Study of structural and magnetic properties presented by Tb$_{1-x}$Pr$_x$Ni$_2$ compounds

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Abstract

On the search for better cores for cryogenic magnetic refrigeration, magnetic and structural properties, such as synchrotron x ray diffraction and magnetization of Tb$_{1-x}$Pr$_x$Ni$_2$ were studied. The results show the linear behavior of the lattice parameter and the Curie temperature.

Key words: Magnetism, Magnetocaloric effect, Structural properties

Introduction

This project was elaborated to evaluate the structural and magnetic properties of Tb$_{1-x}$Pr$_x$Ni$_2$ compounds and its applications on cryogenic magnetic refrigeration. Magnetic refrigeration is based in the magnetocaloric effect, which consists in the material ability to change its temperature due to a variation on the applied magnetic field in an adiabatic process.

Results and Discussion

For the preparation of the Tb$_{0.5}$Pr$_{0.5}$Ni$_2$ alloy, nickel 99.7%, praseodymium 99.9% and terbium 99.9% were melted in an arc furnace in an atmosphere of Ar. Then, synchrotron x ray diffraction data were collected to determine the quality of the compound, based on Rietveld refinement. An analysis of the diffraction pattern peaks position done with Mathematica software presented a = 7.2332 ± 0.0001 Å as the lattice parameter “a” of the compound. Later on, optical metallography showed that the compound presented 3 different phases identified as Tb$_{0.5}$Pr$_{0.5}$Ni$_2$, Tb$_{0.5}$Pr$_{0.5}$Ni$_2$ (majority phase) and Tb$_{0.5}$Pr$_{0.5}$Ni$_2$. Furthermore, magnetization thermal variation from 10 to 320 K at an applied magnetic field H = 200 Oe measurements were taken. Curie temperature $T_c$ = 20.5 K was obtained analyzing the differential plot of the magnetization vs temperature.

The lattice parameters of TbNi$_2$ and PrNi$_2$ has, respectively, 0.056 Å and 0.053 Å difference from Tb$_{0.5}$Pr$_{0.5}$Ni$_2$ lattice parameter “a”. The Curie temperature of PrNi$_2$ is much lower than TbNi$_2$, causing and abrupt fall as terbium is replaced by praseodymium. A fit of lattice parameters and curie temperatures shows that both of them vary linearly with $x$, $y$ = (-208 ± 5)10$^5$x + (13932 ± 3)10$^{-5}$ and $y$ = (-37 ± 2)x + (38 ± 1) describes the linear variation of the lattice parameters and the Curie temperatures, respectively.

Conclusions

It is possible to conclude that praseodymium rich alloys of Tb$_{1-x}$Pr$_x$Ni$_2$ have a low Curie temperature, therefore better for cryogenic magnetic refrigeration. Also, the replacement of terbium by praseodymium causes an abrupt fall of nearly 40 K on the curie temperature, while the lattice parameter vary 0.109 Å, both of them with linear behavior.

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Image 1. Lattice parameter and curie temperature vs composition.