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A metallic glass–metal matrix composite

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Previous efforts [1–3] at incorporating metallic glass ribbons into composite structures made use of only organic matrix material. This note reports results on the feasibility of fabricating a metallic glass–metal matrix composite. There are several advantageous reasons for incorporating metallic glass ribbons as reinforcements in metal matrix composites. For one, ribbon reinforcements should improve the transverse properties of the composite structure [4, 5]. Secondly, metallic glass ribbons offer both a broad spectrum of available alloy systems to choose from [6], as well as the attractive potential of low-cost volume production [7]. Furthermore, a metal matrix composite provides unique capabilities not available from an organic matrix composite [8]. Thus, the development of a metallic glass–metal matrix composite is attractive from the standpoint of achieving a promising structurally efficient, cost effective, material.

In this study, $Ni_{60}Nb_{40}$ metallic glass was incorporated into a metal matrix composite by vacuum hot pressing strips of the metallic glass within a superplastic aluminium alloy. Earlier consolidation efforts [9] in an open hot press demonstrated that a strong interfacial bond can be achieved between the metallic glass ribbon and the matrix alloy. Unfortunately, in this earlier consolidation attempt, the incorporated metallic glass strips were reduced to fragments. The presence of severe biaxial stresses in the open press is thought to be responsible for the fragmentation. To alleviate this problem, a conventional vacuum hot press was used in this current effort.

The metal matrix alloy used in this study is an aluminium alloy, developed by Alcan Ltd., having a composition of 90 wt % Al–5 wt % Ca–5 wt % Zn. The alloy becomes superplastic in the 450 to 500° C temperature range and requires minimal pressure to induce plastic flow. Further details on the microstructure, metallurgy, and mechanical properties of this alloy can be found in [10]. The alloy was obtained as a 2.3 mm thick sheet in the cold-rolled condition. Discs (2.2 cm in diameter) were punched from the sheet, given an abrasive finish with 600 grit SiC paper and ultrasonically washed in ethyl alcohol before being placed in the press.

For the metallic glass ribbon, a $Ni_{60}Nb_{40}$ alloy composition was chosen because of its ductility [11, 12] and reported 650° C crystallization temperature [13]. X-ray diffraction patterns of the as-received, melt spun, ribbon revealed the usual amorphous rings. Bend tests were also performed on the as-received material to insure that the ribbon possessed adequate ductility. Strips were cut from the ribbon and also given an ultrasonic wash in ethyl alcohol before being placed in the press.

The vacuum hot press assembly is shown in Fig. 1. The procedure consisted of making up a stack of aluminium discs with the metallic glass strips interspersed between the discs. The stack was placed into a 2.54 cm diameter cavity of the hot press and put under a small sustained pressure. The vacuum press was evacuated to approximately 10^{-3} torr, and the graphite die assembly was slowly

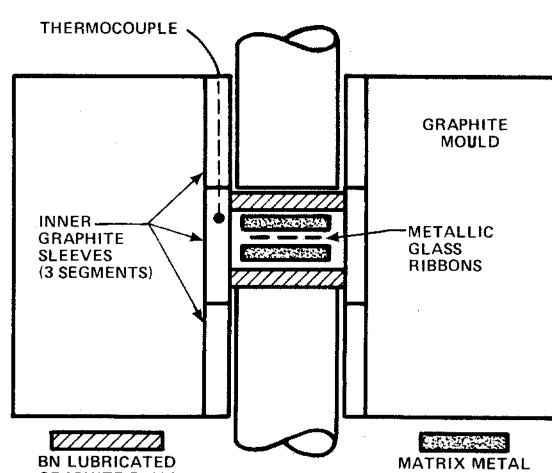

Figure 1 Vacuum hot pressing of metallic glass – metal matrix composite.

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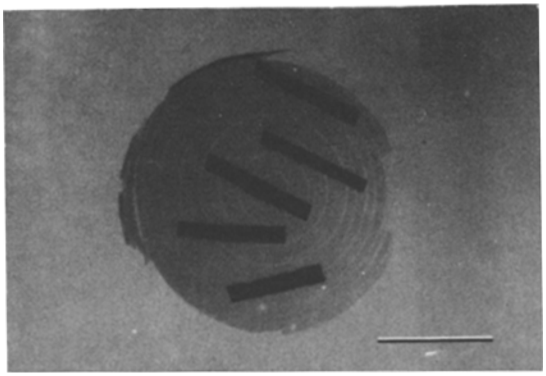

Figure 2 Radiograph of composite showing no metallic glass fragmentation (1 cm marker).

heated to within the 450 to 500° C range. Ram travel and die temperature were continuously monitored. The compression of the stack was initiated when the onset of superplastic flow was detected. A final pressure of 17 MPa was used to fully compress the stack. Care was taken to avoid extruding material past the BN lubricated face discs. A radiograph of a compact processed in the above manner is shown in Fig. 2. No fragmentation of the incorporated metallic glass strips is evident.

The bond strength between the metallic glass strip and the matrix alloy was evaluated by performing a 180° bend test on a narrow sectioned portion of the compact. A macrograph of the bend specimen is shown in Fig. 3. No separations at the metallic glass – metal matrix interface can be detected. Where cracks in the metallic glass occurred in the bend specimen, the interfacial adhesion was still strong enough to retard any debonding, as shown in Fig. 4. To check for evidence of crystallinity, X-ray diffraction patterns were obtained from metallic glass strips chemically extracted from the compact. Only an amorphous ring pattern was observed that was very similar to the patterns taken of the as-received material.

