

## COMPOSITE MATERIALS FROM SURFACE INSULATED IRON POWDERS

E. ENESCU<sup>1</sup>, P. LUNGU<sup>1</sup>, A. BARA<sup>1</sup>, V. BUHARU<sup>2</sup>

<sup>1</sup> – *Advanced Research Institute for Electrical Engineering (ICPE – CA), 313 Splaiul  
Unirii,*

*030138 Bucharest – 3, Romania, tel./fax: +40 21 346.72.83, contel@icpe-ca.ro*

<sup>2</sup> – *S.C. DUCTIL S. A. Buzau, Romania*

*Abstract:* These new soft magnetic materials were obtained from iron powder surface insulated with an inorganic or inorganic/organic layer, by powder metallurgy techniques, namely sintering or agglomerating. The influence of the iron powder sort and insulating layer on the physico-mechanical and magnetical characteristics of the composite materials was studied.

*Key words:* soft magnetic materials, iron powder, surface insulation.

### 1. INTRODUCTION

In the powder metallurgy industry there is the belief that soft magnetic components made from iron powders hold the key to the future prosperity for ferrous-based powder metallurgy products. The benefits of powder metallurgy, such as its near net shaping capabilities with high dimensional accuracy and maximum material savings are making it an increasingly attractive process for the production of soft magnetic components.

While the magnetic and electric properties of powder metallurgy parts was once below that of wrought materials, they are increasingly offering the same, and sometimes better, level of performance. The development of novel powder metallurgy techniques, as well as the intense activity in the research for better performing materials, promises to further advance the industry in the near future.

The new soft magnetic materials elaborated by us are destined to replace the classical magnetic cores, obtained from laminated steel sheets, in various applications like a.c. and d.c. circuits for automotive, domestic and toys industry. For a.c. applications they must have high induction and permeability and low coercive force and total losses. In order to minimize these losses, especially eddy current losses; the electrical resistivity of material must be increased. A highly increased resistivity, for applications at frequencies > 500 kHz, can be obtained by insulating the iron powder particles with an inorganic or/and organic layer, thus obtaining magnetodielectric composites.

## 2. EXPERIMENTS

In our experiments we used, as raw materials, two atomised iron powders, high purity and compressibility sorts: DP 200 and DP 200 HD, supplied by DUCTIL SA Romania. The grain size of powders was  $<160 \mu\text{m}$ .

These powders were initially insulated inorganically, with an iron phosphate layer deposited from an alcoholic  $\text{H}_3\text{PO}_4$  solution, with 0.03% P content. A uniform and continuous layer of about  $0.2 \mu\text{m}$  thickness was obtained.

Then, these particles were organically insulated with 0.5% polyethylene by the bed-fluidized method, using a Würster installation.

As an alternative method, the organic insulation was realised by mechanically mixing the Fe-0.03%P powders with 0.5% solid epoxy resin ROPOXID type (with 10% acrylic resin content), having grain size  $<45 \mu\text{m}$ .

The powders thus insulated were further on processed by powder metallurgy technique: mixing with 0.5% Zn stearate as lubricant, pressing at  $6 \text{ tf/cm}^2$  and sintering at  $1120^\circ\text{C}$ , 1 hour, in hydrogen atmosphere for Fe-P powders, or curing at  $150^\circ\text{C}$ , 1 hour, in air, for Fe-P-PE and Fe-P-ER powders.

A complete technological flow chart is presented in figure 1.

