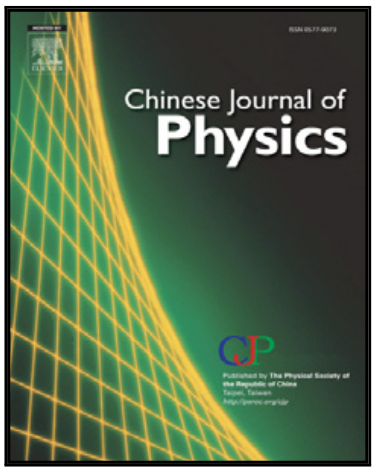

Ferri-para-magnetism of tungsten and its carbide cermets for elevated temperature sensor application

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Ferri-para-magnetism of tungsten and its carbide cermets for elevated temperature sensor application

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In routinely analyzing experimental results of low-temperature, 5 K ≤ T ≤ 300 K, magnetic susceptibility χ(T) of fused tungsten and its fused carbide cermets, hereafter called "the materials", by assuming the susceptibility satisfying the Néel ferrimagnetic formula, $\chi^{-1} = \chi_0^{-1} + \chi_1^{-1} + \chi_2^{-1}$, where χ_0^{-1}, χ_1^{-1}, and χ_2^{-1} are respectively the inverses of the Pauli paramagnetic, $\chi_0 > 0$, a Curie diamagnetic, $\chi_1 = C/T < 0$, and a lattice diamagnetic susceptibilities, $\chi_2 = (-1/b)(T - \Theta_p) < 0$, this study finds that the increase in susceptibility of the materials is principally due to the effect of the Curie diamagnetic term in the formula and might be caused by the demagnetizing field that is induced by the interstitial vacancy in, e.g., tungsten lattice. By extending the formula to the region of lower (< 5 K) and higher (> 300 K) temperatures, one finds two singular points in the susceptibility inverse curve χ^{-1}. One is at $\Theta_p < 0$, and the other $\Theta_a = -C/\chi_0 >> 0$, e.g., $\Theta_p = -1.73$ K, and $\Theta_a = -C/\chi_0 = +8655$ K for tungsten. In view of their susceptibility precisely satisfying the Néel ferrimagnetic formula in the temperature range of 5 K and 300 K, they are called "ferri-para-magnetism" and are good for elevated temperature sensor application if the temperature extension is satisfied. As temperature exceeding an asymptotic temperature, Θ_a, the paramagnetic state turns to a diamagnetic state, suggesting that there might be a superconducting transition at this temperature for some of the materials with Θ_as that are lower than their melting points, e.g., Θ_a(C7M1) = +2735 K and Θ_a(-VC) = +2242 K.

Keywords: ferri-para-magnetism (FPM); the Curie diamagnetism; lattice diamagnetism; the Pauli paramagnetism; demagnetizing field; interstitial vacancy; singular point; sensor; asymptotic temperature; superconducting

I. INTRODUCTION

Tungsten has a melting point (m.p.) of 3410°C that is next to 4027°C, the m.p. of carbon.[1] It is a good electrical conductor with resistivity of 4.96-5.3 μΩ·cm [2-3] at 300 K. The paramagnetic susceptibility of tungsten, at 298 K and at an applied magnetic