Physical Properties of Hastelloy® C-276™ at Cryogenic Temperatures

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Introduction

In recent years, the Ni-Mo-Cr superalloy Hastelloy® C-276™ is used as a substrate material for fabricating superconducting tapes such as YBCO and MgB_2 coated conductors. However, the data of physical properties of Hastelloy C-276 important to these applications are not available. The purpose of this work is to fill this data gap while explore the interesting physics in this alloy of transition metals.

Experimental

The coeffient of thermal expansion (CTE) is measured by variable temperature x-ray diffraction. Quantum design's magnetic property measurement system (MPMS) and physical property measurement system (PPMS) were used to measure magnetization, resistivity, specific heat (C_p), and thermal conductivity (κ).

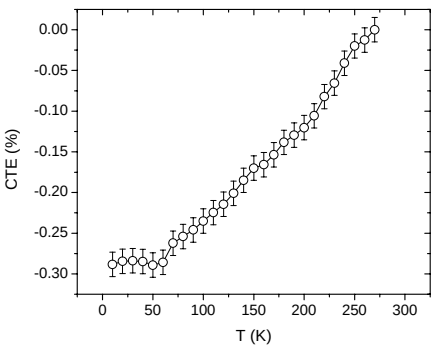

Fig. 1. CTE vs. T.

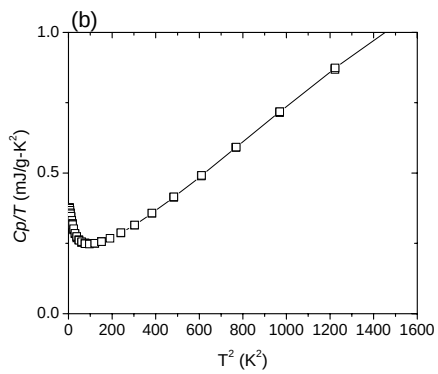

Fig. 2. C_p/T vs. T^2

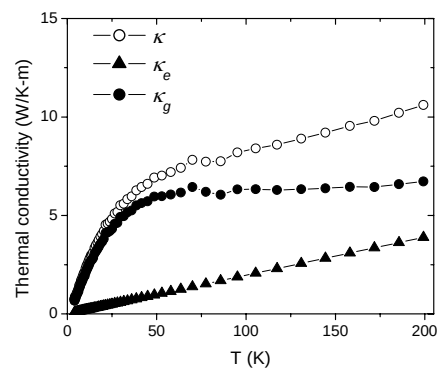

Fig. 3. Thermal conductivity κ and its electron and phonon components κ_e and κ_g

Results and Discussion

Between 4 and 300 K, Hastelloy C-276 shows the Curie paramagnetism with a Curie constant C = 0.091 K. Below 3 K, a spin-glass-like behavior is observed by ZFC and FC χ vs. T measurements. Electrical resistivity has a minimum at ~ 12 K, while at higher temperatures it shows near linear weak T dependence. Fig. 1, 2 and 3 show CTE, C_p and κ as functions of temperature respectively. The C_p between 15 and 40 K in Fig. 2 are fitted with $C_p = \gamma T + AT^3$, where $\gamma = 1.33\text{x}10^{-4}$ J/g-K^2 and A = $5.99\text{x}10^{-7}$ J/g-K^4. An anomaly in C_p occurs below 10 K where C_p/T increases with decreasing T. This can be related to the existence of very small ferromagnetic clusters.[1] In Fig. 3, the κ vs. T data are analyzed by separating the electron (κ_e) and phonon (κ_g) contributions. At the temperatures measured (< 200 K), the phonon contribution κ_g to the total thermal conduction is dominant.

Conclusions

We have measured magnet succeptibility, electrical resistivity, specific heat, and Seebeck coefficient of Hastelloy C-276 from 2 to 300 K, and thermal conductivity from 2 to 200 K. At low temperatures, Hastelloy C-276 is paramagnetic. The resistivity minimum found at ~12 K is related to the Kondo or weak localization effects. An anomaly in C_p below 10 K suggests the existence of very small ferromagnetic clusters. At the temperatures measured (< 200 K), the phonon contribution to the total thermal conduction is dominant.

References

[1] Lu, J., *et al.*, J. Appl. Phys., 101, 123710 (2007).