

Microstructure of Non-fusion Joints: Friction Stir Welding, Transient Liquid Phase Sintering and Pulsed Plasma-Assisted Diffusion Bonding

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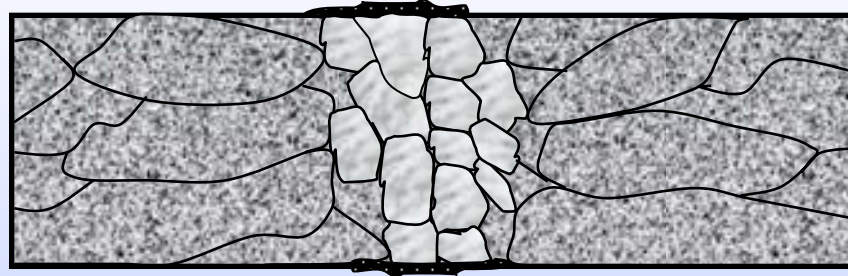
Outline of Presentation

- **Problems with fusion joints in ODS ferritic stainless steels**
- **Friction Stir Welding**
- **Transient-Liquid Phase Bonding**
- **Pulsed Plasma-Assisted Diffusion Bonding**



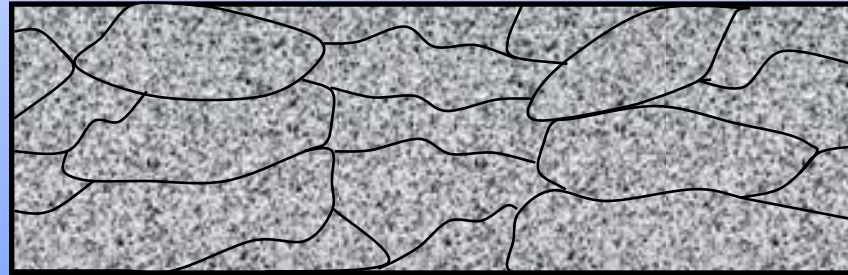
Joint Microstructure

**Fusion
Weld**

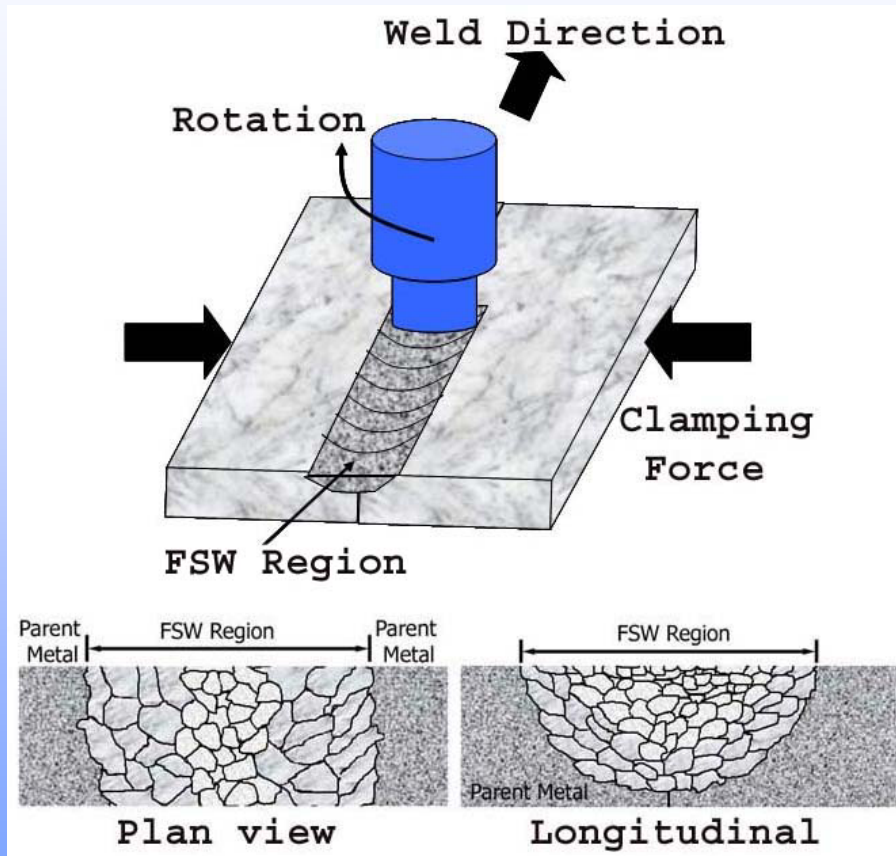


**Original
Interface**

Ideal



Friction Stir Welding



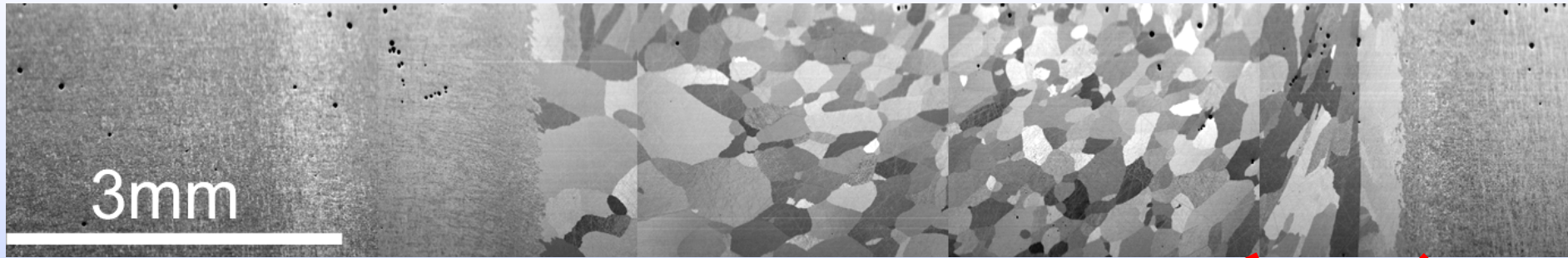
PM2000
Plan view



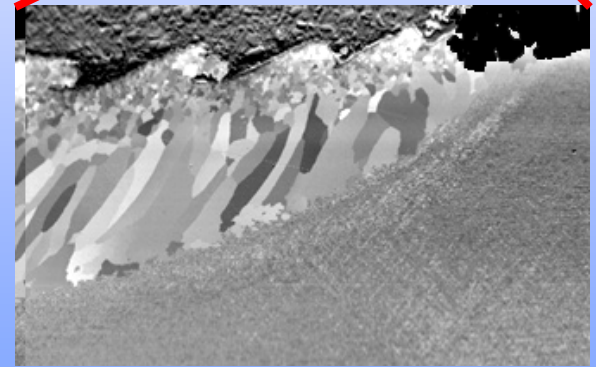
10 mm



Friction Stir Weld in PM2000



