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Intermetallic Phases at a Resistance Spot Welded Fe-Al Interface

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The automotive industry has pursued multi-material designs throughout the years to reduce energy consumption of electric vehicles and emissions on fossil-fuel ones. The approach taken for decades has been joining low density, lightweight materials such as aluminum alloys to high strength steels with reduced sheet thicknesses [1]. The combination of aluminum and steel brings forth the benefits of both materials. However, using conventional joining methods such as resistance spot welding (RSW) when joining some structural materials, the metallurgical incompatibilities of both materials become important. When Fe and Al are brought into intimate contact at elevated temperatures, brittle intermetallic compounds can form and these may compromise the joint's mechanical performance. [2].

We examined an RSW interface between a 1.6 mm thick AlSi coated 2000 MPa UTS press hardened boron steel and 2.0 mm thick 6022-T4 aluminum alloy. Conventional TEM imaging was done on a Tecnai 30 with the STEM and EDS analysis done on a Tecnai F20 TEM/STEM with an EDAX XLT EDS detector. Multipoint diffraction patterns were collected on the Tecnai F20 in microprobe STEM mode with a small C2 aperture using the TIA software to define the area and step the beam.

Several different crystal structures were observed at the boundary. One grain had the composition of $FeAl_2$ (33.5 at% Fe, 66.5 at% Al). Selected area diffraction patterns (SADP) of this phase were collected at several crystal tilt angles with a typical pattern shown in Figure 1. This appeared to be a single crystal though the spot intensities in this SADP indicated the possibility of some sort of ordering. However, when compared with the expected diffraction patterns of $FeAl_2$ it became apparent that the collected SADPs disagreed with the known structure of $FeAl_2$, which is known to be triclinic [3].

To resolve this, we did multipoint STEM diffraction (10x10 and 20x20 points) at several sample tilt values and noted that the diffraction patterns varied with the beam position (Figure 2). Analysis indicated that rather than a single phase as originally thought, the grain consists of two phases - FeAl and Fe_2Al_5. The brighter hexagonal pattern in Figure 1 matches the FeAl structure while the rectangular pattern matches Fe_2Al_5 [4,5]. The two phases show an orientation relationship that appears to be FeAl [111] || Fe_2Al_5 [110] with both the Fe_2Al_5 {002} & {221} || FeAl {110}. Observation of the diffraction pattern array indicates significant bending within the grain. The bending may be due to stress from the lattice mismatch between the two materials since the Fe_2Al_5 {002} = ~2.11Å and {221} = ~2.12Å with the FeAl (110) = ~2.15Å. -- about a 2% mismatch. To match the composition observed in the EDX data requires the grain to be roughly 2/3 Fe_2Al_5 and 1/3 FeAl. [6]

References:
[1] M. Tisza and I. Czinege, *Int. J. Light. Mater. Manuf.*, **1** (2018), p. 229, doi: 10.1016/j.ijlmm.2018.09.001.
[2] N. Chen, et al., *J. Mater. Process. Technol.*, 243 (2017). p. 347, doi: 10.1016/j.jmatprotec.2016.12.015.

[3] I. Chumak, H. Richter, and H. Ehrenber; Acta Cryst C, **66** (2010), pi87
[4] A.N. Bashkatov, et al., Fizika Metallov i Metallovedenie, **32** (1971) p118.
[5] U. Burkhardt, et al., Acta Cryst B, **50** (1994) p313
[6] The authors acknowledge funding from Honda R&D Americas, Inc., Stellantis Metallic Materials Engineering R&D, ArcelorMittal Global R&D, IUCRC award 1822144, and Ma2JIC. We also acknowledge useful discussions with Prof. Hamish Fraser.