Thermal Expansion Mechanism of Elemental Liquids

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The use of liquid metals as a cooling agent for electronic devices in spatial restrictions (e.g., central processing units (CPUs)) has received increasing attention in recent years. Thus, the thermal expansion of these liquid metals should be considered for the cooling design and packaging process. While the thermal expansion of solids has been well explained with the anharmonicity of an effective potential, the thermal expansion behavior of the liquids is less understood since it is more complicated and quite different from the case of solid. For instance, the attractive part of the potential governs the thermal expansion in solids, while the repulsive part plays a significant role on the expansion in liquids. Moreover, accurate measurement of liquid thermal expansion coefficients (a_T) is very challenging over 3000 K, which prevents from obtaining a universal law for the thermal expansion of the liquid metals.

In the present work, we precisely and consistently measure the a_T of nineteen transition metal liquids over 3000 K by using electrostatic levitation (ESL). Interestingly, we find that dimensionless thermal expansion coefficient K_L (= $a_T T_m$) at melting temperature shows a strong dependence with the order in the periodic table. In each period, K_L first increases and reaches the maximum value at Group VIII (i.e., Fe, Ru, Os), and then decreases with the atomic number. In the same group, from Period IV to VI, K_L of early transition metals (ETMs) first decreases and then increases while that of late transition metals (LTMs) continuously decreases. These two rules make Zr have the smallest K_L among all the transition metals investigated here. We will show the measurement results and discuss the origin of thermal expansion for liquid metals.