**SEM plan view image of PM2000 FSW
Annealed at 1380°C for 1h
after removal of top layer**

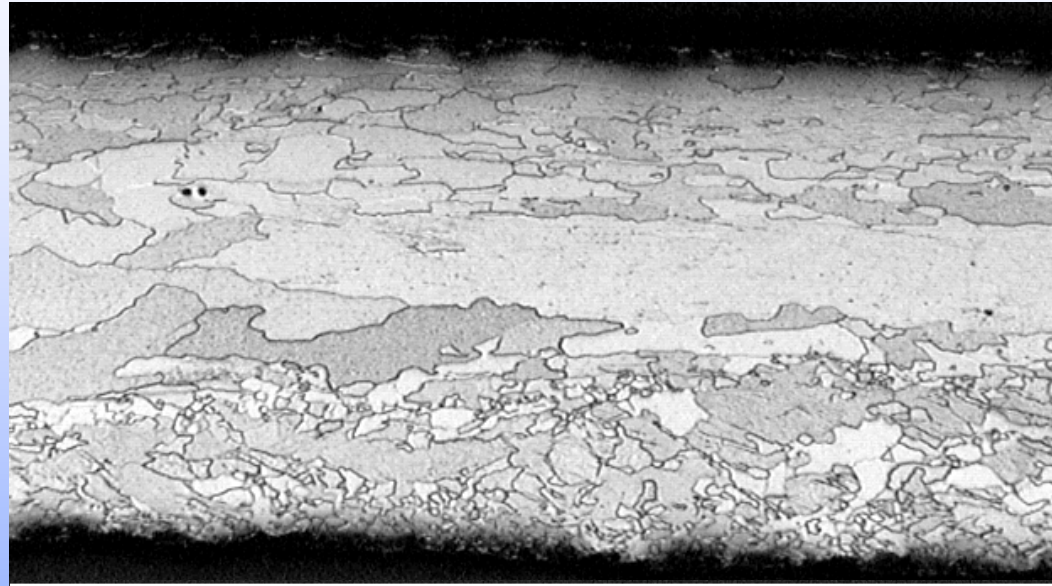


Cross section 1mm



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Friction Stir Weld in PM2000



06-0852-09

GJT-3 PM2000
friction stir welded

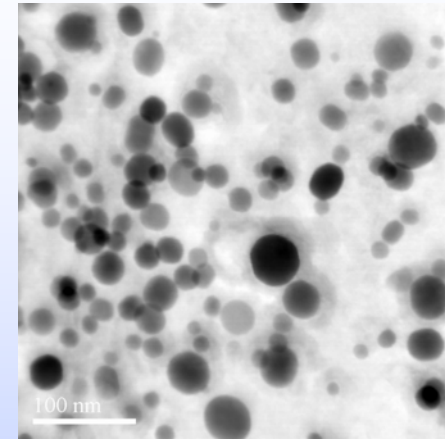
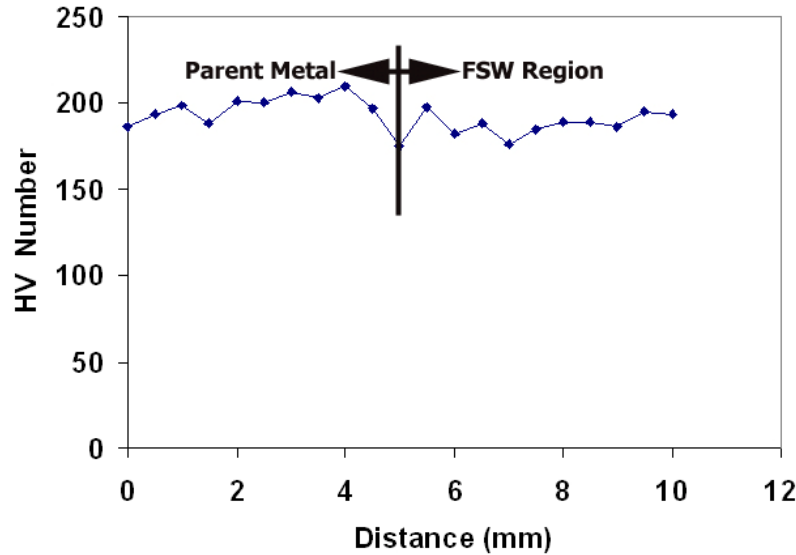
50X 100µm
Modified Keller's

Annealed, rolled at 175°C, 40% reduction,
then recrystallised at 1380°C for 1h.



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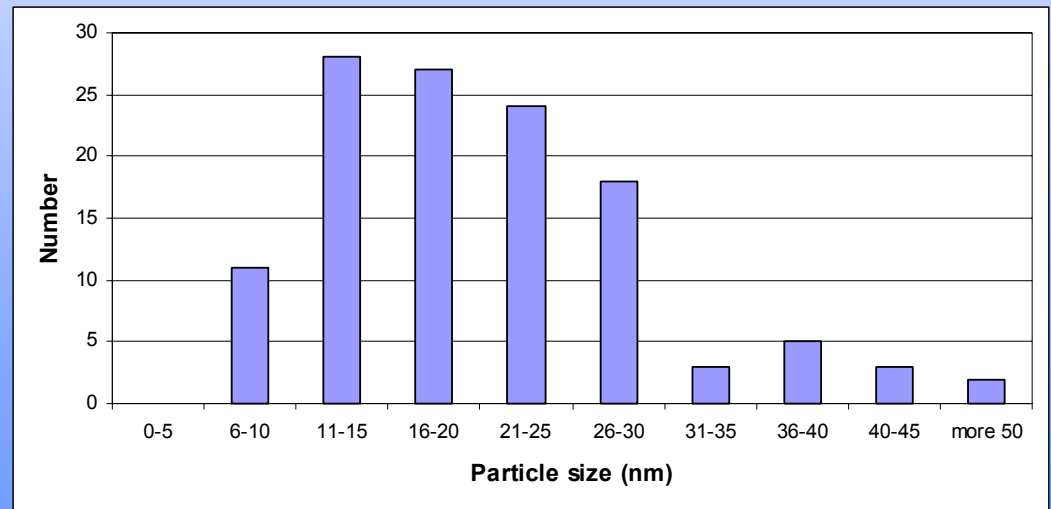
Friction Stir Weld in PM2000



Particle extraction

Hardness

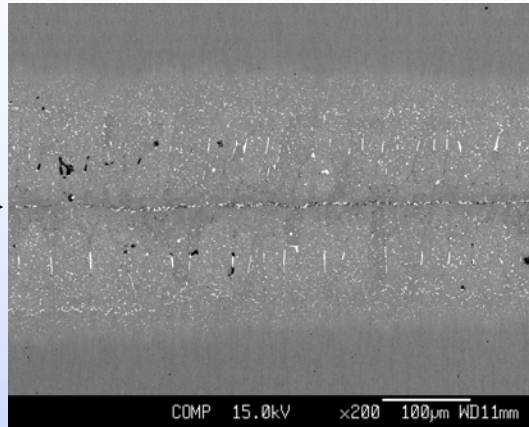
Particle Size
Distribution of
Friction Stir-Welded
Region in PM2000
after 1 hr heat
treatment at 1380°C



