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EBSD and XRM of Phases in Vacuum Cast Composite Alloys

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Introduction

There have been a number of new processes developed that allow the joining of very dissimilar materials such as titanium alloys, wear resistant white irons, cast irons and ceramic materials to ferrous (mild steel) and non-ferrous (aluminium) alloys. These new processes have allowed the development of more complex composite shapes to be produced. However, with any new process development, an understanding of the mechanism of bonding is required. Through the use of x-ray mapping (XRM), chemical phase imaging as well as electron back scattered diffraction (EBSD) analysis, very useful information on the mass transport across the interface as well as phase segregation, texture variations and phase distribution within the bond interface can be obtained. Results from this investigation on a number of bonded materials are presented and the importance of XRM and EBSD in providing a better understanding of the physical and chemical processes involved in metallurgical bonding/welding of dissimilar materials discussed.

Method

A number of samples were investigated, which included titanium/aluminium cast joints, wear resistant white iron/mild steel vacuum cast joints and white iron/tungsten carbide/mild steel cast joints. All samples were mounted in a bakelite mount, cross-sectioned with a diamond wafering blade and polished to a 1μm finish using diamond abrasives. For EBSD analysis the final mechanical damage was removed by chemical-mechanical polishing using colloidal silica. A HKL Technology EBSD system attached to the LEO Supra 55VP FEG SEM was operated at 20kV accelerating voltage and 20mm working distance for EBSD mapping. X-ray maps were collected at 20kV accelerating voltage using a Moran Scientific energy dispersive x-ray analysis and mapping system attached to a Jeol 35CF SEM.

Results and Discussion

A secondary electron image (SEI) of the interface region between the titanium and aluminium alloy can be seen in Figure 1. The aluminium alloy contained approximately 12% silicon and as evident, excellent bonding exists between the two metals. Figure 1 also shows the elemental x-ray maps of the interface, which were used to generate correlation plots (scatter plots), where pixel frequency versus element concentration profiles are plotted against each other in two dimensions for two selected elements within the sample. The clusters observed in these plots correspond to different phases within the bond interface. The contributing pixels to each cluster in the correlation plot can be used to reconstruct the spatial distribution of its associated phase in a chemical image of the specimen. Of particular interest to this study were the branches and links between clusters in each correlation plot and how these features relate to the chemical distribution of elements both in and around the bond region. Preliminary analysis indicated that these links and branches in the correlation plot correspond to solid solutions between chemical phases and diffusion gradients with a number of different phases forming.

Investigations of the interface region between the white iron and steel revealed no cracking and excellent bonding exists between the two metals. The EBSD results (Figure 2) revealed M_7C_3 carbides surrounded by M_3C carbides with similar orientation in a ferrite iron phase. These EBSD results provide a greater insight into the solidification sequence of the white iron and a new understanding on the changing concentration profile of the liquid alloy during solidification. Proper interpretation of the correlation plots as well as the EBSD results will provide a better understanding of the chemical processes involved in the bonding of dissimilar materials.

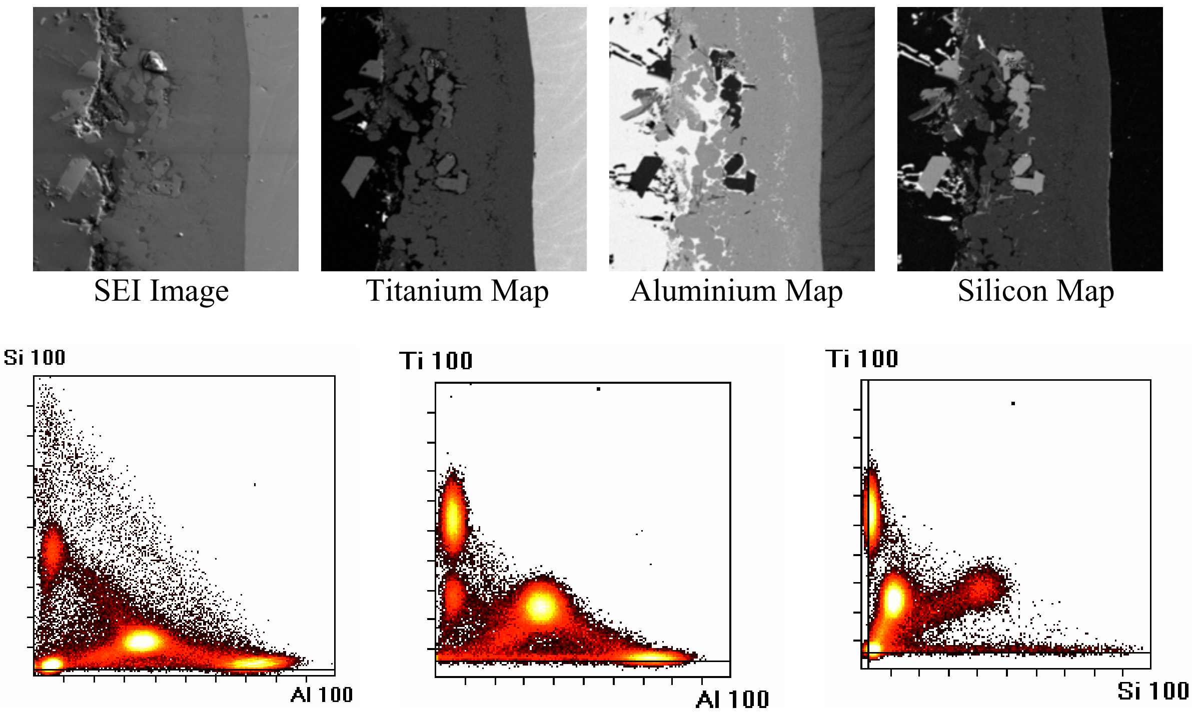
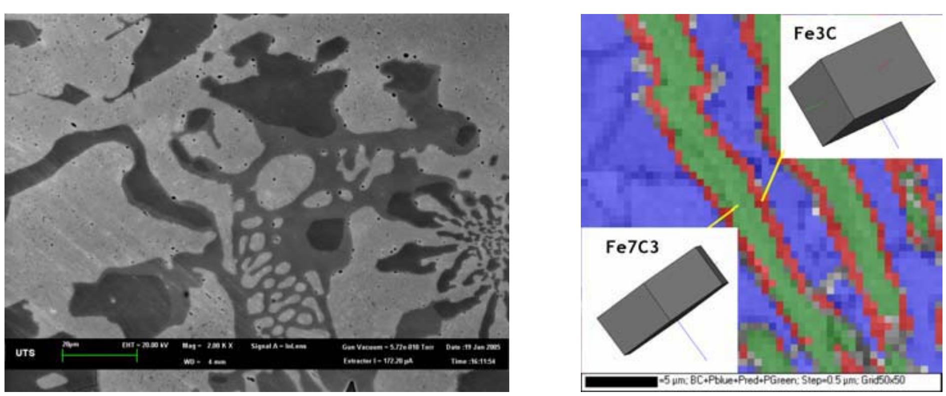


Figure 1: SEI Image, titanium, aluminium and silicon x-ray maps and correlation (scatter) plots of the interface region between the titanium and aluminium vacuum cast composite alloy.



a. b.

Figure 3: a) In-lens image of interface region showing phase difference and b) EBSD map showing M_7C_3 carbides surrounded by M_3C carbides in a ferrite iron phase of interface region.

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