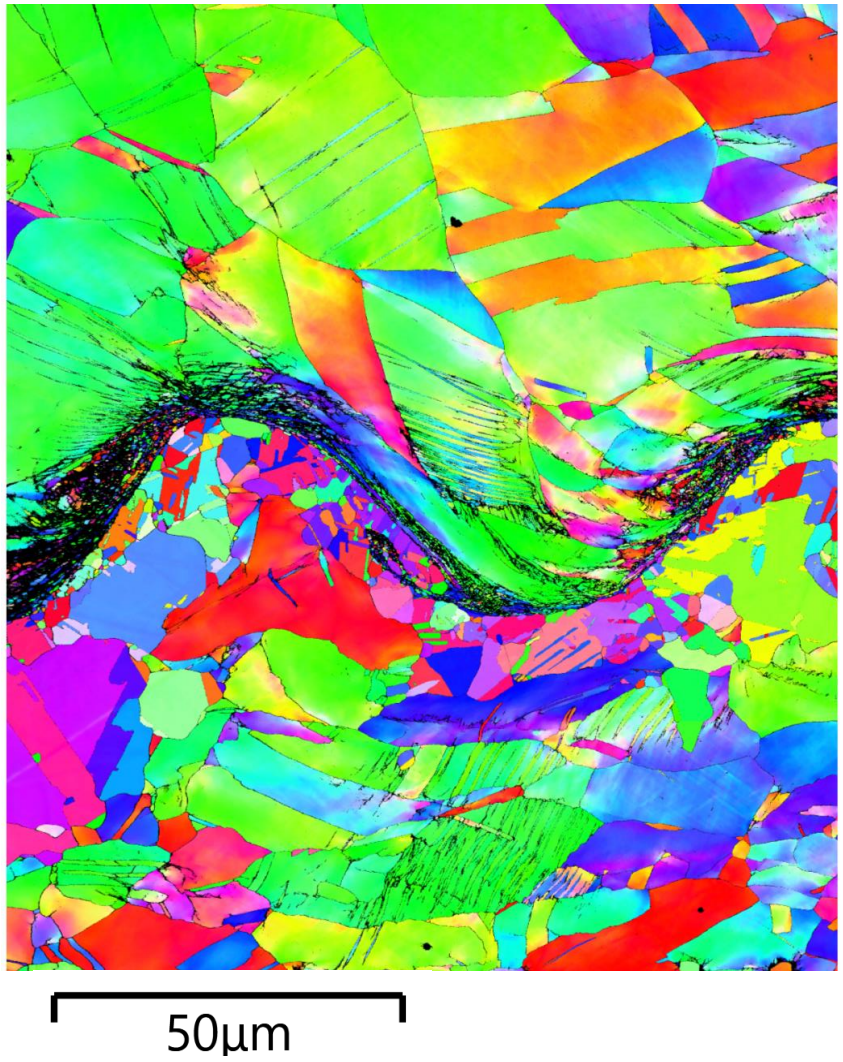


EBSD image on JSM-7100F (Jeol) – (a) - Al/Cu plates welded by MPW – Wavy interface

Flyer (Cu)

(b)

