Experimental Report HS1365

Properties of magnetic materials are a subject of great scientific and practical interest. An enormous amount of experimental and theoretical investigations have been carried out to get a deeper understanding of the nature of magnetism in solids[1]. One of the most well known and still not fully understood phenomenon related to magnetism is the so-called Invar effect. In 1897 Guillaume[2] discovered the original Invar property of the face centered cubic (*fcc*) iron-nickel alloys containing about 35 at.% Ni, which exhibits an anomalously low (almost zero) and constant thermal expansion over a wide region around room temperature. Subsequently he found the temperature-independent elastic behavior of Fe-Ni-Cr alloys that is now known as the "Elinvar" effect. We have measured the pressure – volume (P-V) relations for cubic iron-nickel alloys for three different compositions, $Fe_{0.64}Ni_{0.36}$, $Fe_{0.55}Ni_{0.45}$, and $Fe_{0.20}Ni_{0.80}$. It is observed that for a certain pressure range the bulk modulus does not change or even can decrease to some minimum value, after which it begins to increase under still higher pressure. In our experiment we observe for the first time a new effect, namely that the Fe-Ni alloys with high Ni concentrations, which show positive thermal expansion at ambient pressure, become Invar system upon compression over a certain pressure range (Fig. 1).

The P-V-T relations for $Fe_{0.92}Ni_{0.08}$, $Fe_{0.85}Ni_{0.15}$, $Fe_{0.8}Ni_{0.2}$, $Fe_{0.75}Ni_{0.25}$, $Fe_{0.64}Ni_{0.36}$, $Fe_{0.53}Ni_{0.64}$, and $Fe_{0.20}Ni_{0.80}$ are measured up to 180 GPa and 1250 K. We also observed decomposition of $Fe_{0.80}Ni_{0.20}$ alloy at pressures above 15 GPa on the mixture of Fe-reach (*hcp*) and Ni-reach (*fcc*) phases. This two phases did not homogenize upon heating at 1200 K during 8 hours at pressure above 60 GPa. This result is very important for understanding the process of planets (particularly Earth) differentiation.

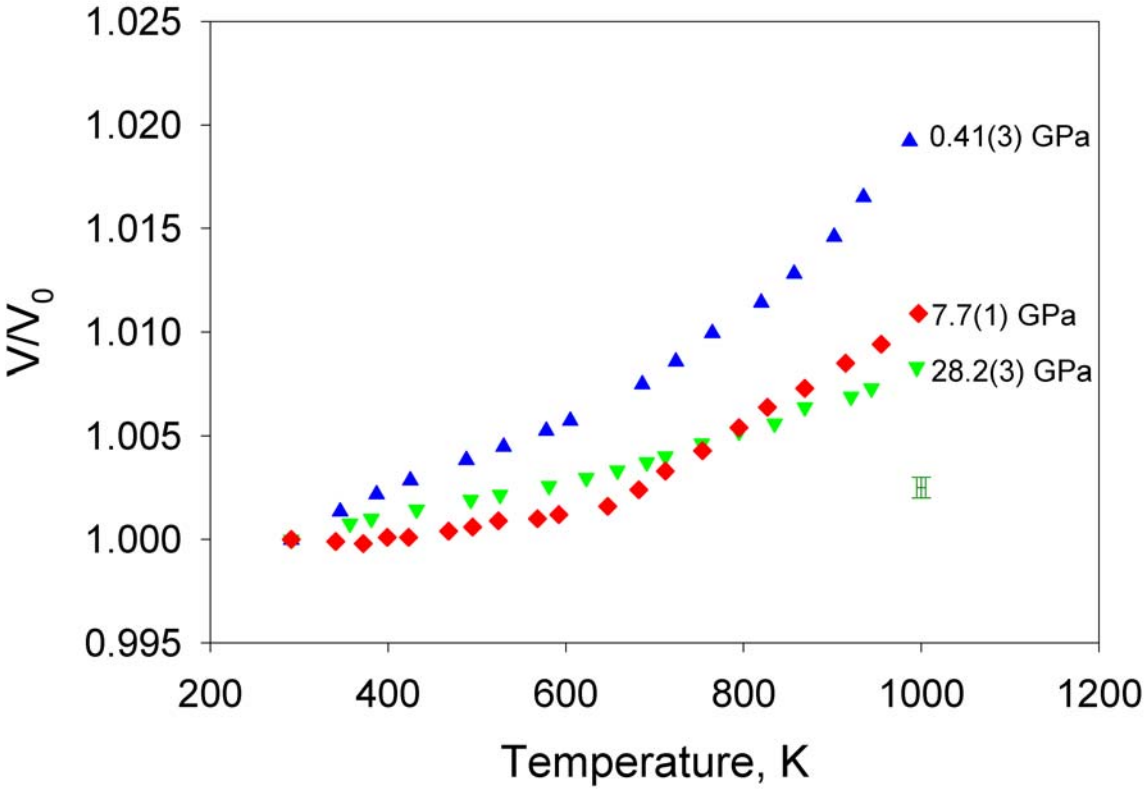

Fig. 1. Variation of relative volume of $Fe_{0.55}Ni_{0.45}$ alloy at 0.41(3) GPa, 7.7(1) GPa, and 28.3(3) GPa. During the heating, pressure maintained constant within the experimental error. At 7.7(1) GPa and at temperatures between 291 K and 500 K, $Fe_{0.55}Ni_{0.45}$ practically does not expand (α=0.2(3) 10^{-5} K^{-1}), while no anomalies in thermal expansion of this alloy were observed at 0.41(3) and 28.3(3) GPa. Error bars show uncertainties in temperature and volume.

Principal publications:

O. L. Anderson, L. S. Dubrovinsky, S. K. Saxena, T. Le Bihan, Vibrational Grunasen Parameter of Fe to 300 GPa, **Geophys. Res. Letters**, 2001, 28, 399-402.

L. S. Dubrovinsky, N. A. Dubrovinskaia, T. Le Bihan, Aggregate Sound Velocities and Acoustic Grüneisen Parameter of Iron up to 300 GPa and 1200 K, **Proceedings of National Academy of Science (USA)**, 2001, 98, 9484-9489.

L.S. Dubrovinsky, N.A Dubrovinskaia, I.A. Abrikosov, M. Vennström, F. Westman, S Carlson, M. van Schilfgaarde, and B. Johansson. Pressure Induced Invar Effect in Fe-Ni Alloys, **Physical Review Letters**, 2001, 86, 4851-4854.