American Mineralogist, Volume 106, pages 1077–1082, 2021

Precise determination of the effect of temperature on the density of solid and liquid iron, nickel, and tin

Asaka Kamiya[1], Hidenori Terasaki[1,2,*], and Tadashi Kondo[1]

[1]Department of Earth and Space Science, Osaka University, Machikaneyama 1-1, Toyonaka, Osaka 560-0043, Japan
[2]Department of Earth Sciences, Okayama University, Tsushimanaka 3-1-1, Kita-ku, Okayama, 700-8530, Japan

Abstract

Density and thermal expansion coefficient of metals are fundamental characteristics to describe the equation of state. Especially for liquid metals, the reported data for density and thermal expansion coefficient vary in the literature, even at ambient pressure. To determine the density of solid and liquid metals precisely at high temperatures and ambient pressure, we have developed a high-temperature furnace. The densities of solid Sn, Ni, and Fe were determined from the sample image with an uncertainty of 0.11–0.7% in the temperature range of 285–1803 K with increments of 1–10 K. The density of solid Sn decreased linearly with increasing temperature up to 493 K, and then the decrease became drastic until the melting temperature (T_m) was reached. By contrast, for solid Ni and Fe, the densities decreased linearly with increasing temperature up to the T_m (1728 and 1813 K) without any drastic density drop near T_m. This suggests that Ni and Fe do not exhibit the "premelting effect."

The density of liquid Fe was determined with an uncertainty of 0.4–0.7% in the range of 1818–1998 K with temperature increments of 5 K. The obtained thermal expansion coefficient (α) of liquid Fe was well approximated as either a constant value of $\alpha = 2.42(1) \times 10^{-4}$ K^{-1} or a linear function of temperature (T); $\alpha = 1.37(10) \times 10^{-3} - [6.0(6) \times 10^{-7}]T$ [K^{-1}] up to at least 2000 K.

Keywords: Density, thermal expansion, metal, liquid