Welding direction



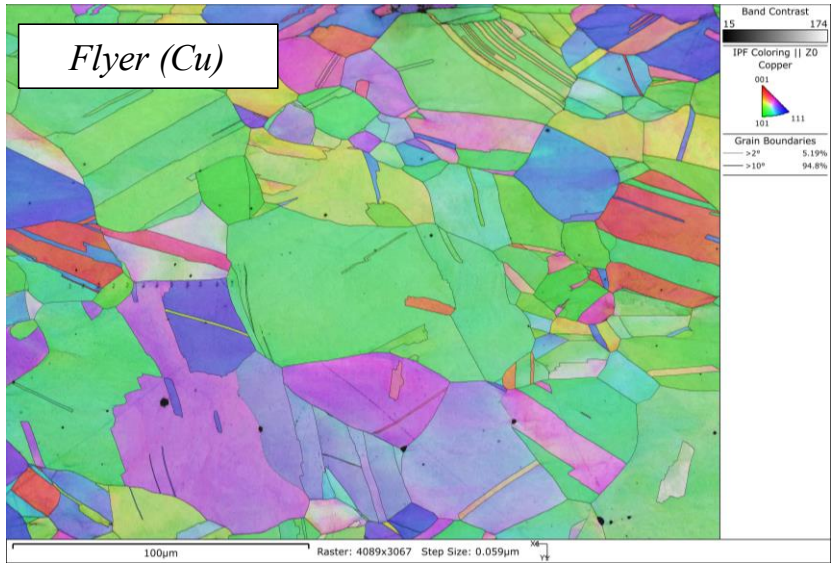
Base (Cu)

EBSD image on JSM-7100F (Jeol) – (b) - Cu/Cu plates welded by MPW – Wavy interface

Microstructure - EBSD

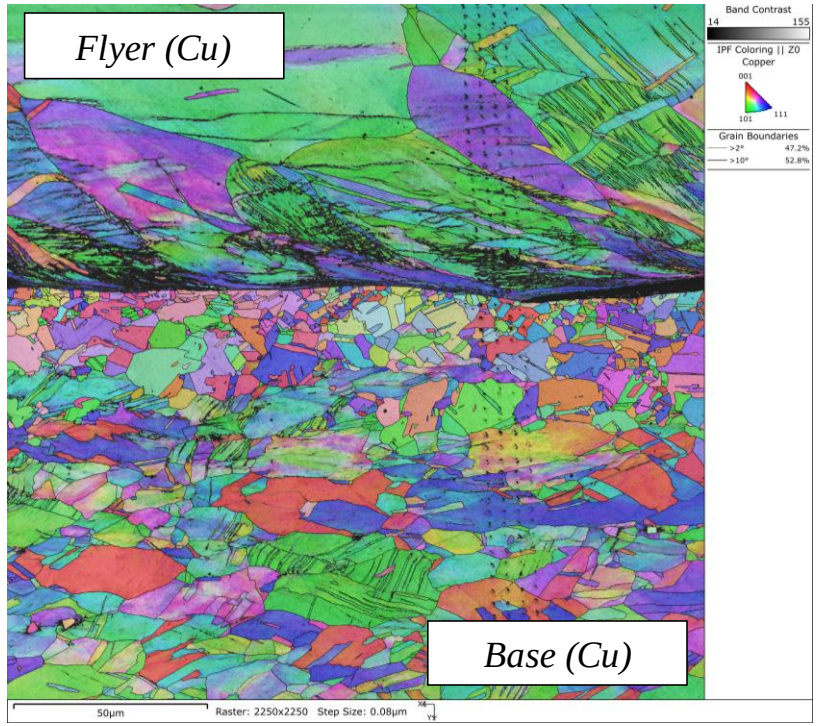
- Global microstructure evolution (Cu/Cu)

(a)