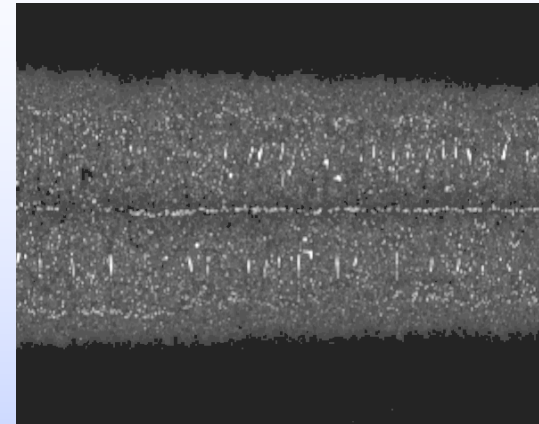
TLP Bonding of PM2000

Original
Interface →

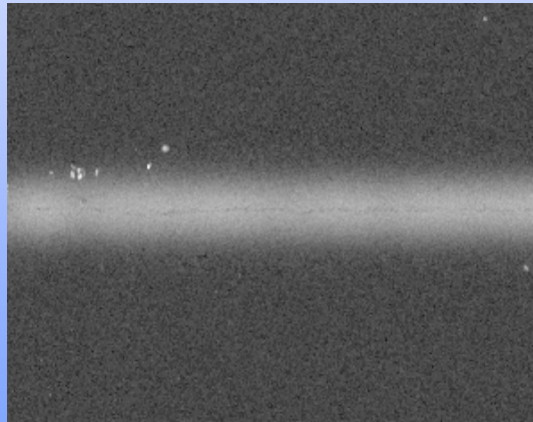
BSE
Image



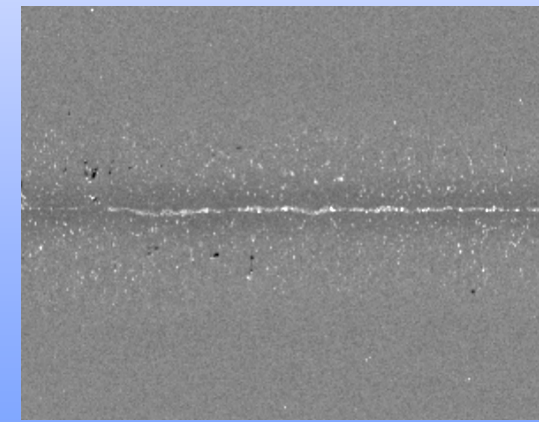
Au map



Si map



Al map



As-joined

Bornstein, Hurley and Wright (2006)

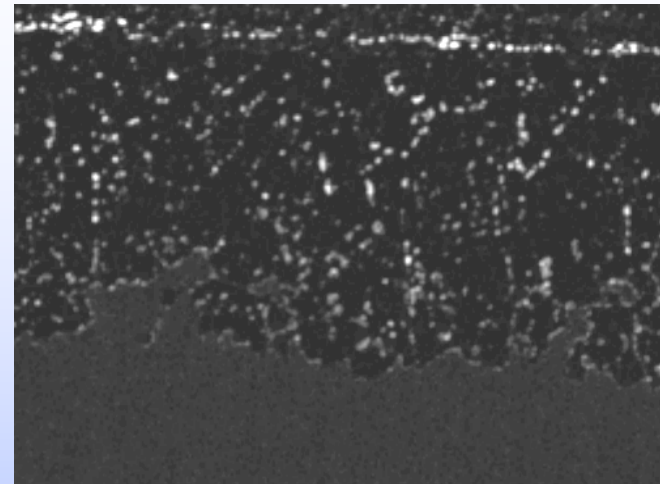
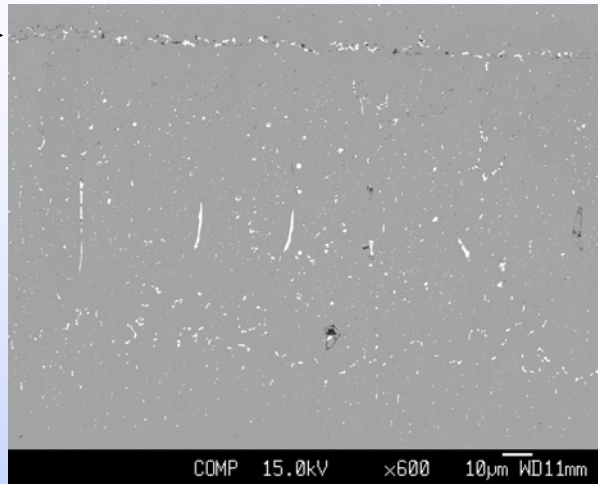


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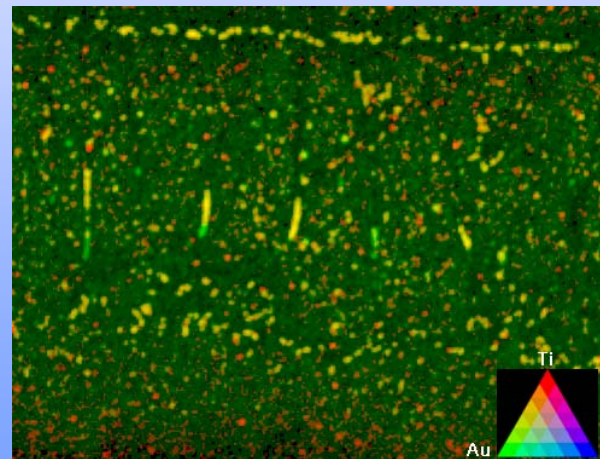
TLP Bonding of PM2000

Original
Interface →

BSE
Image



Y map



Au + Ti
map

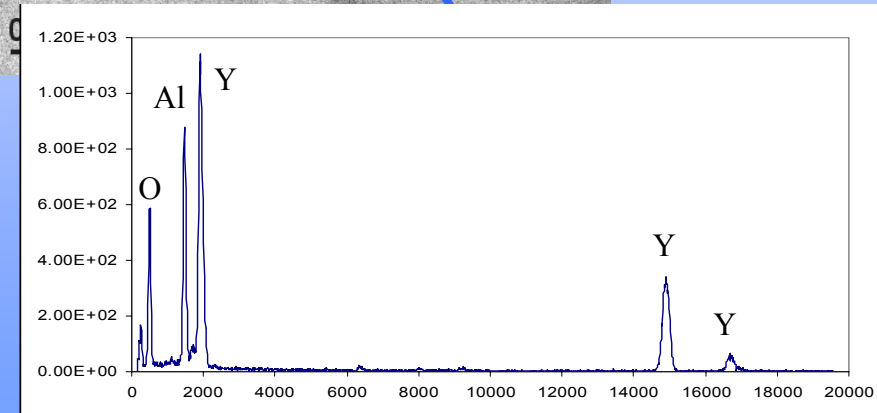
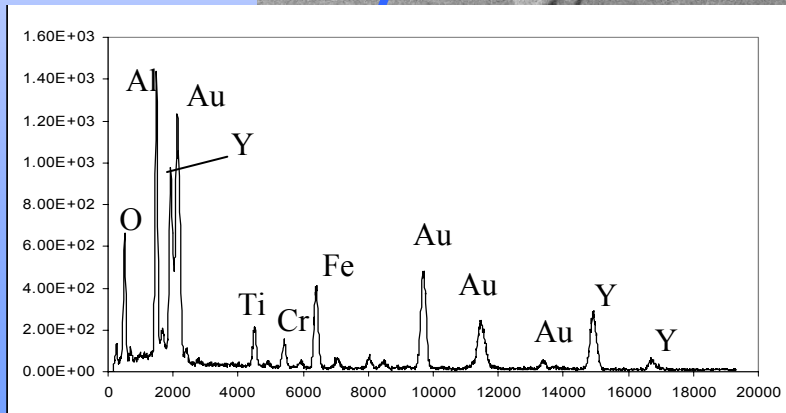
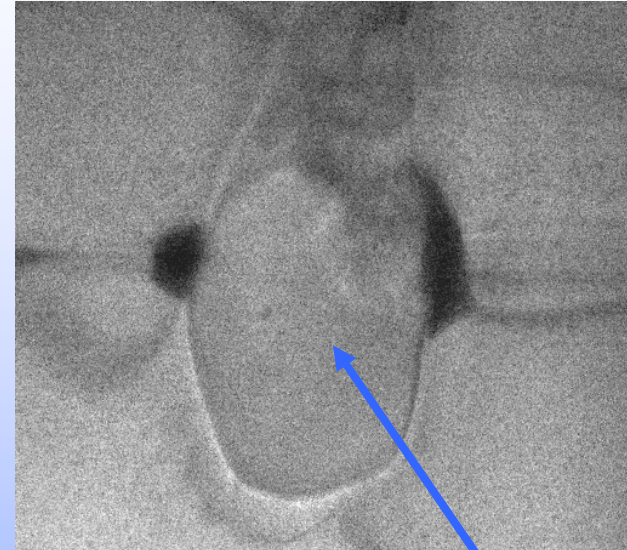
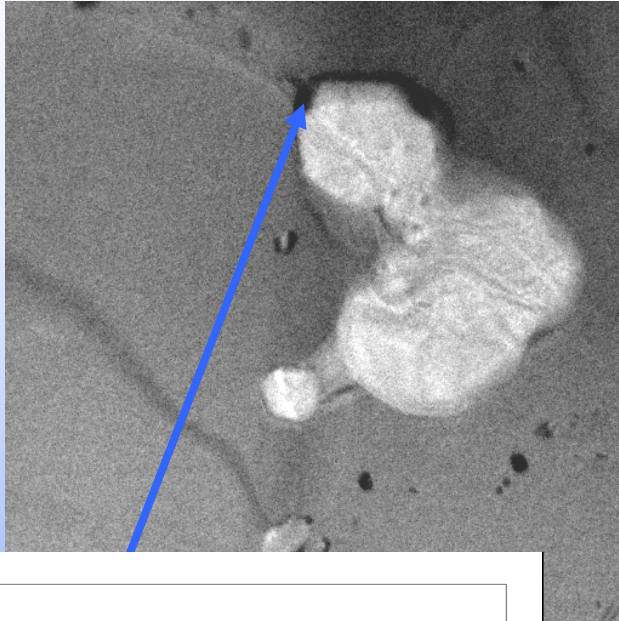
Annealed for 4h at 1000°C after joining

