Effect of Hypercooling Limit for Supercooling Behavior and Glass Formation

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Supercooling of liquids is a crucial phenomenon to understand and control crystallization and vitrification in many research fields. In particular, why and how a supercooled liquid cools down below a critical temperature, called hypercooling limit ΔT_{hyp}, has been a key question to understand the non-equilibrium crystal growth and glass formation, which has still been very ambiguous. Also, it is not trivial to predict or measure hypercooling behavior of the liquid melts itself.

In the present work, we carry out a systematic and comprehensive study to understand the origin of hypercooling behavior and its role in glass formation with elemental to multi-component liquids forming BMGs by using a containerless electrostatic levitation technique. Remarkably, we find that the hypercooling behavior of liquids is determined by the combination of undercoolability U_{max} (= $\Delta T_{\mathrm{max}}/T_{\mathrm{m}}$) and hypercoolability U_{hyp} (= $\Delta T_{\mathrm{hyp}}/T_{\mathrm{m}}$), unlike the common belief that deep supercooling is the prerequisite to observe hypercooling. This provides an answer for a long-standing question of why certain materials show hypercooling behavior, although their liquids only have a small degree of supercooling. Moreover, we find that hypercooling limit is clearly related to glass forming ability, which explicitly reveals the hidden role of the hypercooling limit in glass formation in both thermodynamic and kinetic viewpoints. The present results provide not only a key parameter for materials design with hypercooling behavior, but also a new insight for understanding glass formation.