Indian J. Phys. **68A** (6), 587 – 590 (1994)

IJP A
— an international journal

Magnetostriction of nickel ferrites containing divalent iron ions

M T Korayem
Department of Physics, Faculty of Science, Alexandria University, Alexandria, Egypt

Received 30 May 1994, accepted 27 September 1994

Abstract . Magnetostriction measurements on nickel ferrites containing divalent iron ions are reported for the temperature range of 80 K to 300 K. It is found that the magnetostriction constant λ_{111} is highly dependent on the ferrous content and electron ordering on octahedral sites. Introduction of tetrahedral divalent nickel ions by chemical quenching changes λ_{111} as well as λ_{100}

Keywords : Magnetostriction, nickel ferrous ferrites

PACS Nos. : 75 40 -s, 75 50 Ee, 75.80 +q

Anisotropy and magnetostriction of ferrites are strongly influenced by transition metal ions with an orbitally degenerate ground state. By substitution in the lattice, the degeneracy is lifted which gives energy levels, strongly depending on the direction of magnetostriction. Specially, the contribution of Fe^{2+} ions to the magnetostriction has been found to be complex due to electron migration and ordering [1-3].

As magnetostriction data on ferrous ferrites are rare in literature, we have performed an investigation on the magnetostriction in these materials. In the present work, the results on nickel ferrous ferrites are reported.

The magnetostriction of a single crystal $Ni_xFe_{3-x}O_4$ is measured from 80 K to 300 K. The fractional change of length is measured as function of the rotation of the magnetic field in the (001) and $(1\bar{1}0)$ planes respectively. The obtained curves are analysed with the usual 2-constant expression for the magnetostriction of cubic materials [4], the constants λ_{100} and λ_{111} are determined measuring the maxima in the traced curves $\frac{\Delta l}{l}$ versus the angle of rotation.

Figure 1 shows that λ_{100} changes as function of the composition $Ni_xFe_{3-x}O_4$ but is nearly temperature independent in the considered temperature range. This is in contradiction

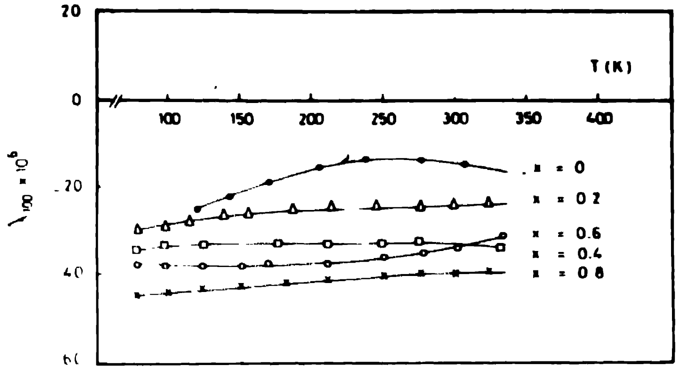

Figure 1. Magnetostriction λ_{100} of $Ni_xFe_{3-x}O_4$ plotted against temperature for various nickel concentration x

with the results of Smokotin *et al* [5] who found a strong temperature dependence of λ_{100} for $NiFe_2O_4$. However, Krishnan and Rivoire [6] showed that the magnetostriction of this compound can be changed by quenching the crystals which induces migration of Ni^{2+} ions to tetrahedral sites. Even a small number of Ni^{2+} on tetrahedral sites gives a large temperature-dependent contribution to the magnetostriction [7] which complicates the study of the magnetostriction is this system.

The crystals under investigation were annealed at 1100° C and cooled with a rate of 600°/hour, which may give very small concentration of Ni^{2+} on tetrahedral sites, and this can explain the deviation from literature.

The room temperature values of λ_{111} in this experiment are below the straight line drawn between the extreme compositions $x = 0$ and $x = 1.0$, which can be attributed to the negative contribution $\Delta\lambda_{111}$ of a small number of tetrahedral Ni^{2+}. To be sure that tetrahedral Ni^{2+} occurs in this system we measured also the magnetostriction on quenched specimens of $Ni_xFe_{3-x}O_4$ and Fe_3O_4. For $x = 0.6$, only a change of the magnetostriction λ_{111} and λ_{100} of about 20 % is observed, which must be due to Ni^{2+} migration, while for Fe_3O_4 no change is observed.

In comparison with the values in literature, this effect is small [6,7]. However, this difference and the scattering in literature data [6,7] can be explained by the complex kinetics of the cation exchange between the sublattices [10], which is not easy to control during the quenching process.