Bornstein, Hurley and Wright (2006)



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Agglomeration of particles surrounded by Au rich phase

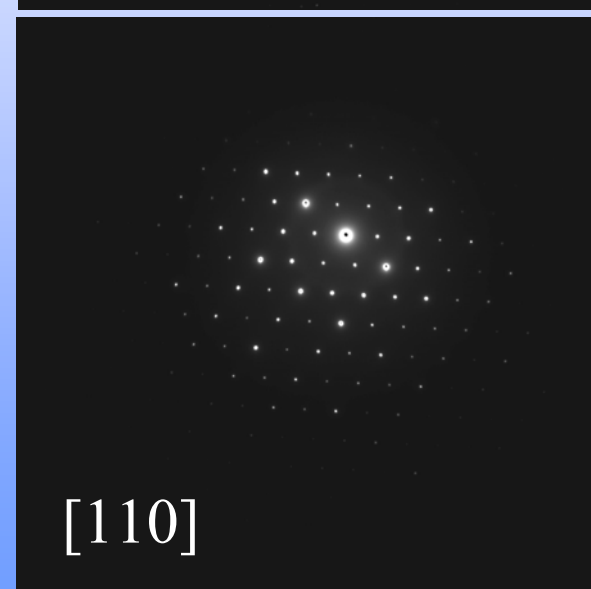
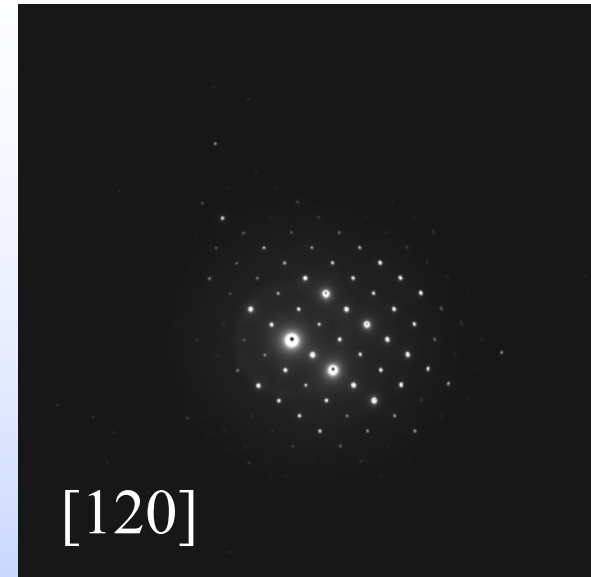
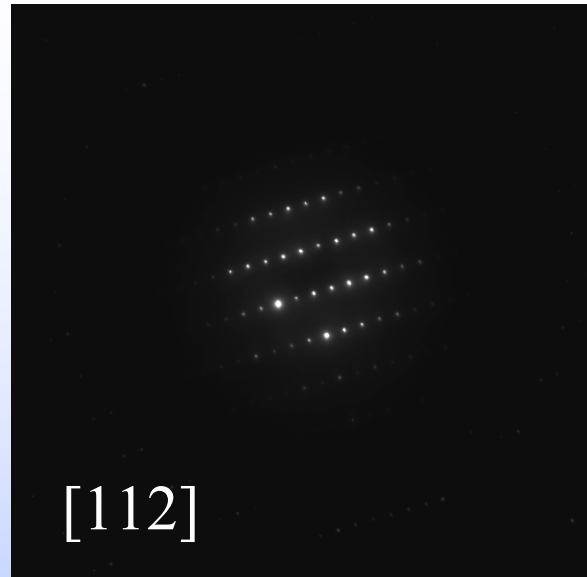
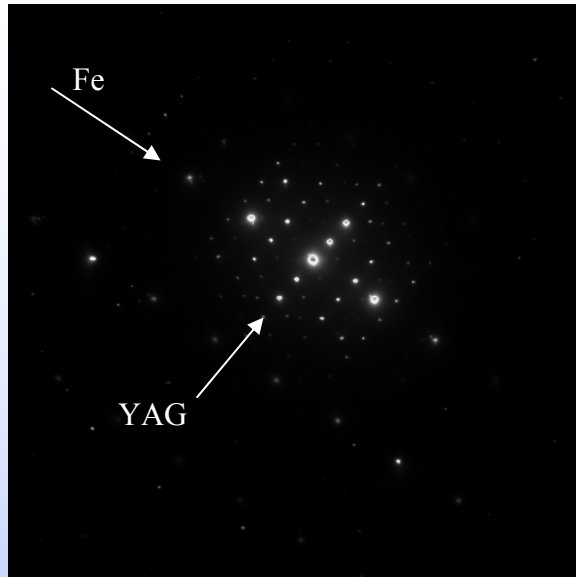


**PM2000 annealed for 4h
at 1000°C after joining**



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Diffraction Patterns from YAG Particles



FeCrAl matrix plus
YAG ($\text{Y}_3\text{Al}_5\text{O}_{12}$)

