Magnetic properties of agglomerated Fe_3C - nanoparticles in a carbon matrix

K. Lipert[1], J. Kaźmierczak[1], I. Pełech[2], U. Narkiewicz[2],
H.K. Lachowicz[1], and A. Ślawska–Waniewska[1]

[1]*Institute of Physics, Polish Academy of Sciences,*
Lotników 32/46, 02-668 Warsaw, Poland
[2]*Institute of Chemical and Environment Engineering, Technical University of Szczecin*
Puławskiego 10, 70-322 Szczecin, Poland

In the recent years, a great attention was focused on magnetic nanoparticles because of their unique physical properties and also because of a possibility of their practical applications in medicine and biotechnology (hyperthermia, targeted drug delivery, contrast agents in MRI) as well as in catalysis, magnetic separation, gas sensors and many others.

The aim of the present work is to investigate structural characteristics and magnetic properties of nanoparticle agglomerates of iron carbide (Fe_3C) in a carbon matrix. The specimens have been prepared by a carburization of nanocrystaline iron with ethylene. The measured samples, marked for short as S1 and S2, were diversified in respect of the ratio of carbon to iron mass during carburization, which was equal 0,715gC/gFe and 1,687gC/gFe, respectively. In both cases the amount of carbon was well above that sufficient to transform iron into Fe_3C.

The structure of both measured sample were analyzed by TEM and X-ray diffraction (XRD). A system of nanoparticles with size distribution ranging from 20 to 100 for the S1-sample and from 20 to even more than hundred nanometers in the case of the S2-sample was revealed. The measured ZFC-FC curves (not shown here) indicate also that such a wide distribution of the particle sizes is present in both samples.

Magnetic properties were measured using vibrating sample magnetometer (VSM). Thermo-remanence magnetization, hysteresis loops, zero field- and field-cooled measurements were carried out in the temperature range from 5 to 300K. Both samples did not exhibit pure superparamagnetic behavior within this temperature range since even at room temperature their coercivity is far from zero. It is well known that for a system of non-interacting, single domain randomly oriented particles their coercivity should follow the formula

$$H_c(T) = H_c(0)\ \{1 - [T/T_B]^{1/2}\},$$

where T_B is the mean blocking temperature.

Fig. 1 shows the coercivity, derived from the hysteresis loops measured for both samples, plotted as a function of the square root of the temperature. As is seen, both dependencies are linear in the range of higher temperatures. The extrapolated values of the maximum blocking temperature (*i.e.*, blocking temperature of the largest particles), calculated according to the above equation, are equal T_B = 348K and T_B = 710K for the S1 and S2 samples, respectively.

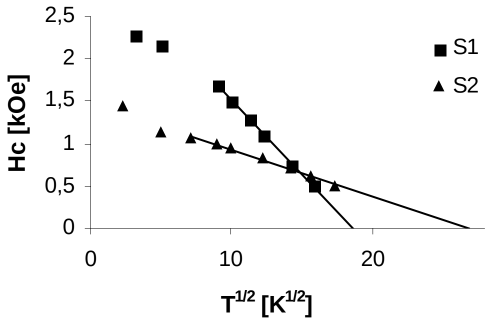

Fig. 1. Coercive force *versus* square root of temperature.

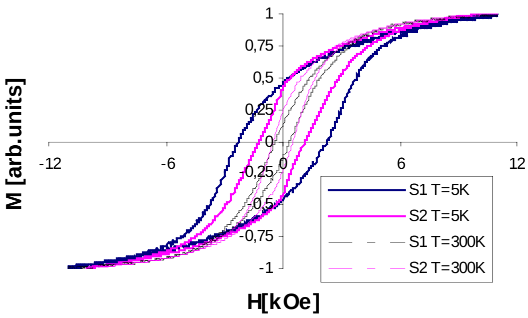

Fig. 2. Hysteresis loops measured at temperature of 5 K and 300 K.

It is worth to note, that the value of remanence magnetization at low temperatures is very close to half of the value of saturation magnetization, being equal 0,46 and 0,41 for S1 and S2 samples, respectively (see Fig. 2). This seems to be in a good agreement with the Stoner-Wohlfarth model [1].

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[1] E.C. Stoner and E.P. Wohlfarth, IEEE Trans. Magn., **27** (1991) 3475.

Name of the presenting author (poster): Kamil Lipert
e-mail address: lipert@ifpan.edu.pl
url's: http://www.ifpan.edu.pl