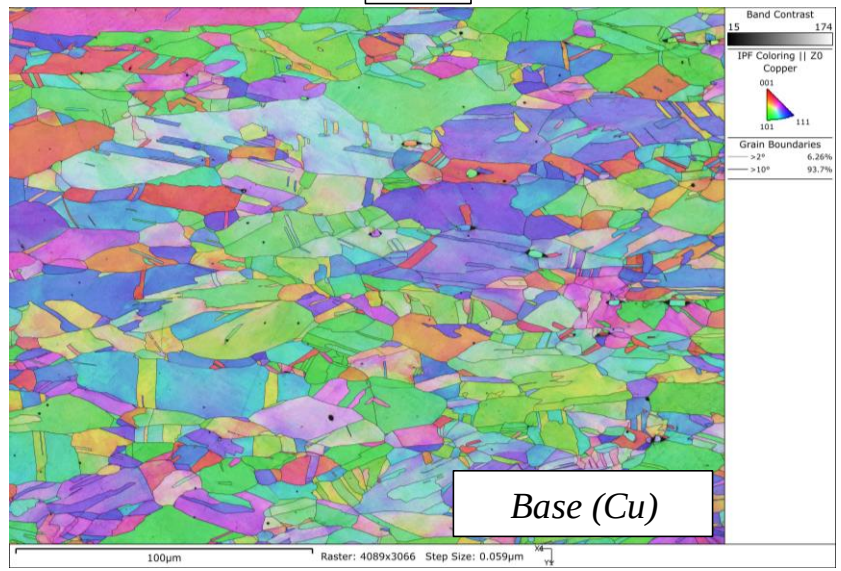


Welding direction

(b)



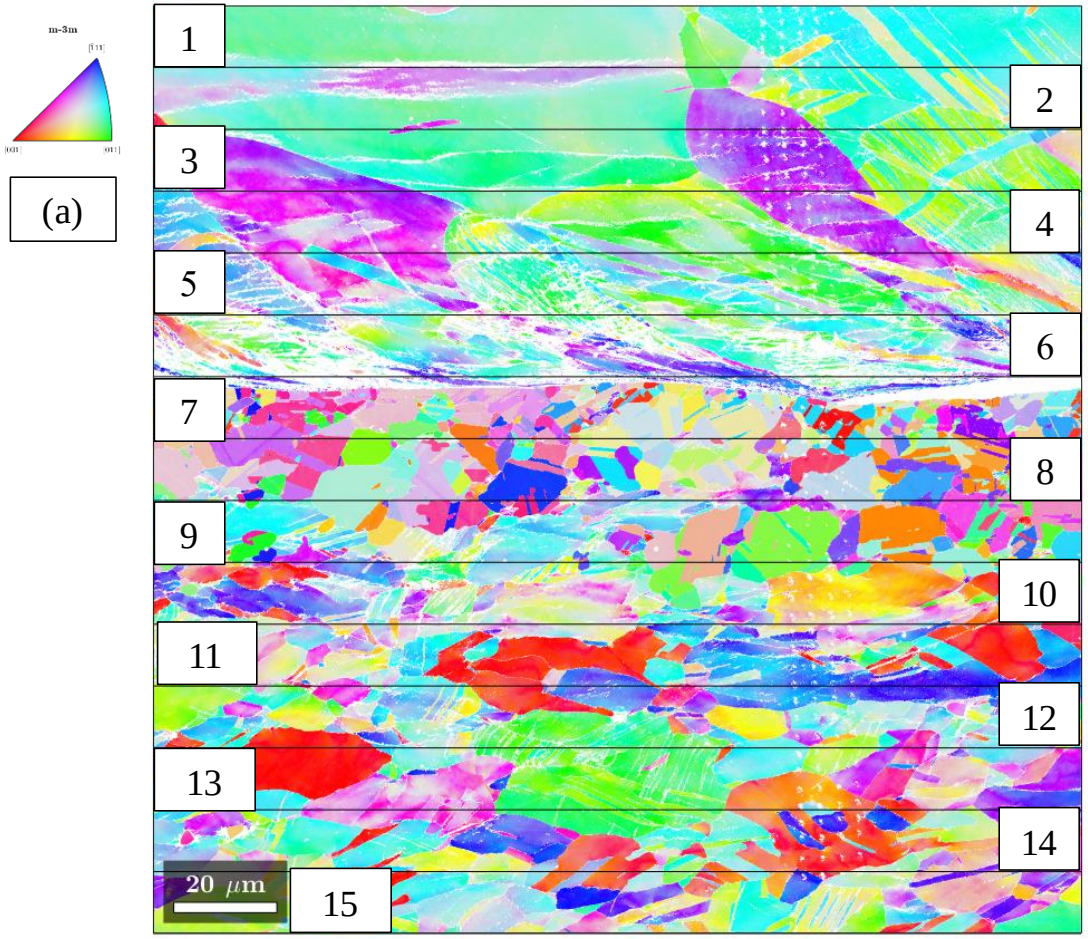
(c)