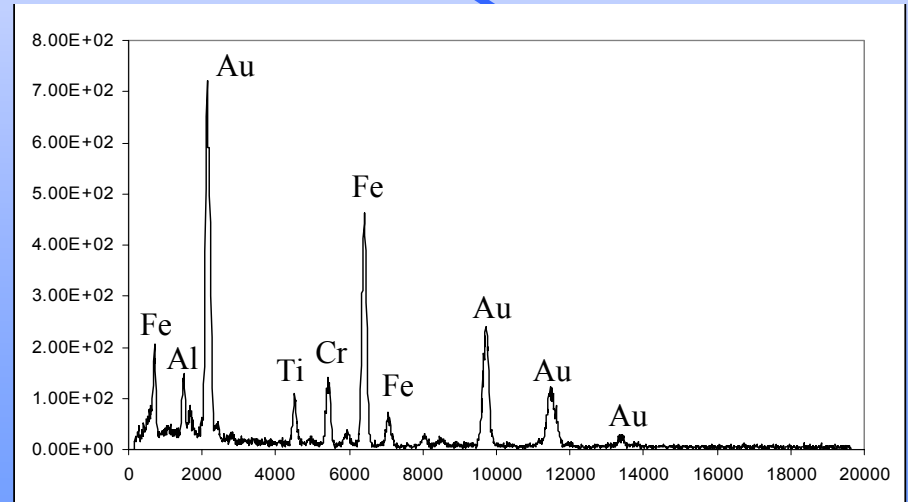
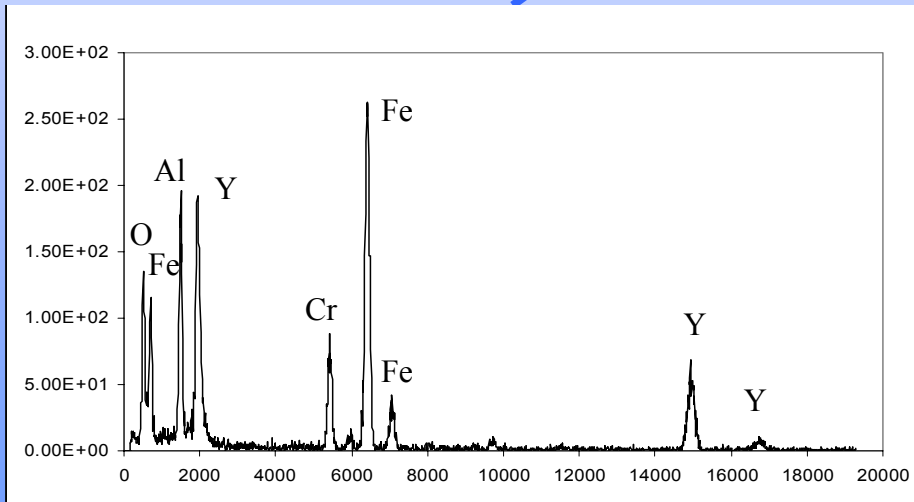
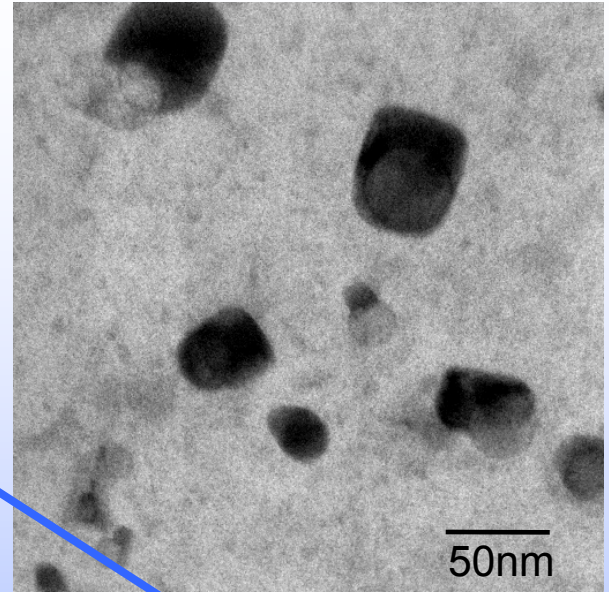
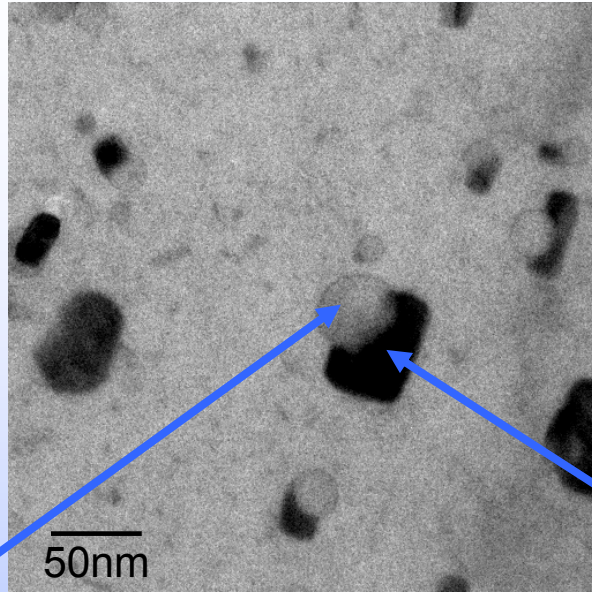
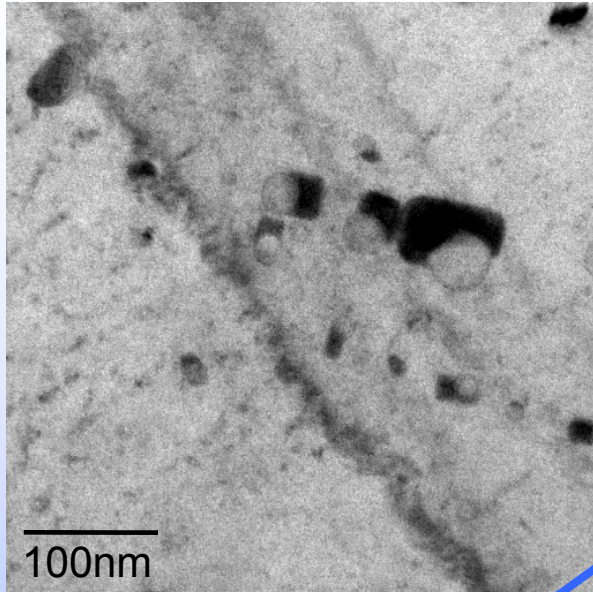
$d_{\text{YAG}(002)} / d_{\text{Fe}(110)} = 2.94$
c.f. 2.962 from PDF files.

(Addition of 20% Cr increases
lattice parameter of Fe by 0.2%)

