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INFLUENCE OF MAGNETIC FIELD ON PROPERTIES OF NANOPARTICLES PRODUCED BY ELECTROSPARK METHOD

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ABSTRACT

Electrospark dispersion (ESD) is one of the production methods of fine-grained powders (FGP) of metals and alloys [1-2]. This method has a series of physical and technological advantages. It is simple enough as installation, ecologically clean, has no waste products, has low energy intensity and high efficiency. More over, high temperatures (>4000K) in zone of powders synthesis, super high rates of cooling (>109 K/s), high degree dispersion of obtained product (10 ÷ 1000 nm) are characteristic for this method.

Under spark discharge duration in zone of plasma channel and surrounding liquid the electric and magnetic fields of complex shapes arise, which evidently influence on dispersion process. In this connection, investigation of external persistent magnetic field influence on phase composition and dispersion of fine-grained Fe powders was the main objective of the work.

NOMENCLATURE

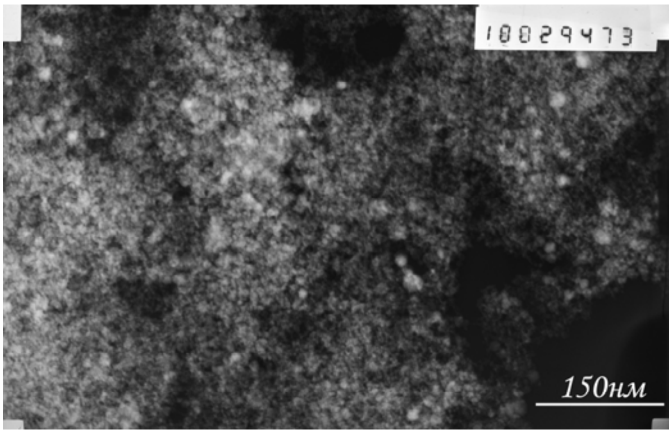
Subscripts

ESD	Electrospark dispersion
FGP	fine-grained powders
ADL	arc discharge in the liquid phase
CSR	coherent-scattering region
CNS	carbon nanostructures
ADLP	arc discharge in the liquid phase where a layer of powder reagent is used as an anode

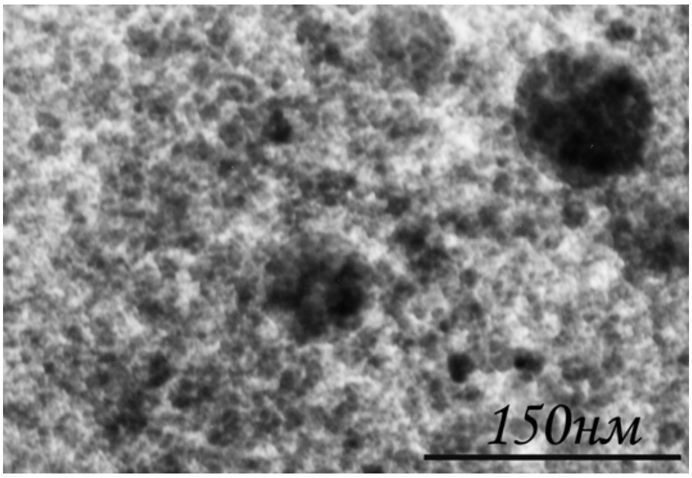
RESULTS AND DISCUSSION

Electrospark dispersion of Fe was carried out in distilled water and ethanol in the installation which was designed in the Institute for Problems of Materials Science of NASU. Voltage between the electrodes was chosen to be 150 V, average current value during spark discharge time was in interval 200-300 mA. Crystalline structure and phase composition of FGP were investigated using X-ray diffractometer DRON-3.0 in cobalt radiation, and magnetic properties - using ballistic magnetometer in field range up to 300 kA/m at room temperature. The external magnetic field of 80 kA/m strength was formed by persistent magnet and ceramic reactor for powders synthesis was placed between of its poles. Particles sizes were determined by electron microscope, and coherent scattering range (CSR) sizes – according to X-ray lines broadening by approximation method [3].

In Figure 1 micro images of high-grained Fe particles, produced in distillate water with magnetic field absence and with its applying, are given. As it was shown in a few papers [1-2, 4-5], spherical shape particles with wide sizes distribution are formed using ESD method. This experimental fact is supported by micro images which are given. They testify also that magnetic field influences significantly on produced powders dispersion – under external magnetic field applying particles which are formed have essentially more large sizes: if $H = 0$, particle sizes are in 1÷100 nm range, and if $H \neq 0$ particle sizes are in 25÷250 nm range.