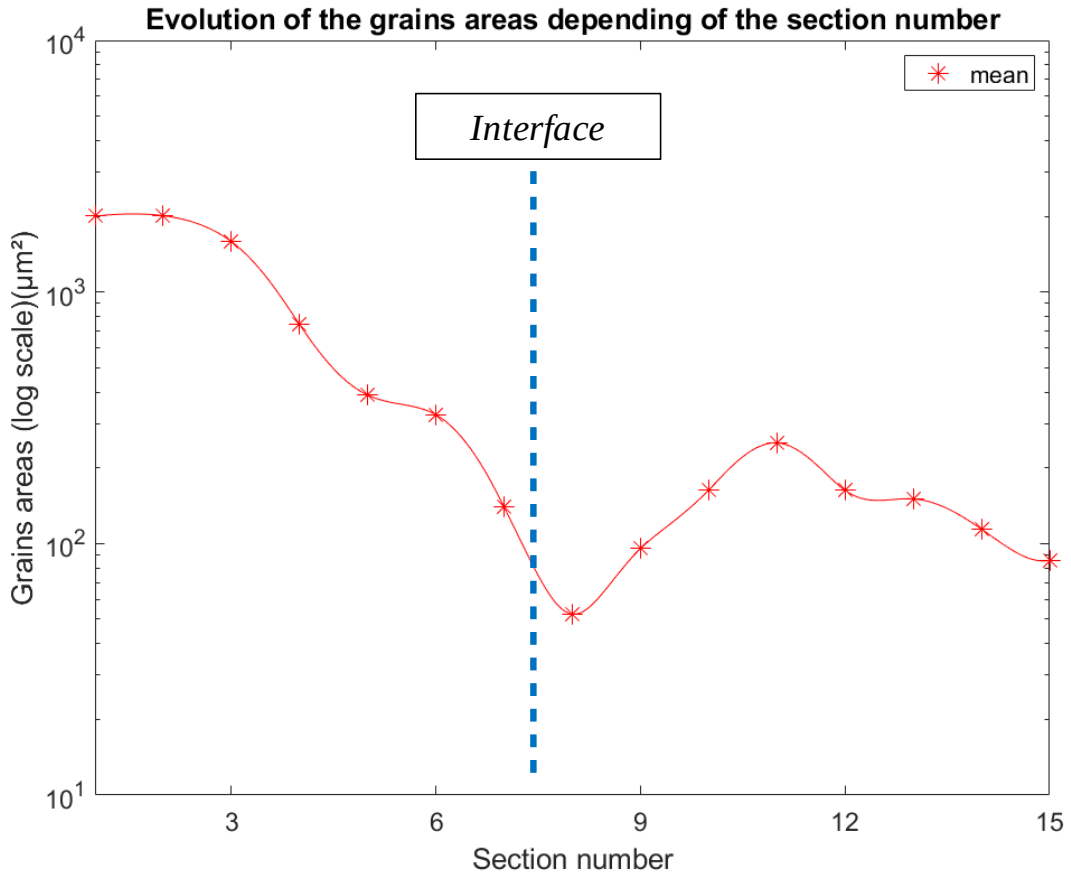
EBSD image on JSM-7100F (Jeol) – (a)(b)(c) – Cu/Cu plates welded by MPW – Microstructural comparison

Microstructure - EBSD

- Local microstructure evolution on the interface



EBSD image on JSM-7100F (Jeol) – (a)– Cu/Cu welded by MPW – Position of the section number