PM2000 annealed for 4h at 1000°C after joining



Duplex Particles

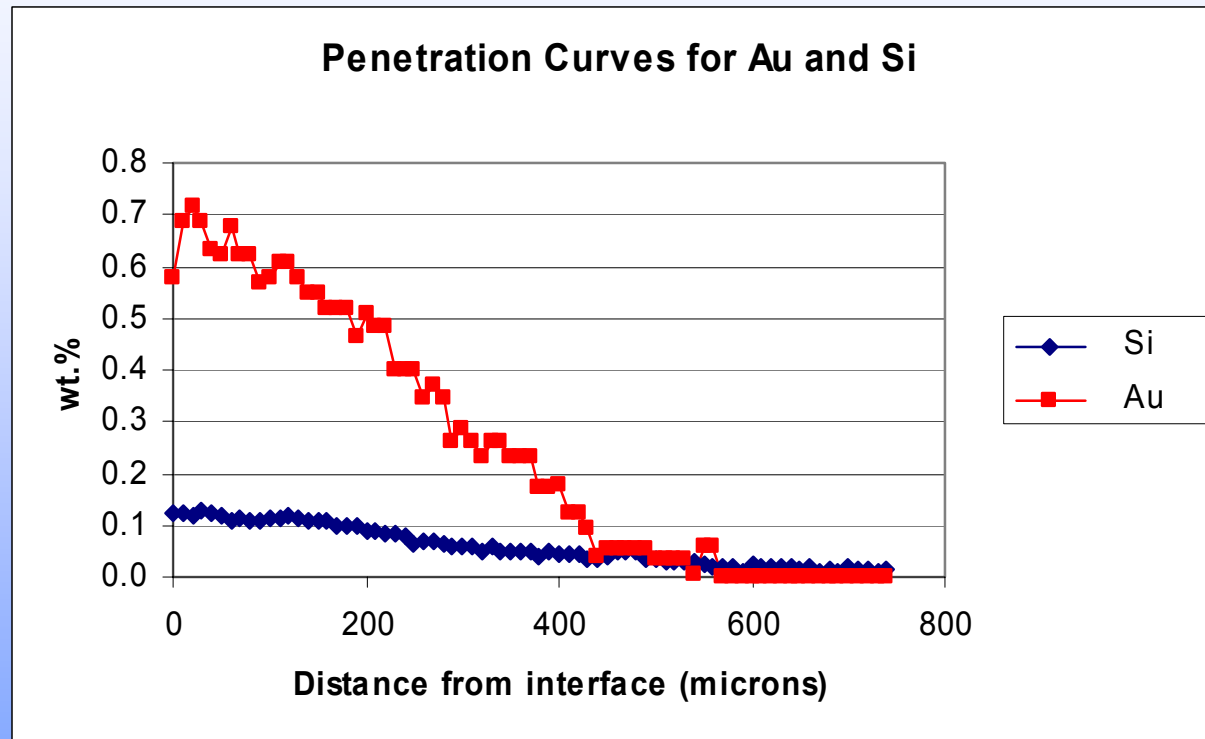


**PM2000 recrystallised
after joining**



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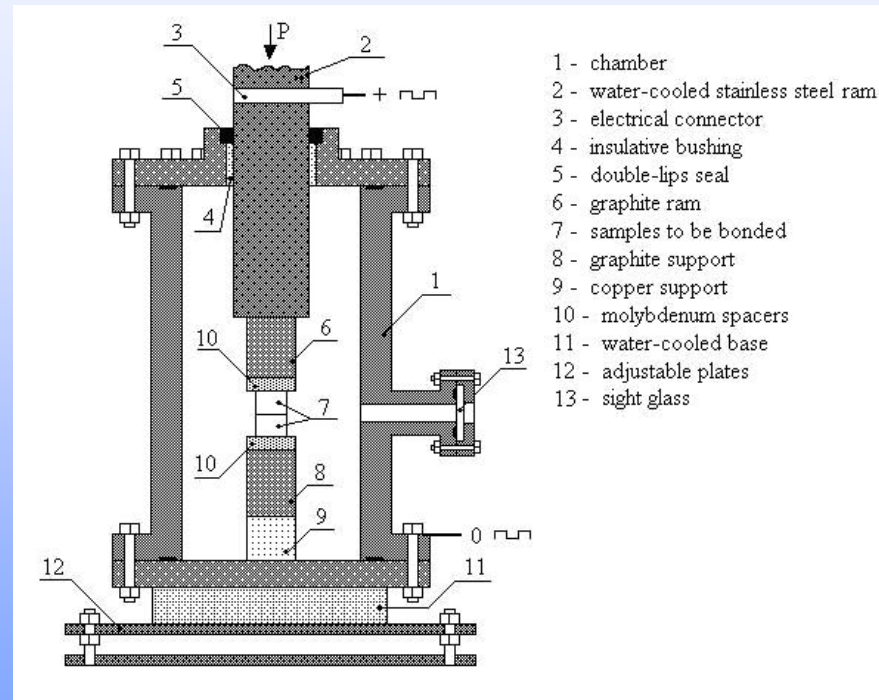
Diffusion of Au and Si away from the interface



After 1 h at 1380°C in air



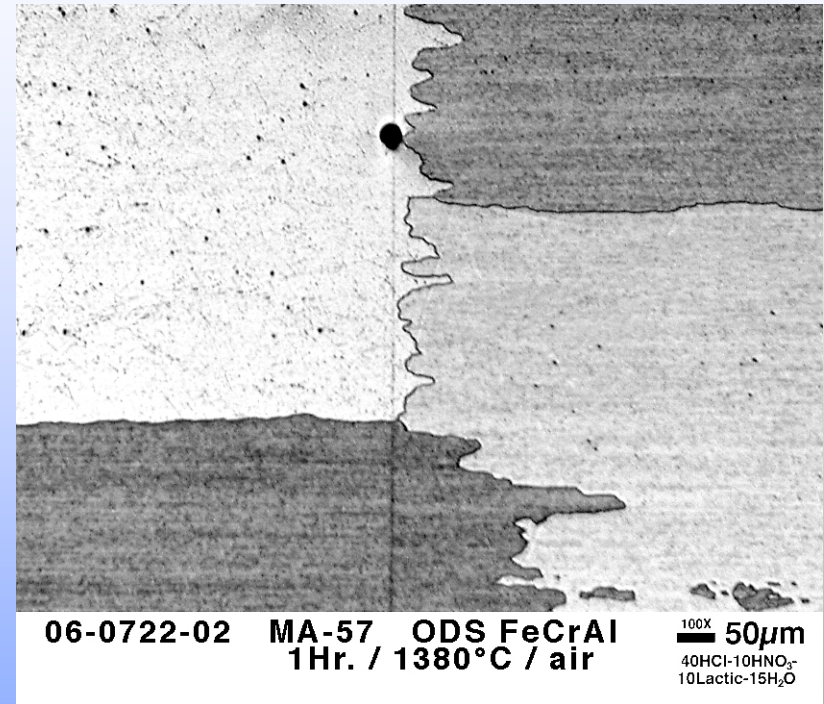
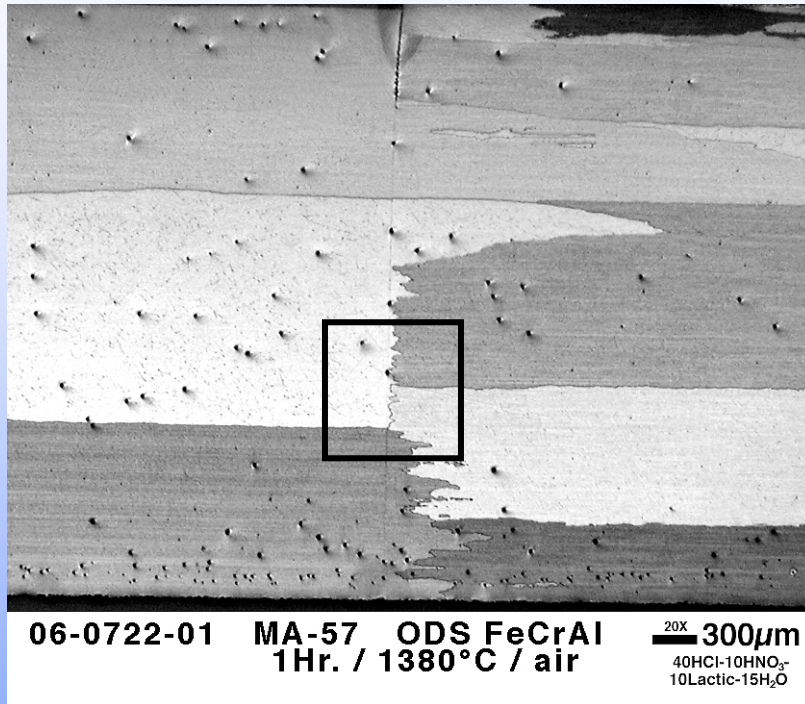
Plasma-assisted pulse diffusion bonding