In Figure 2, λ_{111} is plotted against temperature for various nickel concentration x. For $x > 0.4$, λ_{111} is slightly temperature dependent. For $x \lesssim 0.2$, λ_{111} is positive at room temperature, decreases gradually with decreasing temperature and becomes negative below

100 K. The same tendency was observed in the Mg Fe ferrite system [3], which can be attributed to electron ordering on octahedral sites 'Verwey ordering in magnetite'. At room

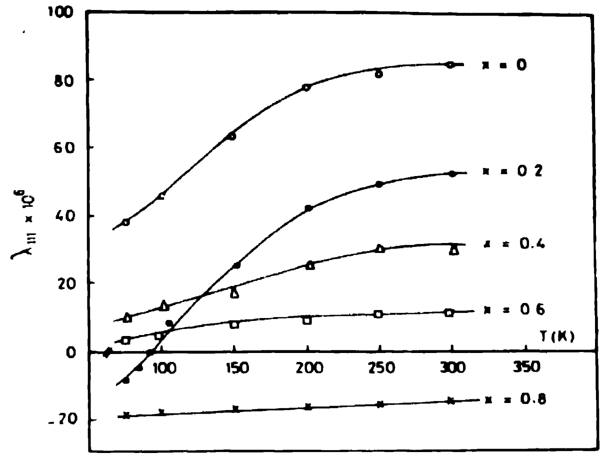

Figure 2. Magnetostriction λ_{111} of $Ni_xFe_{3-x}O_4$ plotted against temperature for various nickel concentration x

temperature, this ordering has no influence which can be seen from Figure 3, where λ_{111} is plotted against the nickel content x.

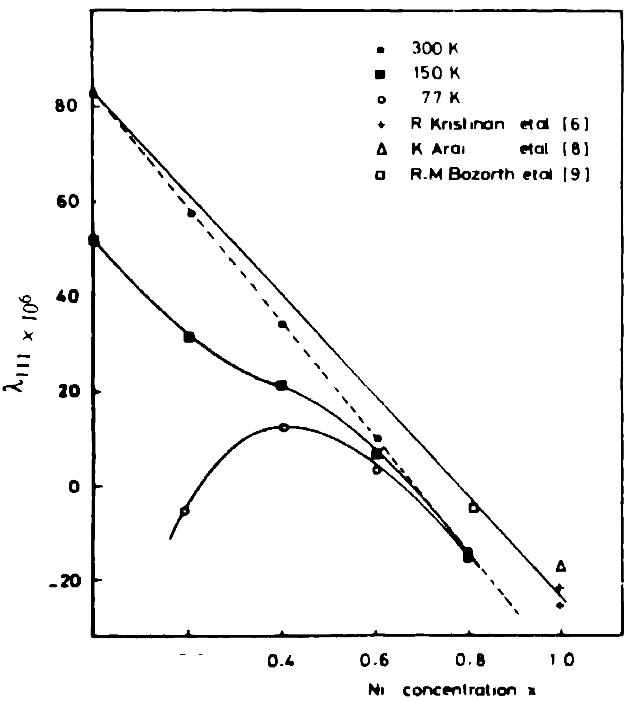

Figure 3. Magnetostriction λ_{111} as a function of the nickel content x in $Ni_xFe_{3-x}O_4$

At 300 K, λ_{111} is linearly dependent on $(1-x)$ *i.e.* the Fe^{2+} content. At lower temperature where the Verway ordering can occur, the composition dependence becomes non-linear.

Acknowledgment

The author wishes to thank Dr. A H El-Sayed for performing some experimental work in Genowa, Italy.

References

[1] J Sloncewski *J Appl Phys.* **32S** 253 (1961)

[2] J Klerk, V A M Brabers and A J M Kuipers *J. de Phys* **38** CI-187 (1977)

[3] V A M Brabers, A A Hizsch, W C van der Vlauten and P Doremalen *IEEE Trans Mag. Mag* **14** 895 (1978)

[4] E Kneller *Ferromagnetisms* (Berlin . Springer Verlag) p 233 (1962)

[5] E M Smokotin, E V Rubalskaya, G A Petrovskii, Yu M Yakovlev and L M Protopopova *Bull USSR Acad Sci* **34** 952 (1970)

[6] R Krishnan and M Rivoire *Phys. Stat Sol. (a)* **7** K39 (1971)

[7] K T Liolioussis and A J Pointon *J de. Phys* **38** CI 191 (1977)

[8] K Arai and N Tsuya *J. Phys Chem Solids* **36** 463 (1975)

[9] R M Bozorth, E F Tilden and A J Williams *Phys Rev* **99** 1788 (1955)

[10] V A M Brabers and J Klerk *J. de Phys.* **38** CI-207 (1977)