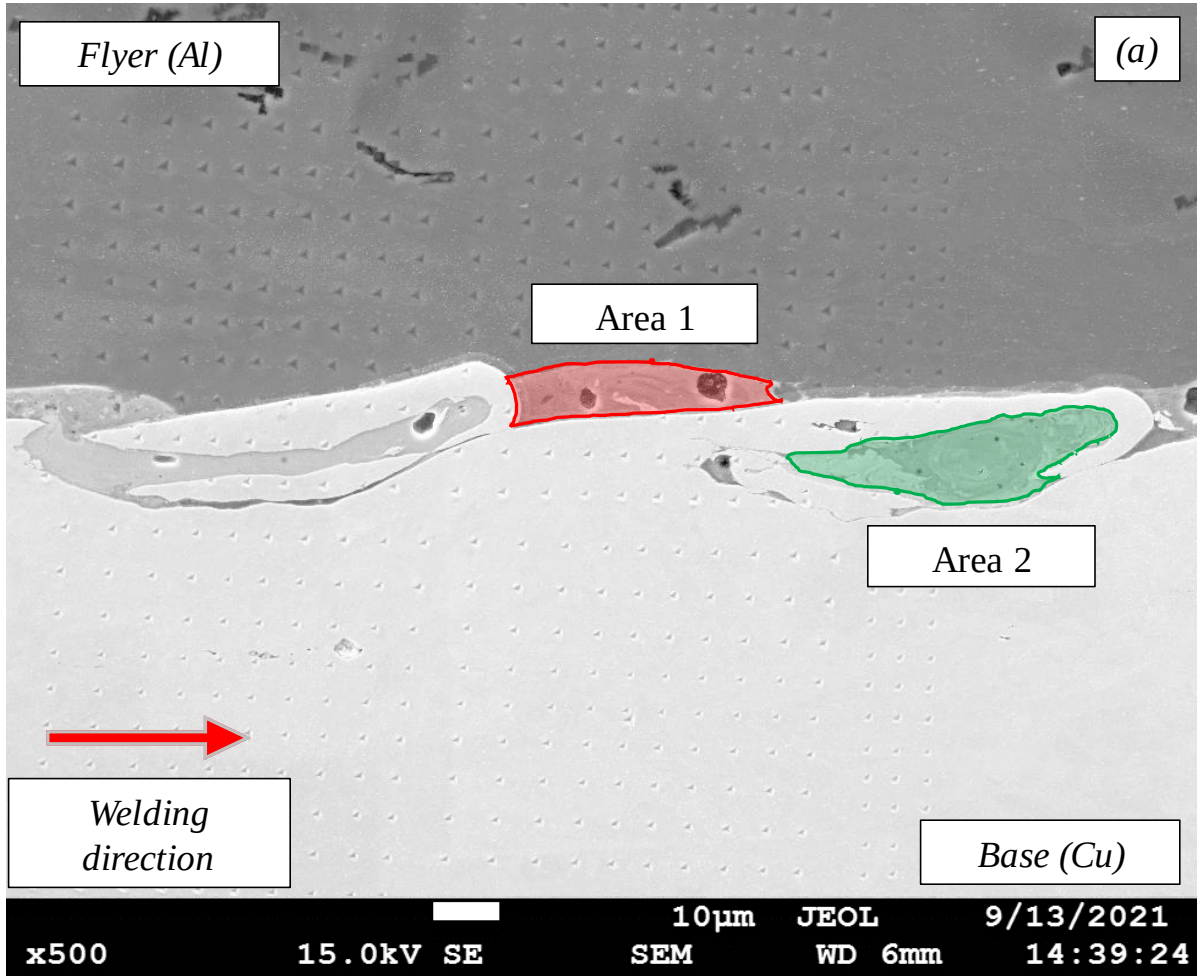
Microstructure - EDS

- Different kind of intermetallic compounds present for Al/Cu samples

	% Weigth	
Elements	Area 1	Area 2
Copper (Cu)	53.2	65.8
Aluminum (Al)	46.8	34.2

- Spatial diffusion very limited between Cu and Al

