

## EPMA Studies on Reactions Between Ti and Al during Spark Plasma Sintering

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Spark plasma sintering (SPS) is a promising techniques for the production of near-net-shape TiAl components for structural applications [1]. Previous studies on SPS of Ti-Al composites have revealed a two-step reaction mechanism for the formation of  $\gamma$ -TiAl. Results show that first, all of the Al was consumed to form  $\text{TiAl}_3$  via reaction 1 ( $\alpha\text{-Ti}+3\text{Al}=\text{TiAl}_3$ ) at a temperature below the melting point of Al; and second,  $\gamma$ -TiAl was formed by further interdiffusion between  $\text{Al}_3\text{Ti}$  and the remaining Ti at higher temperatures via reaction 2 ( $2\text{Ti}+\text{TiAl}_3=3\text{TiAl}$ ) [2, 3]. However, a review of published studies reveals that the diffusive reaction mechanism between Ti and  $\text{Al}_3\text{Ti}$  under electric field remains poorly understood. The objective of the present work was to identify the phases formed by the diffusive reaction between Ti and  $\text{TiAl}_3$ , as well as their formation sequence, and thereby provide insight into the reaction mechanisms that govern the formation of  $\gamma$ -TiAl from Ti and  $\text{TiAl}_3$ .

A cryomilled Ti-Al powder blend with a chemical composition of  $\text{Ti}_{53}\text{Al}_{47}$  was SPS consolidated at 600°C for 15 min. Under these conditions the  $\text{TiAl}_3$  diffusion layers were fully developed. The as-sintered compacts were further SPS consolidated at 1250°C for 5 min. The diffusion layers disappeared, and lamellar phase colonies developed along with regions of high Al concentration (dark contrast on Fig 1a). Representative backscattered SEM micrographs are shown in Fig 1.

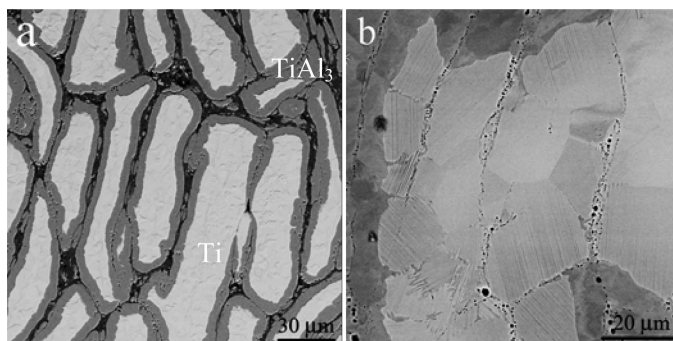
To reveal the details of the intermediate reactions, compacts consolidated by SPS at 600°C for 15 min were further SPS processed at 900°C for 5 and 10 min. A typical SEM micrograph from the latter sample is shown in Fig 2a. The interdiffusion between  $\text{TiAl}_3$  and Ti caused development of multiple intermetallic layers between them. XRD data obtained from these samples (e.g. Fig. 2e) revealed the presence of TiAl,  $\text{TiAl}_2$  and  $\text{Ti}_3\text{Al}$  in addition to the reactants Ti and  $\text{TiAl}_3$ . This phase sequence is in accordance with the Ti-Al binary phase diagram, which also shows the existence of metastable  $\text{TiAl}_2$  phase. EPMA X-Ray mapping and quantitative analysis were done at 15keV and 10nA beam conditions on the area shown in Fig 2a. The Ti and Al maps are shown in Figs 2b and 2c, respectively. An X-Ray line scan was acquired along the position shown by the dark bar in Fig 2a, and the results are shown in Fig 2d. As per the phase diagram, the metastable  $\text{TiAl}_2$  phase appears up to 1215°C. This implies that the SPS processing temperature for the complete formation of  $\gamma$ -TiAl should be higher than 1215°C.

### Acknowledgments

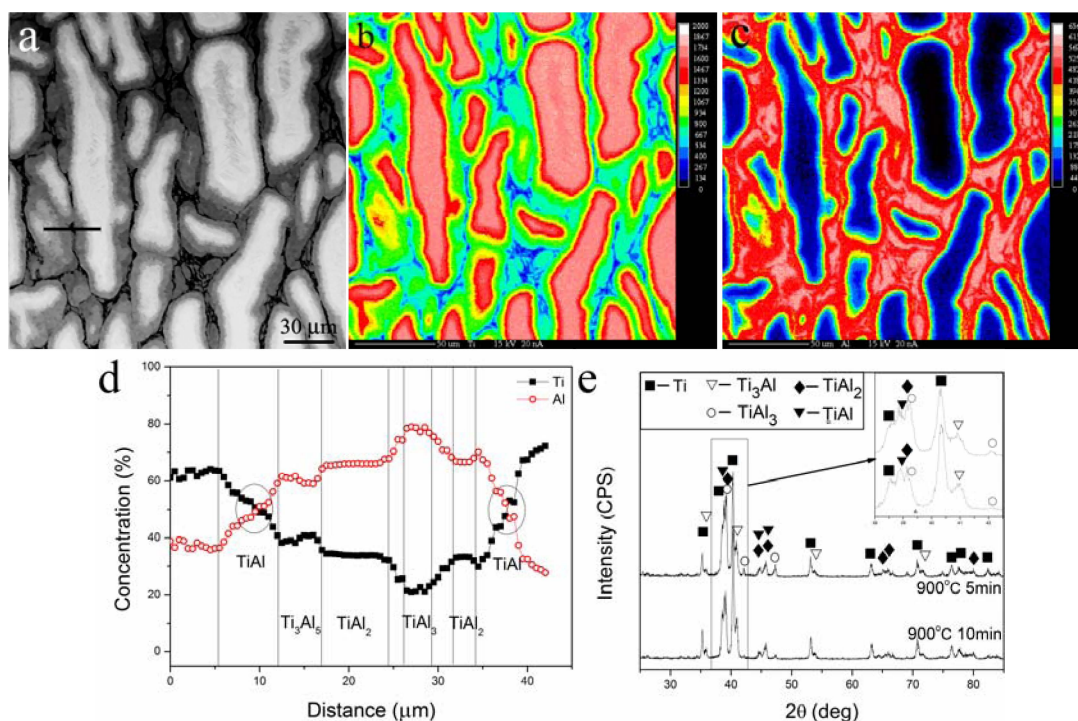
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**Figure 1:** Backscattered SEM micrograph of cryomilled Ti-Al powder blend compact after SPS at 600°C for 15 min (a) and SPS at 600°C for 15 min followed by SPS at 1250°C for 5 min (b) on Ti-Al powder compacts.



**Figure 2.** Cryomilled Ti-Al powder blend compact after SPS at 600 C for 15 min followed by SPS at 900°C for 10 min, Backscattered SEM micrograph (a), EPMA X-Ray mapping of the Ti (b) and Al (c) X-Ray line scan across interfaces (d). XRD patterns of the Ti-Al compact SPS at 600°C for 15 min followed by SPS at 900°C for 5 and 10 min.