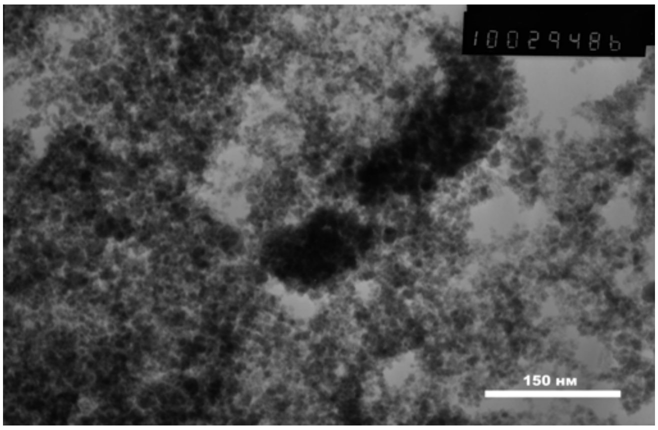


a)



b)

Figure 1 Synthesis of Fe nanostructural in H2O: a) H=0; b) H≠0



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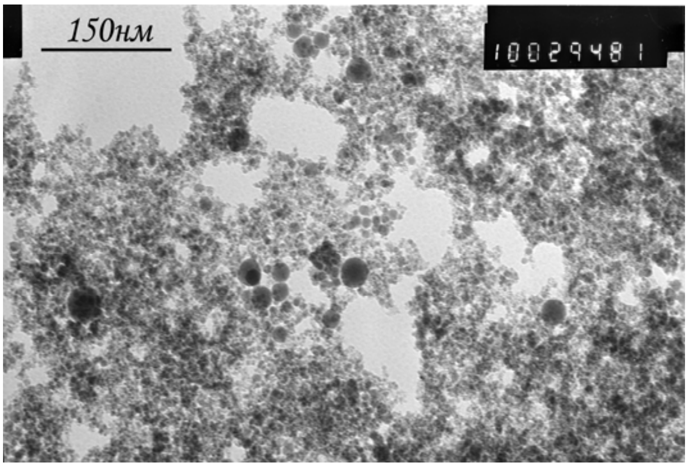

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Figure 2 Synthesis of Fe nanostructural in ethanol: a) H=0; b) H≠0

Phase-structural characteristics of produced powders change also. It follows from the Table 1 in which results of X-ray structural investigation for phase composition and CSR sizes of powders are given. Primarily, it should be pointed out that CSR sizes data support electron microscopic results – dispersion degree of powders decreases under magnetic field applying. Phase composition of all phase components for Fe FGP, produced in distillate water, does not change practically under magnetic field applying (Figure 2). Per contra, for FGP, produced in ethanol, slight ~2% increasing of ferromagnetic α-phase amount was detected. CSR sizes under magnetic field applying increase both for FGP, produced in distillate water and also for FGP, produced in ethanol. So, CSR sizes increasing of α-Fe equals 1000 nm and 360 nm for FGP, produced in distillate water, and for FGP, produced in ethanol, they are 1000 and 100 nm under H ≠ 0 and H = 0 respectively.

Table 1

Phase composition and CSR sizes of Fe powders, produced in distillated water and ethanol under external magnetic field applying.

Experimental conditions	Phase composition	%, mas. content	c, nm
Water, H=0	α- Fe, Fe_3O_4, FeO	88; 2; 10	360, -, 150
Water, H≠0	α- Fe, Fe_3O_4, FeO	88,5; 1,5; 10	1000, -, 200
Ethanol H=0	α- Fe, γ- Fe	93; 7	1000, 13
Ethanol H≠0	α- Fe, γ- Fe	95; 5	100, 15

An increase of α-Fe phase in powder under magnet field applying can be explained by negative contribution of nucleuses magnet moments interaction energy of ferromagnetic α-Fe phase in total energy of the system which leads to arising of thermodynamic stimulus for these nucleuses formation.

External magnet field applying during formation and growth of nucleuses process for ferromagnetic α-Fe phase can lead to one more phenomenon – increasing of dipole-dipole interaction between ferromagnetic α-Fe phase particles magnet moments; this can be caused by orienting activity of magnetic field on magnet moments of particles. An increase of magnet interaction between α-Fe phase particles, in its turn, will promote processes of particles convergence and agglomeration. This was detected as their effective sizes increasing during X-ray structural and electron microscopic experiments.

CONCLUSION

As conclusion we would like to notice, that detected effect values could be more significant with the use of external magnetic field of greater strength. In our case external magnetic field value did not exceed 80 kA/m. Thereby, the carried out investigations have shown that external magnetic field using during electrospark dispersion of materials can be used for the change of phase composition and dispersion degree of produced powders.

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