  ≈ 2-3 µm - no long range impact

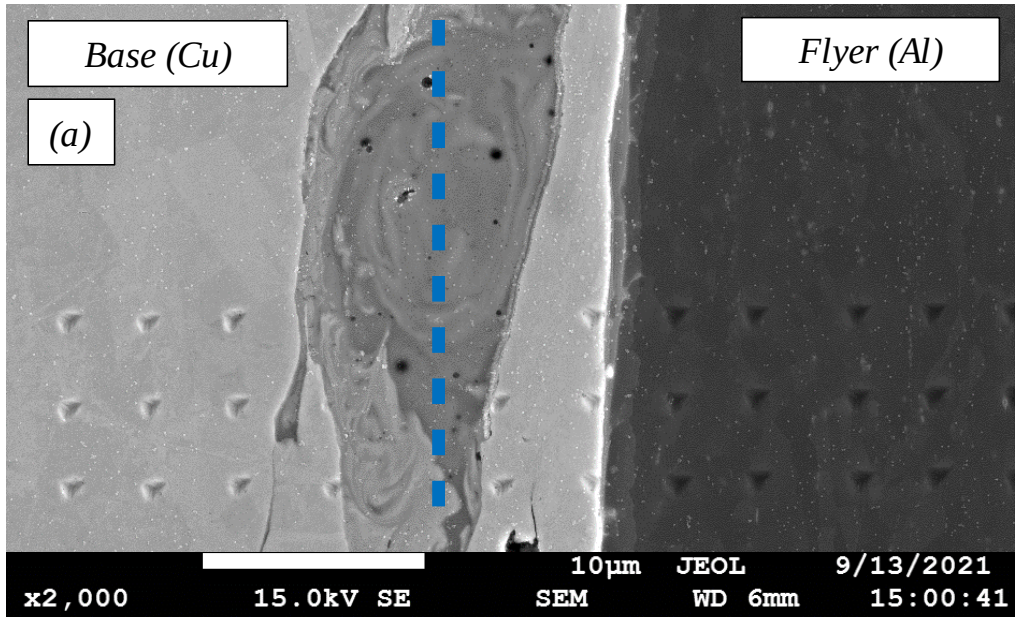


SEM image on JSM-7100F (Jeol) – (a) - Al/Cu plates welded by MPW – Wavy interface with nano-indentation – Areas with the EDS characterization