The results of this study demonstrate that vacuum hot pressing is a feasible technique to fabricate metallic glass – metal matrix composites. The consolidation can be accomplished without the gross degradation of the incorporated metallic glass, provided the consolidation occurrs below the crystallization temperature of the metallic glass and at a temperature that insures extensive superplastic flow of the metal matrix. Advantage is thus taken of the superplastic nature of the matrix alloy to achieve good solid state bonding [14].

If these observations prove to be generally true, it should be possible to fabricate a wide assortment of metallic glass – metal matrix composites using processing schemes more amenable to large scale structures. Furture efforts plan to address the mechanical properties of these composites as well as to investigate the interfacial compatibility of this new class of materials.

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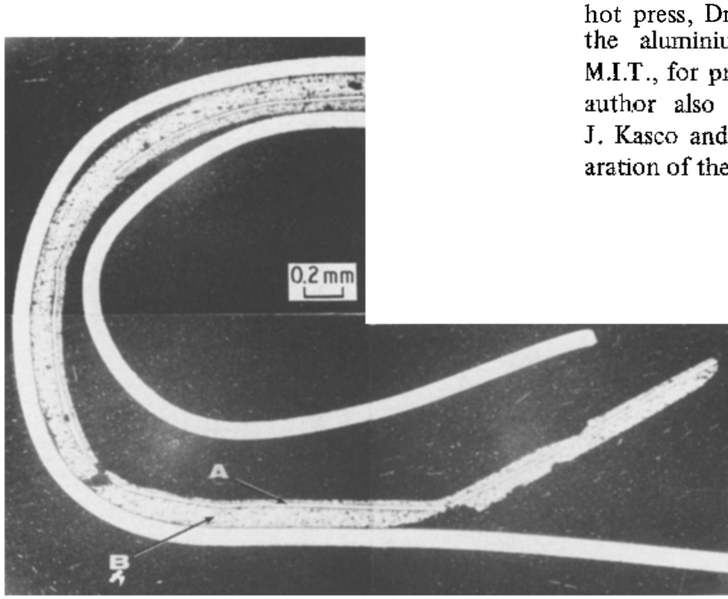

Figure 3 180° bend specimen of sectioned composite showing A metallic glass and B aluminium matrix.

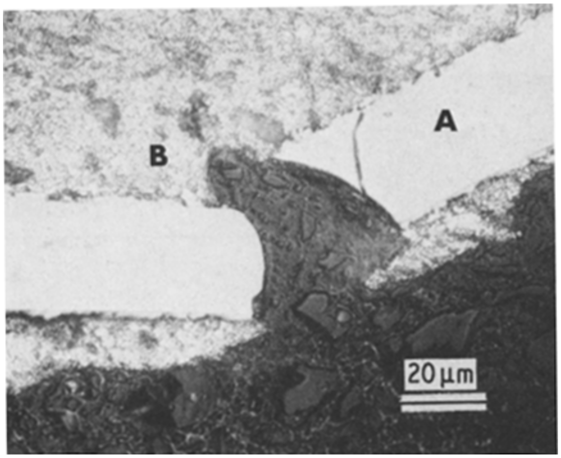

Figure 4 Fracture of a metallic glass strip in composite showing strong interfacial adhesion A metallic glass and B aluminium matrix (20 μm marker).

References

1. W. M. S. B. W. KADIR, C. HAYZELDEN and B. CANTOR, *J. Mater. Sci.* 15 (1980) 2663.
2. D. J. GOLDWASSER and B. H. KEAR, *Mater. Sci. Eng.* 23 (1976) 237.
3. J. R. STRIFE and K. M. PREWO Report UTRC/R80-914389-18 (AD 089102) (United Technologies Research Center, East Hartford, 1980).
4. J. C. HALPIN and R. L. THOMAS, *J. Comp. Mater.* 2 (1968) 488.
5. M. J. HORDON, *ibid.* 7 (1973) 521.
6. H. S. CHEN, H. J. LEAMY and C. E. MILLER, *Ann. Rev. Mater. Sci.* 10 (1980) 363.
7. H. JONES and C. SURYANARAYANA, *J. Mater. Sci* 8 (1973) 705.
8. K. G. KREIDER (ED), "Metallic Matrix Composites" (Academic Press, New York, 1974).
9. S. J. CYTRON, to be published in Proceedings of the Symposium on Rapidly Solidified Amorphous and Crystalline Alloys, Boston MA, November 1981. (Elsevier North Holland, Amsterdam).
10. D. M. MOORE and L. R. MORRIS, *Mater. Sci. Eng.* 43 (1980) 85.
11. K. D. KRISHNANAND and R. W. CAHN, *Scripta Met.* 9 (1975) 1259.
12. R. C. RHUL, B. C. GIESSEN, M. COHEN and N. J. GRANT, *Acta Met.* 15 (1967) 1693.
13. B. C. GIESSEN, M. MADHAVA and D. E. POLK, *Mater. Sci. Eng.* 23 (1976) 145.
14. C. PAEZ and R. W. MESSLER Jr, in "A Collection of Technical Papers on Structures and Materials" Proceedings of the Conference St. Louis, April 1979 (AIAA/ASME/ASCE/AHS) pp. 208–220.

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