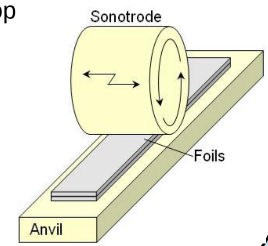
DIFFUSION AS A BONDING MECHANISM DURING ULTRASONIC CONSOLIDATION OF METAL FOILS

J. E. Mueller (PhDMSE), J.W. Gillespie Jr., S. G. Advani, T. A. Bogetti (ARL)

University of Delaware . Center for Composite Materials . Department of Materials Science and Engineering

WHAT IS ULTRASONIC CONSOLIDATION?

- Ultrasonic Consolidation (UC) is a solid-state processing technique that can be used to weld metal foils together.
- Using a foil-fiber-foil method or prepreg tapes, metal matrix composite (MMC) structures can be fabricated through a layered build-up process.
- Metal foils are placed on top of a stationary anvil and a rotating horn travels the length of the foils.
- Three machine variables:
  - Applied normal force or load
  - Oscillation amplitude
  - Welding speed



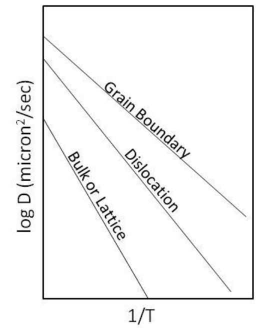
MOTIVATION

Bonding Mechanisms	Description
Plastic Deformation	Metal matrix flow caused by dislocation movement
Diffusion	Transfer of mass across an interface
Acoustic Softening	Reduction of stress necessary for plastic deformation to occur through the application of ultrasonic energy,
Continuous dynamic recrystallization	Formation of subgrains through recovery and polygonization stages
Mechanical Interlocking	Metal flows into irregularities of another metal and locks mechanically
Interfacial Metal Melting	Molten metal flow at the interface

- Although there are several possible bonding mechanisms, there are many questions regarding the role of diffusion during UC.
- It is important to characterize diffusion as a bonding mechanism to understand the main influences on bond quality and identify the effect of microstructural changes during the bonding process.
- Calculating the interdiffusion coefficient provides a means to quantify the extent of diffusion occurring.

DIFFUSION

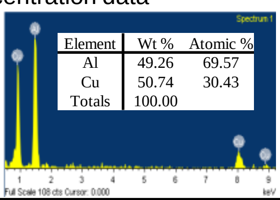
- Diffusion during UC is widely debated due to short weld times and low temperatures.
- Grain boundaries and dislocations provide fast paths for diffusion to occur.
- Activation energies for grain boundary and dislocation diffusion are lower compared to bulk diffusion, leading to higher diffusion coefficients.
- Evidence of subgrains at the weld interface and increased dislocation density with ultrasonic energy supports diffusion during UC.



EXPERIMENTAL TECHNIQUE

- Scanning Electron Microscopy (SEM) image of welded interface

- X-ray Energy Dispersive Spectroscopy (XEDS) provides concentration data



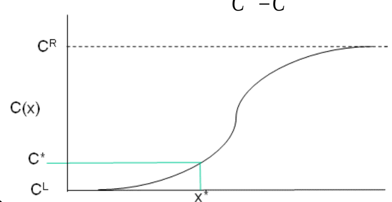
Element	Wt %	Atomic %
Al	49.26	69.57
Cu	50.74	30.43
Totals	100.00	

CALCULATION OF THE INTERDIFFUSION COEFFICIENT

Den Broeder equation:

$$\tilde{D} = \frac{1}{2t\left.\frac{\partial C}{\partial X}\right|_{C^*}}\left[(1-\varphi)\int_{-\infty}^{x^*}(C(x)-C^L)dx+\varphi\int_{x^*}^{\infty}(C^R-C(x))dx\right]$$

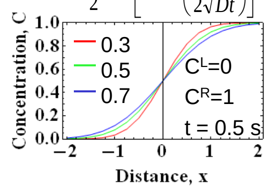
$$\text{where}\quad \varphi=\frac{C^*-C^L}{C^R-C^L}$$



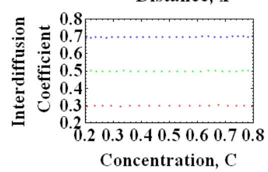
DEN BROEDER VALIDATION

- The conc. independent solution to Fick's 2[nd] Law was used.

$$C(x)=C^R-\frac{C^R-C^L}{2}\left[Erfc\left(\frac{x}{2\sqrt{Dt}}\right)\right]$$



- Applying the data to the den Broeder equation, expected values were obtained.



FUTURE WORK

- Determine the experimental variability
- Calculate interdiffusion coefficients for an array of process variables
- Isolate the effects of ultrasonic amplitude and temperature
- Study the role of dislocations and grain boundaries

ACKNOWLEDGEMENTS

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