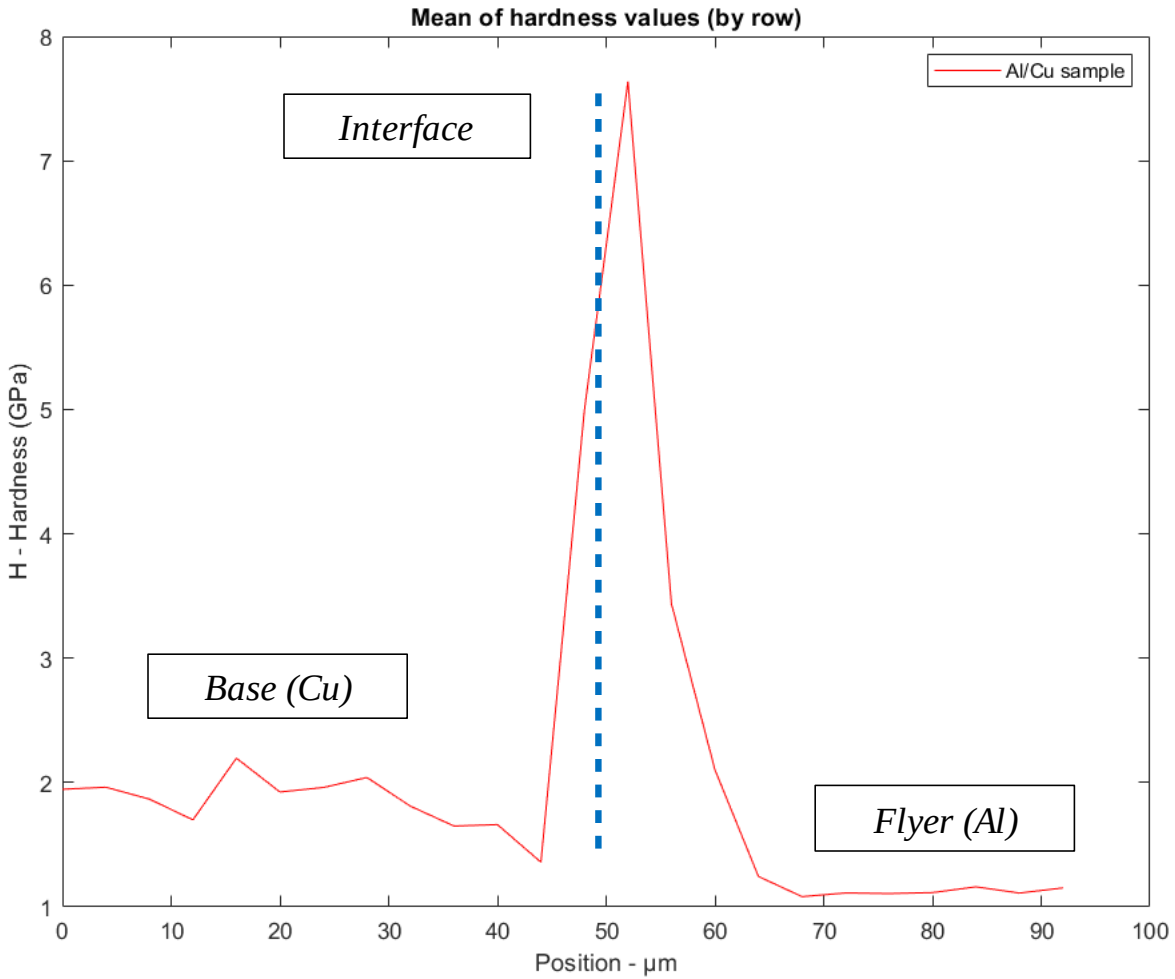
Mechanical - Nanoindentation

- Al/Cu samples:

  Intermetallics impact on the interface hardness



SEM image on JSM-7100F (Jeol) – (a) - Al/Cu plates welded by MPW – Wavy interface with nanoindentation (nanoindenter – Hysitron TI980 – Bruker)



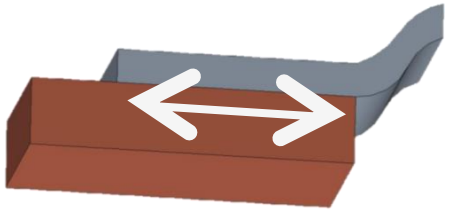
Conclusion

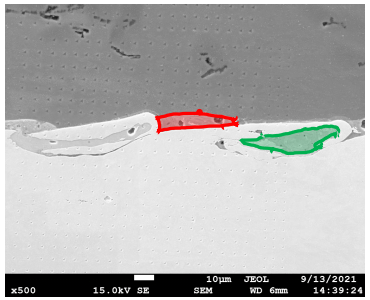
- Conclusion:
  - Different intermetallic compounds composition
  - Important local hardness variation accross the interface (Al/Cu)
  - Local modification for the grains size at the interface (Cu/Cu)
  - Effective welding “length” is varying along the welding seam

- Outlook:
  - Characterization of the different intermetallics compounds and local characterization of the welding seam
  - Determination of the global effective welded area
  - Deeper analysis for grain sizes and orientation

Questions?

Thanks you for your attention – Any questions?





Benjamin Zielinski, PhD student
benjamin.zielinski@uphf.fr

Laboratoire d'Automatique, de Mécanique et d'Informatique Industrielles et Humaines
LAMIH, Université Polytechnique Hauts-de-France,
UMR CNRS 8201, 59300 Valenciennes, France