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The Microstructure of $MoSi_2/TiB_2$ Composites Produced by Displacement Reactions vs. Powder Consolidation

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Two basic approaches have been attempted thus far in the processing of $MoSi_2$ composites, namely, artificial compositing and in-situ reactions. For artificial compositing, the reinforcement is introduced into the material as a previously formed component. The resulting interfacial reactions due to the lack of thermodynamic equilibria between the matrix and reinforcement phases, and the difficulties involved in the processing to prevent these interactions, i.e. coatings, are the most important drawbacks of artificial compositing. In-situ reactions, on the other hand, rely on the formation of the matrix and the reinforcements during heating and/or consolidation and have been used to produce composites that are more thermodynamically stable. To date, two different kinds of in-situ reactions have been used (1) a direct reaction of the elements involved in the composite to be produced and (2) displacement reactions involving compound phases. Displacement reactions are solid-state diffusional phase transformations that involve at least one compound among the reactants. A significant disadvantage of the in-situ reactions compared with artificial compositing is the limitation that the stoichiometries of the reactants and products impose on the volume fraction of the reinforcing phase that can be generated [23, 13]. The size and characteristics of the final microstructures obtained through solid-state reactions depend significantly on the size and distribution of the particulate reactants. Many studies on molybdenum disilicide composites have demonstrated that particle size affects significantly the grain size of the $MoSi_2$ that is formed during processing. Thus, the mechanical properties of the composite are affected since properties like the fracture toughness of the composite are strongly influenced by the grain size of the $MoSi_2$.
In this study, reactions using "small" vs. "large" boron and silicide reactant powders were assessed (Fig. 1) as well as the adjustment of the matrix-reinforcement ratio (Fig. 2) by addition of pre-reacted reactant powders, and diffusion couples as an initial approach to artificial compositing (Fig. 3). The "small" reactant powders led to greater densification in the final composite. It was also found that the shape of the TiB_2 grains is initially strongly influenced by the size of the reactant particles. Smaller powders led to highly compacted pellets and initially elongated TiB_2 grains due to the simultaneous growth of a large number of fine grains. Larger powders produced more regular equiaxed TiB_2 grains. The reaction zone at the interfaces in the diffusion couples appeared to consist of several phases. The increase in width of the reaction zone after 12 hours at 1550°C suggested that there was a lack of equilibrium up to this temperature. These results are not in agreement with the results obtained in the reaction samples in which equilibrium appeared to be achieved between $MoSi_2$ and TiB_2 at 1400°C. Thus, the formation of this reaction layer has been attributed to the presence of secondary phases that are not in equilibrium at this temperature and consequently react when placed in contact. Thus, such interactions are expected in artificial composites.

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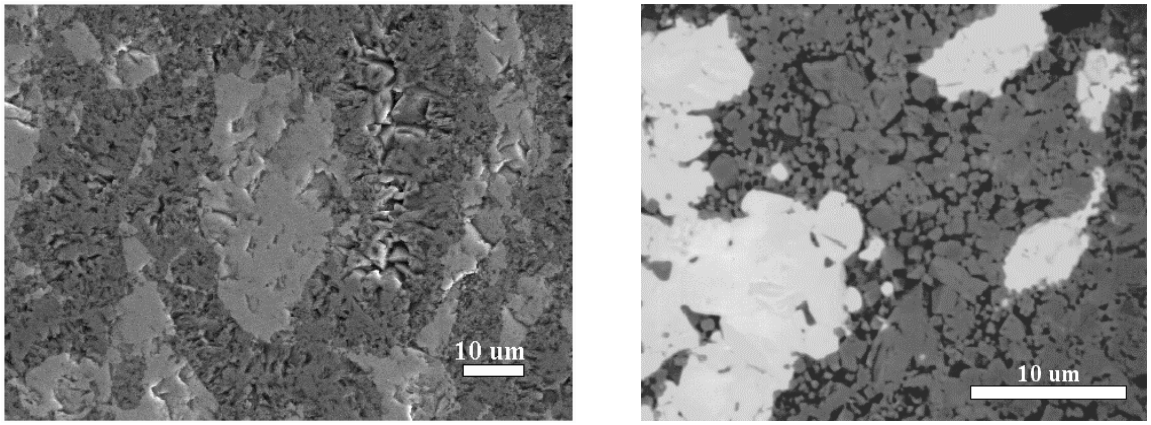


(a) (b)

FIG. 1. Secondary and backscattered electron images of the microstructures of samples a) using a smaller size of reactant powders and b) using a larger size of reactant powders.

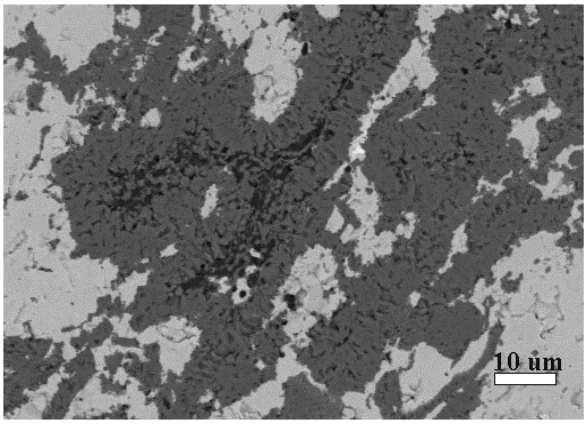
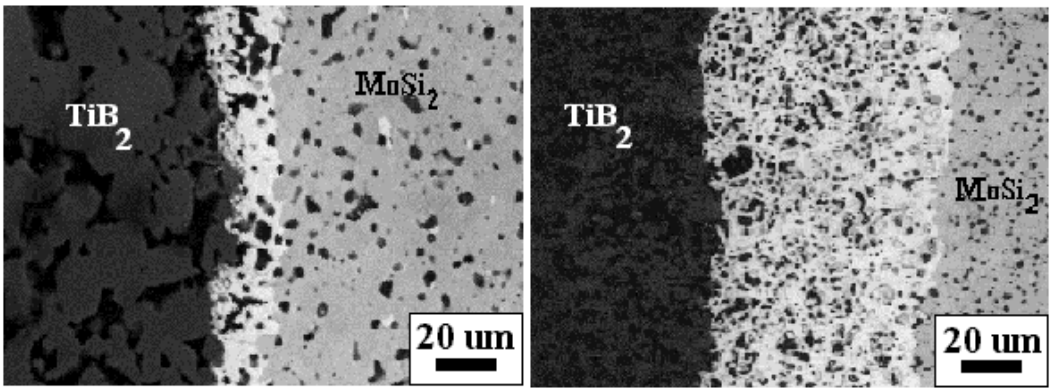


FIG. 2. Backscatter electron image of a displacement reaction sample prepared with addition of pre-reacted powders to adjust the matrix-reinforcement ratio.



(a) (b)

FIG. 3. Backscatter electron images of the reaction layer formed in the diffusion couples (a) after 12 hours at 1400°C, and (b) after 12 h at 1550°C.

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