Eugene Dyadko, MER Corporation,
Tucson, AZ

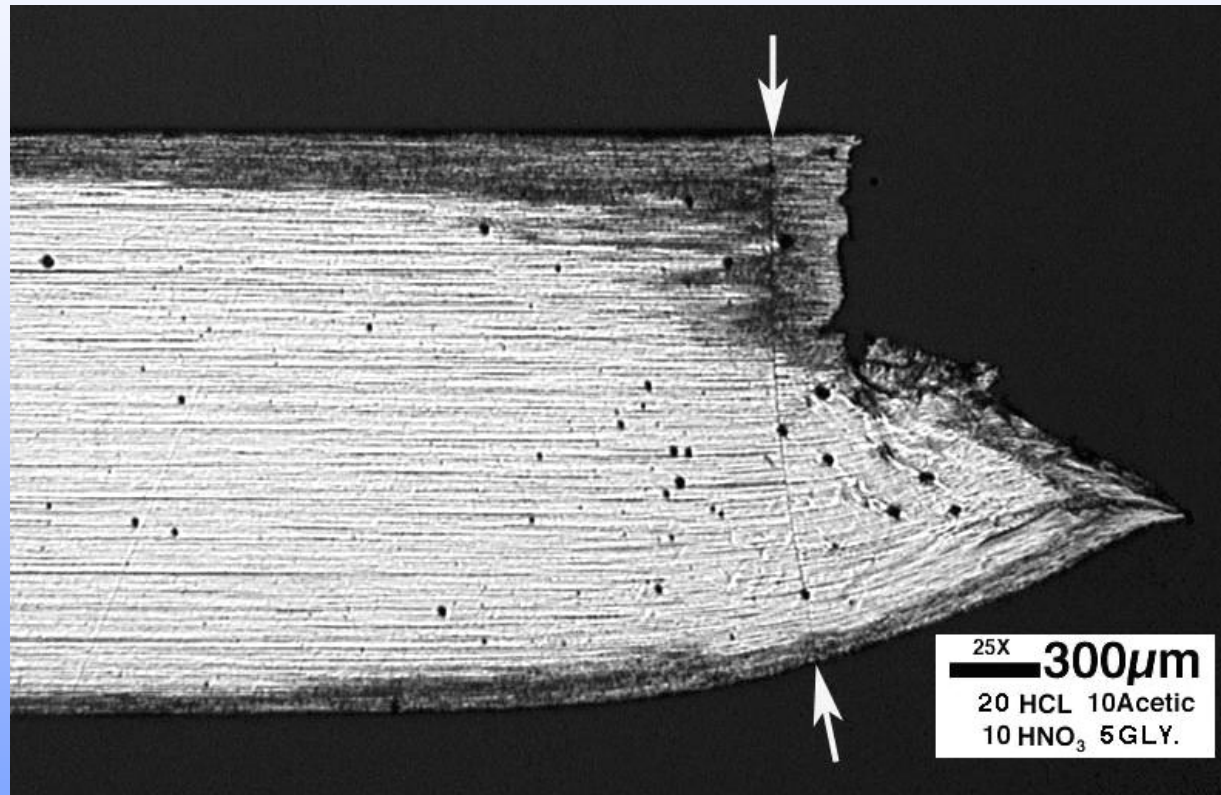


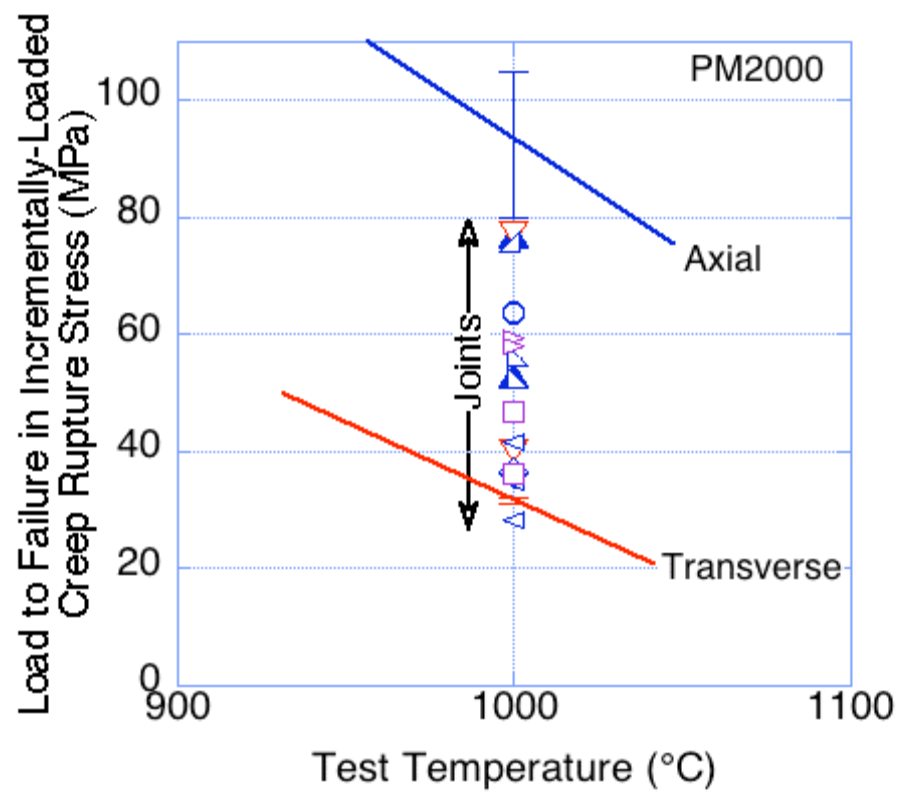
Plasma-assisted pulse diffusion bonding



Wright and Dyadko (2006)

