Development of Al_2O_3-B_2O_3-SiO_2 Glass for Space Shuttle Coating

Jun-Yan Qiu[1], Yi-Tsung Lee[1], Cheng-I You[1], Guan-Yi Hung[2], Pin-Yi Chen[1], Chi-Shun Tu[3], *Kuei-Chih Feng[1]

[1]*Research Center for Intelligent Medical Devices, Ming Chi University of Technology*
[2]*International Ph.D. Program in Innovative Technology of Biomedical Engineering and Medical Devices, Ming Chi University of Technology*
[3]*Fu Jen Catholic University Department of Physics*

- **Aim of the work and its relationship to the status of the field**

This research is mainly devoted to developing the outer layer of heat-resistant glass coatings for the space shuttle. As the space shuttle passes through the atmosphere, it will produce a high temperature above 1350 °C. The glass coating protects the inner porous ceramic fiber bricks, which act as thermal insulation to form a thermal protection system (TPS). The high-silicon-based borosilicate glass easily forms devitrification and thermal cracking at high temperatures. Thus, this study aims to utilize alumina added to borosilicate glass to inhibit devitrification and the thermal cracking of borosilicate glass at high temperatures. Moreover, Al_2O_3 has an extremely high melting point of ~2072 °C which helps to enhance the glass transition temperature (Tg) of the Al_2O_3-B_2O_3-SiO_2 glass system. Lastly, this study aims to utilize the excellent adherence of Al_2O_3-B_2O_3-SiO_2 glass coated on aluminum-silicon fiber bricks. The bottom of the base material, which is the aluminum-silicon fiber bricks, is vital to achieve stable bonding.

- **A summary of the applicant's specific contributions and how they demonstrate exceptional ability and future promise**

The team has successfully created Al_2O_3-B_2O_3-SiO_2 glass with increased Tg (above 900 °C), which effectively suppressed the high-temperature cristobalite phase produced by devitrification. This study has confirmed the feasibility of adding Al_2O_3 to inhibit devitrification and thermal cracking and matched the thermal expansion coefficient (BSA 2.7~3.3, mullite = 4.5 (10^{-6}/K)), low thermal conductivity at high temperature (0.606 W/mK), suitable for thermal insulation coatings for high-temperature aerospace coatings. Moreover, the subsequent addition of cermet can effectively connect the substrate to the coating at high temperatures. With that, the coating plays an important function as a high-temperature anti-oxidation to protect cermet, thus realizing high emissivity thermal protection system.

- **A summary of significant results of the work and how they relate to the specific research area**

Al_2O_3 added in B_2O_3-SiO_2 glass plays a vital role to increase the Tg and to inhibit the devitrification in the thermal protection system (TPS) in the adhesion between the coating and the fiber bricks. it's an antioxidant protective layer at high temperatures to prevent excessive cermet oxidation. The formation of Al_2O_3-B_2O_3-SiO_2 glass on the surface allows the repair of cracks and forms repeatable TPS. Thus, Al_2O_3-B_2O_3-SiO_2 glass has high potential applied in aerospace applications.

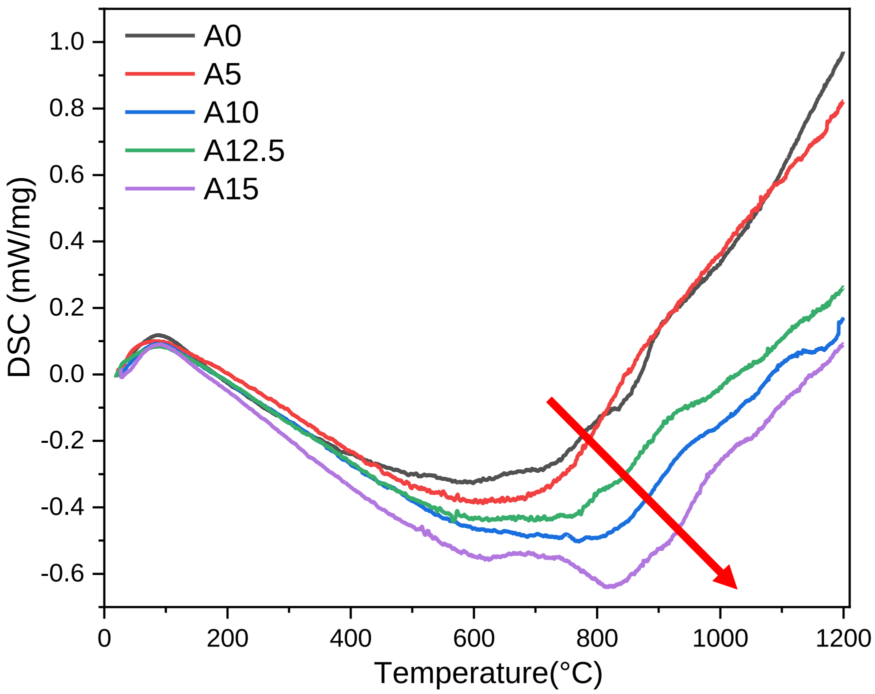

Fig1. Alumina-borosilicate glass DSC analysis.

- **A list of any publications authored by the applicant that are relevant to this research.**

[1] Ferraiuolo, M., and O. Manca, "Heat transfer in a multi-layered thermal protection system under aerodynamic heating". International Journal of Thermal Sciences, 53: p. 56-70, 2012.
[2] Dick, S.J., S.J. Garber, and J.H. Odom, "NASA HISTORY", 2009.
[3] Goldstein, H.E., D.B. Leiser, and V.W. Katvala, "Reaction cured glass and glass coatings". Google Patents, 1978.
[4] Stewart, D.A., H.E. Goldstein, and D.B. Leiser, "High temperature glass thermal control structure and coating". Google Patents, 1983.
[5] Plummer, C. and A. Donald, "Crazing mechanisms and craze healing in glassy polymers". Journal of materials science, 24(4): p. 1399-1405, 1989.
[6] Marshall, R.R., "Devitrification of natural glass". Geological Society of America Bulletin, 72(10): p. 1493-1520, 1961.
[7] Gupta, T.K. and J.-H. Jean, "Origin of cristobalite formation during sintering of a binary mixture of borosilicate glass and high silica glass". Journal of materials research, 9(4): p. 999-1005, 1994.