Study of Crystallization Behavior, Kinetics and Thermodynamics of Bulk Metallic Glasses Using Noncontact Electrostatic Levitation Technique

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Sundeep Mukherjee

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ABSTRACT

The exceptional stability against crystallization of recently developed bulk metallic glasses, together with the non-contact measurement techniques to investigate their thermophysical properties, have opened the doors for detailed studies of these systems in the deep undercooled liquid state. The primary objective of this thesis is identification of reliable predictive indicators of glass-forming ability based on the measured thermophysical properties and intrinsic crystallization behavior of bulk metallic glasses. A number of bulk metallic glass-forming alloys having widely different glass-forming abilities are chosen for this investigation. All of the measurements are carried out using the noncontact high vacuum electrostatic levitation technique to avoid any heterogeneous nucleation effects from container walls or environment.

The measured kinetic properties, viscosity, and free volume are found to have the most pronounced influence on glass-forming ability, while the thermodynamics show weak correlation with the trends in glass-formation. The glass-forming melts show orders of magnitude higher viscosity compared to pure metals. Among the glass-forming alloys, better glass formers have higher melting temperature viscosity, higher fragility, and show a smaller change in volume upon crystallization compared to poor glass formers. The melting temperature viscosity is correlated with volume change upon crystallization in accordance with Cohen-Grest free-volume theory for a wide variety of alloys.

To quantify the glass-forming ability, Time-Temperature-Transformation (TTT) curves of a number of glass-forming melts are measured over a wide temperature range between their glass-transition and melting temperatures. A pronounced effect of overheating is observed on the undercooling levels and crystallization time scales. This is attributed to oxide particles acting as heterogeneous nucleation sites unless dissolved by overheating above their melting points. The TTT curves, obtained after eliminating the heterogeneous influences, are found to scale with their respective glass transition temperatures. The TTT curves are analyzed within the framework of nucleation theory to obtain a quantitative correlation between crystal-melt interfacial tension, melt viscosity, and glass forming ability.

Finally, the crystallization behavior, microstructure, and melt viscosity of an *in situ* ductile phase reinforced amorphous matrix composite is investigated as a function of the processing temperature. The results for the *in situ* composite are compared with those of the monolithic bulk metallic glasses.

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