Plasma-assisted pulse diffusion bonding

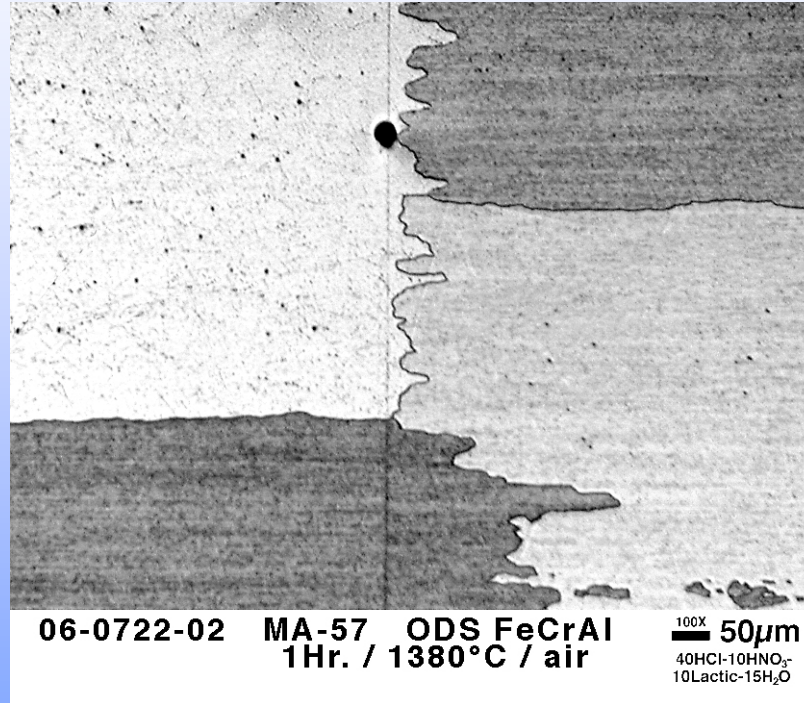




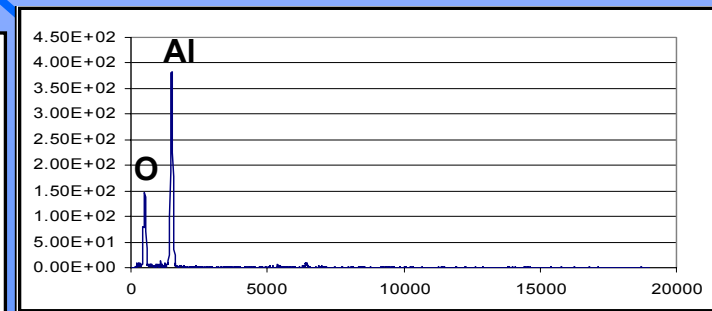
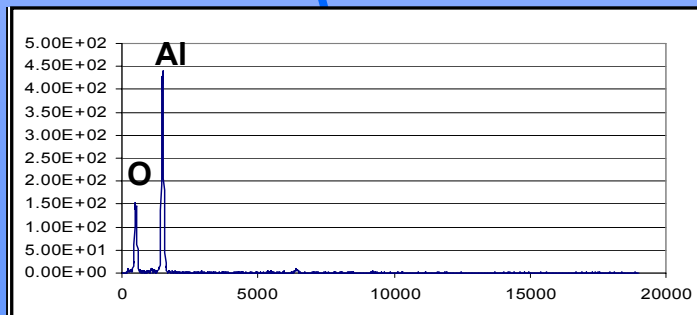
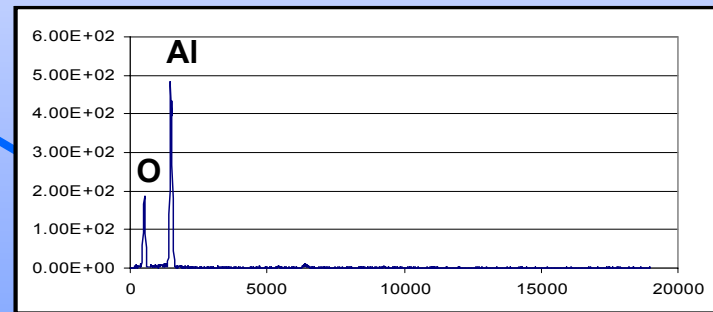
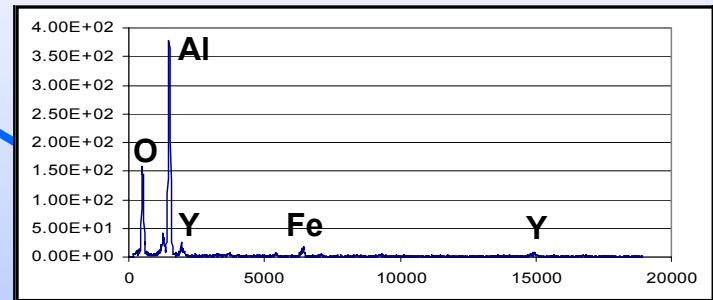
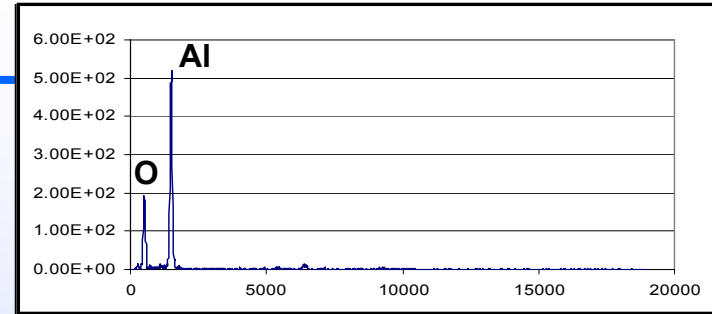
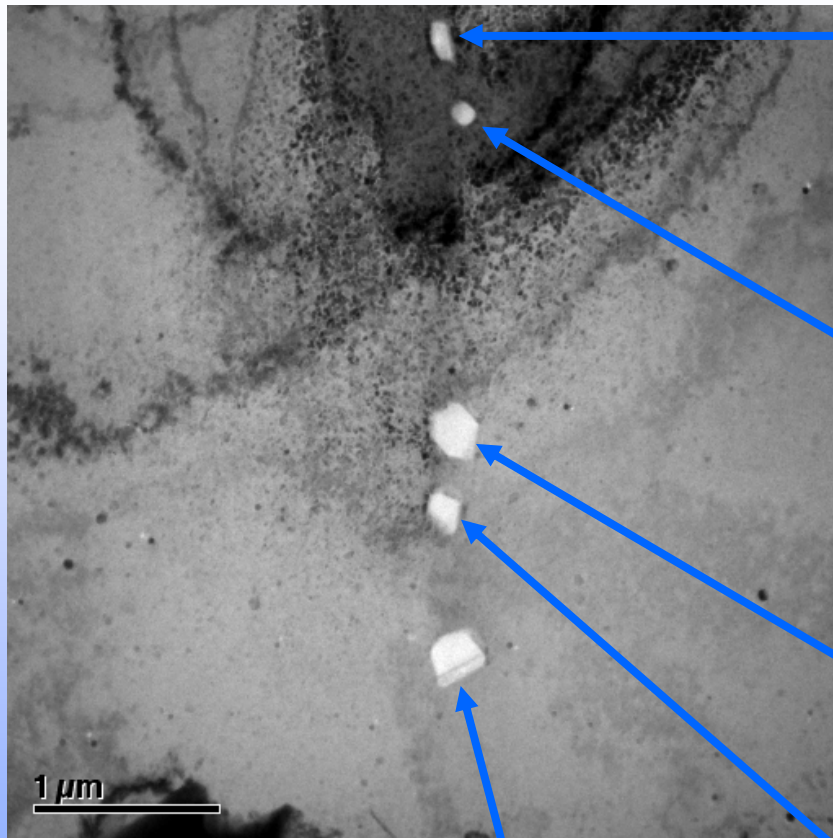
I. G. Wright ORNL



Plasma-assisted pulse diffusion bonding



Plasma-assisted pulse diffusion bonding



Conclusions and Future Work

- **All three methods of joining ODS alloys look to hold great promise.**
- **The grain structure of friction stir welds can be modified by a small amount of further deformation. Welds in sheets, which are amenable to secondary recrystallisation, are now needed.**
- **The TLP process needs to be modified to reduce any agglomeration of oxide particles near the interface, but the gold and silicon appear to diffuse rapidly away from the interface without causing further disruption to the structure.**

Conclusions and Future Work

- **The weld interface after plasma assisted bonding is very clean and only marked by a row of remnant alumina particles, which do not pin the grain boundaries during secondary recrystallisation.**
- **The successful joining of ODS FeCrAl alloys, which has alluded us for so long, finally appears to have been achieved.**

Acknowledgements

The supply of samples and advice from Gordon McColvin at Siemens UK is gratefully acknowledged.

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