# Effect of Ternary Elements on Microstructure and Mechanical Properties of $MoSi_2$ based Composites

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## 1. Introduction

Intermetallic compounds such as aluminides and silicides have drawn a great attention for high-temperature structural applications. over the past twenty years, researchers have studied many alloy systems and processing routes to select potential intermetallic compound for applications at high temperature. $MoSi_2$, which has been widely used as a heating element due to its excellent oxidation resistance at high temperature, is one of the candidate materials. It has a high melting point (2020℃) and low density ($6.24Mg/m^3$). However, the room temperature ductility and low high temperature strength need to be improved for applications as structural materials.

In order to improve the mechanical properties of $MoSi_2$ alloys, alloy with Al, B, Nb addition were prepared by an advanced consolidation process that combined mechanical alloying and pulse discharge sintering (MA-PDS). Their microstructure and mechanical properties were investigated.

## 2. Experimental Procedure

The nominal compositions for this study were $MoSi_2$-3~10at.% X(X=Al, B, Nb). The particle sizes of Mo and Si were less than 3㎛ and 74㎛ respectively, and the purities were 99.9% and 99%, respectively. The size of both the added elements, Al and Nb, was less than 48㎛ and B was less than 10㎛. Their purities were 99%, 99.9% and 99.9%, respectively. The mechanical alloying was conducted as follows : The powders mixed into the desired composition were put into the milling container in air or inside a glove box where Ar gas was continuously circulated. Milling was carried out in a vibratory ball mill with a frequency of 25㎐ and an amplitude of 2.5mm. The milling time was 200hours. The cylinderical stainless steel container had an inner diameter of 120mm and a height of 120mm. Hardened steel balls with a 25.4mm diameter were used and mixed powders were loaded with a ball/powder ratio of 75/1. The mechanical alloyed powders were filled into a graphite mold and were pre-pressed at room temperature. After pre-pressing, sintering was carried out in pulse discharge sintering equipment under a pressure of 55㎫ at 1400℃. Microstructure of the sintered samples was examined with a Scanning Electron Microscope (SEM) and the synthesized phases were identified by X-Ray-Diffraction (XRD) method. Vickers hardness test was carried out. Specimens with a gauge section of 1.5mm×2mm×10mm for the tensile test were cut from the sintered compacts with an electric discharge machine (EDM). Tensile tests were performed under a cross head speed of 0.05mm/min at room temperature and 1000℃. The fracture surfaces after tensile tests were observed using SEM.

## 3. Result & Discussion

Figure 1 represents the Vickers hardness of the four materials. For comparison, the

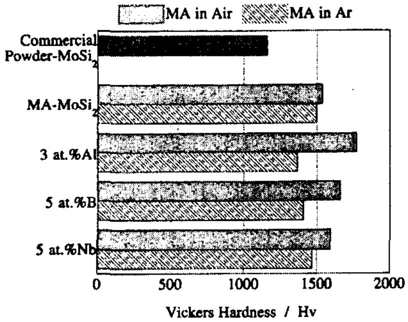

Fig.1 Vickers hardness of $MoSi_2$ and $MoSi_2$-X (X=Al, B or Nb) alloy fabricated by MA-PDS process.

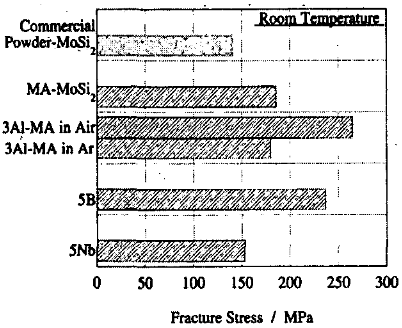

Fig.2 Fracture stress of $MoSi_2$ and $MoSi_2$-X (X=Al, B or Nb) alloy fabricated by MA-PDS process.

hardness of $MoSi_2$ sintered from a commercial powders of less than 50㎛ size is also shown in the figure. The commercial powders were sintered by PDS process under the same temperature. The hardness values of the samples fabricated by MA-PDS process were higher than that of the sample sintered from commercial powders. As a general rule, the samples sintered from the powders milled in air showed higher hardness as compared to those of milled in Ar. The Al alloyed sample sintered from powders milled in air had the highest hardness. For the samples sintered from powders milled in the Ar atmosphere, monolithic $MoSi_2$ gave the highest hardness, so it may be suggested that the addition of X was not effective in the increase in hardness.

Figure 2 presents the fracture stress at room temperature for the four materials milled in Ar gas together with the alloy sintered with commercial powders. One exception is the 3Al alloys which were milled respectively in air and in Ar gas. For the pure $MoSi_2$ alloy, the fracture stress values of the samples fabricated by MA-PDS process were higher than that of the sample sintered from commercial powders due to the fine grain size. The 3Al sintered from the powders milled in air showed the highest fracture stress as well as hardness while 5Nb showed the lowest one for the samples sintered from powders milled in Ar.

## 4. Conclusion

(1) The microstructure of $MoSi_2$ alloys fabricated by the MA-PDS process was much finer than that of sample sintered from the commercial $MoSi_2$ powders. Alloys made from powders milled in Ar had fewer silica or alumina phase as compared to their counterparts sintered from powders milled in air, presumably because of the suppression of the oxidation process during milling in Ar.

(2) The $MoSi_2$ alloys fabricated by the MA-PDS process showed high hardness values due to their fine grain sizes. The hardness of the sintered alloys made from the powders milled in air was much higher than that of the samples made from the powders milled in Ar because of the higher volume fraction of oxides.

(3) From the tensile test results at ambient temperature and 1000℃, the Al added $MoSi_2$ made from powders milled in air had a higher fracture stress due to the suppression of $SiO_2$ formation and the formation of fine $Al_2O_3$.