Preparation and Corrosion Resistance of Fe-Cr-Mo-C-B-P Bulk Glassy Alloys

Katsuhiko Asami,[1] Shujie Pang,[1] Tao Zhang[1] and Akihisa Inoue[1]

[1]Tohoku University
Institute of Materials Research 2-1-1 Katahira
Aoba-Ku
Sendai 980-8577
Japan

INTRODUCTION

For application of glassy alloys to engineering fields,it is required for them to have high chemical stability in the environments in service. In a previous work, the authors have reported the preparation of corrosion resistant Fe-Cr-Mo-C-B bulk glassy alloys with a diameter of 1 mm (1, 2). Moreover, since it has been reported that the addition of P was very effective for increasing the corrosion resistance of Fe-Cr-based amorphous alloys (3), it is interesting to study P-containing alloys. Therefore, multicomponent alloys in Fe-Cr-Mo-C-B-P system were investigated in detail in this work. A series of new bulk glassy alloys with larger size and high corrosion resistance in aggressive media were developed in Fe-Cr-Mo-C-B-P system.

EXPERIMENTAL

Glass-forming ability was evaluated from temperature interval of supercooled liquid region ($dT_x = T_x - T_g$, where T_x is the crystallization tempeature and T_g is the glass transition temperature) and reduced glass transition temperature (T_g/T_l where T_l is liquidus temperature) by using melt-spun alloys. Bulk alloys were prepared by casting into copper molds and confirmed by X-ray diffraction. The formation of the glassy phase without crystallinity was further confirmed by TEM. The thermal stability of the supercooled liquid for the cast glassy Fe-Cr-Mo-C-B-P samples with different thickness was examined by DSC. Corrosion resistance of the alloys were examined by electrochemical and weight loss measurements in HCl solutions at room temperature.

RESULTS AND DISCUSSION

Glass-forming ability (GFA)

Although the diffraction patterns of some melt-spun alloys (*e.g.* $Fe_{43}Cr_{16}Mo_{16}C_{25}$) showed crystalline peaks implying crystalline phases involved, most of the X-ray diffraction patterns consisted only of a broad peak. As a result, it was clarified that the $Fe_{43}Cr_{16}Mo_{16}(C, B, P)_{25}$ alloys were able to be amorphized over a wide composition range. High glass-forming ability was evidenced by a large dT_x of 40 - 90 K and a high T_g/T_l of 0.54 - 0.60 for this alloy system over a wide composition range.

Preparation of bulk metallic glasses

A series of bulk metallic glasses were successfully prepared in $Fe_{43}Cr_{16}Mo_{16}(C,B,P)_{25}$ system by copper mold casting. The largest size of the metallic glasses reached up to 2.7 mm in diameter for $Fe_{43}Cr_{16}Mo_{16}C_{15}B_{10}$ alloy, which exhibits the highest GFA in the above criterion. The bright-field electron micrograph revealed no appreciable contrast corresponding to a crystalline phase. The electron diffraction pattern consisted only of halo rings. The DSC curves of the cast glassy $Fe_{43}Cr_{16}Mo_{16}C_{15}B_{10}$ rods with a diameter of 1.2, 1.6, 2.2 and 2.7 mm together with that of the melt-spun ribbon were measured and compared. The melt-spun ribbon exhibited single-stage crystallization. The bulk glassy samples showed a very small second exothermic peak after the main exothermic reaction, which was due to the transition of metastable phases to stable phases. In the thickness range up to 2.7 mm, the T_g, T_x and dT_x remain almost constant. It is therefore further confirmed high GFA of the Fe-Cr-Mo-C-B-P alloys and high thermal stability of the supercooled liquid for the bulk glasses.

Corrosion behavior of bulk metallic glasses

Even after immersion in 1, 6 and 12 N HCl solutions at 298 K open to air for one week, the weight loss of the Fe-Cr-Mo-C-B-P bulk metallic glasses was undetectable implying a corrosion rate of less than 10^{-2} mm y^{-1} which is the reproducibility limit for the present measurement. The potentiodynamic polarization curves of the $Fe_{43}Cr_{16}Mo_{16}C_{15}B_{10}$ and $Fe_{43}Cr_{16}Mo_{16}C_{10}B_5P_{10}$ metallic glasses in 6 N HCl solution showed no distinct difference in polarization behavior between the ribbon and bulk glassy samples of the same compositions. The $Fe_{43}Cr_{16}Mo_{16}C_{10}B_5P_{10}$ metallic glasses both in ribbon and bulk forms were spontaneously passivated in 6 N HCl solution. However, the surface films of the $Fe_{43}Cr_{16}Mo_{16}C_{15}B_{10}$ metallic glasses were not stable by anodic polarization. Nevertheless, no pitting corrosion was observeded. The $Fe_{43}Cr_{16}Mo_{16}C_{10}B_5P_{10}$ metallic glasses were spontaneously passivated with a passive current density of about 10^{-1} A m^{-2} and exhibited a wide passive region before the transpassive dissolution of chromium, indicating their higher corrosion resistance in comparison with that of the phosporus free glassy alloys.

CONCLUSIONS

1. Fe-base bulk metallic glasses with a thickness up to 2.5 mm are able to be prepared in Fe-Cr-Mo-C-B-P system by copper mold casting. The Fe-Cr- Mo-C-B-P system metallic glasses exhibit a large supercooled liquid region (dT_x) up to 90 K and a high reduced glass transition temperature (T_g/T_l) reaching 0.6, indicating a high GFA and high thermal stability of the supercooled liquid.
2. The bulk metallic glasses in Fe-Cr-Mo-C-B-P system exhibit good corrosion resistance in HCl solutions. Phosphorus in the metallic glasses has beneficial effect on corrosion resistance.

REFERENCES

1. S. Pang, T. Zhang, K. Asami and A. Inoue, Mater. Trans., **42**, 376 (2001).
2. S. Pang, T. Zhang, K. Asami and A. Inoue, Scripta Materialia, submitted.
3. K. Hashimoto, M. Naka, K. Asami and T. Masumoto, Corros. Engng., **27**, 279 (1978).