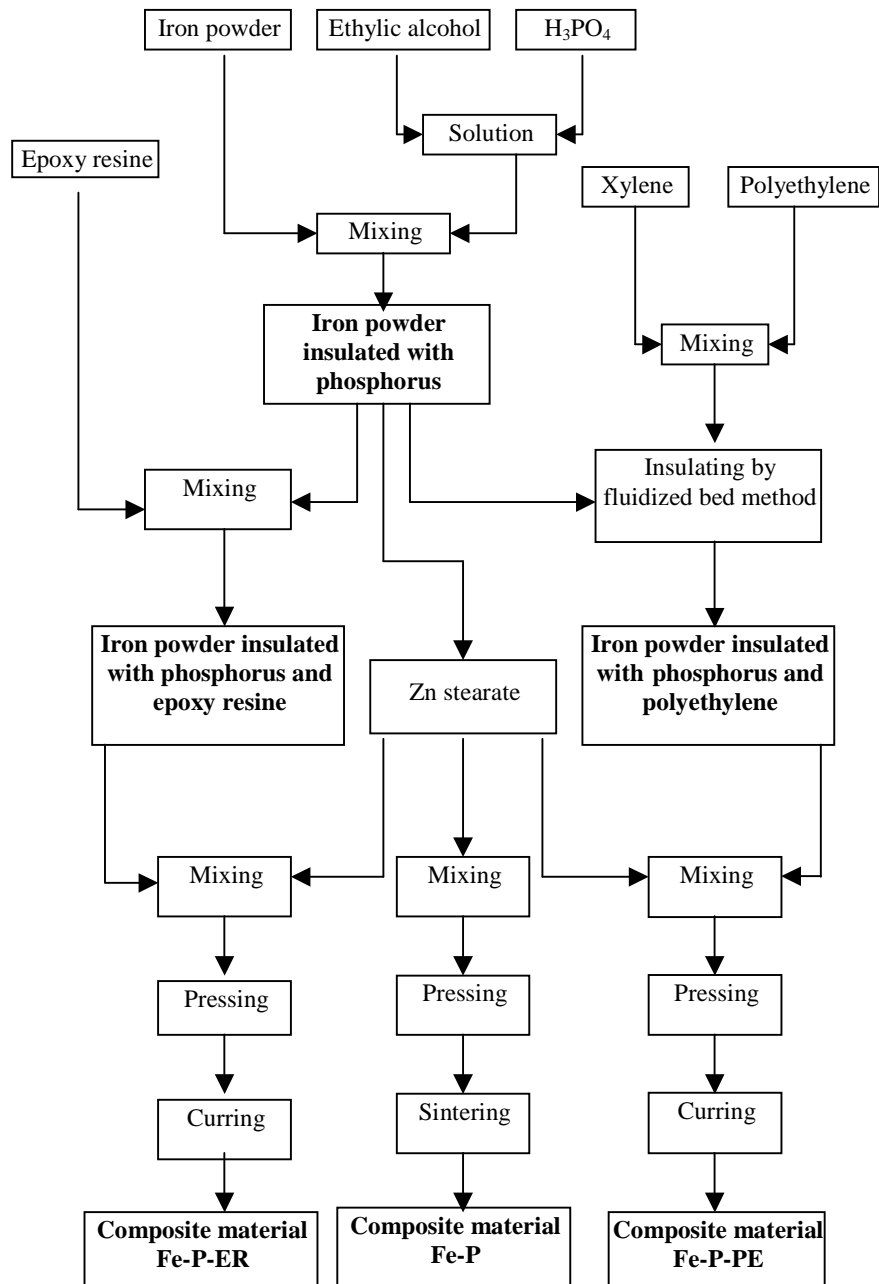


Fig. 1- The technological flow chart for obtaining the inorganic and inorganic/organic insulated composite materials

### 3. RESULTS AND DISCUSSIONS

All the elaborated materials were characterized from physico-mechanical (density, hardness, mechanical strength, magnetic properties) and microstructural point of view. The magnetic properties were determined from hysteresis curves drawn in d.c. on cylindrical samples of  $d=12\text{mm}$ .

In the following tables the results of these measurements for tested materials are presented. From the table 1 it can be seen the beneficial influence of the phosphorus insulation of iron particles on the mechanical (hardness and tensile strength) and magnetical (maximum induction, remanence, coercive force and permeability) properties of the sintered materials. This is due to the liquid phase sintering which appears at the grain boundaries leading to a better sinterability of the material and a decrease of pores content, as it can be seen from the microstructural aspect (figure 2).

*Table 1*

The main physico-mechanical characteristics of Fe and Fe-P materials from Fe powders  $<160\ \mu\text{m}$ , pressed at  $6\ \text{tf}/\text{cm}^2$  and sintered at  $1120^\circ\text{C}$ .

Material	Density $\text{g}/\text{cm}^3$	Hardness HV	Tensile strength $\text{N}/\text{mm}^2$	$B_{\text{max}}$ Gs	$B_r$ Gs	$H_c$ Oe	$\mu$ ( $H_c=2Oe$ ) Gs/Oe
DP 200	7.15	70.0	375.8	13 600	11 800	1.88	3 555
DP200+ 0.03%P	7.17	72.9	557.3	14 000	12 000	1.85	3 700
DP 200 HD	7.20	73.7	429.6	13 800	11 850	1.63	3 600
DP200HD+ 0.03%P	7.19	79	563.6	14 200	12 100	1.60	3 750

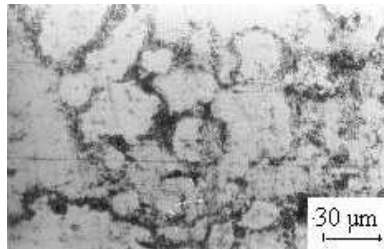


Fig. 2 - Microstructural aspect of the Fe-0.03%P sintered material

For the agglomerated materials the physico-mechanical characteristics are illustrated in the tables 2 and 3. From the presented values it can be observed the influence of the insulation method on these characteristics. Thus, the Fe-P-PE composite materials, which have a polyethylene layer around of each powder particle, present a better densification than the Fe-P-ER materials obtained by mechanical mixing. This is reflected by the values of mechanical strength and magnetic properties, especially maximum induction and permeability.

On the other hand, comparatively with the Fe-P sintered materials, the agglomerated materials have much lower values of the remanence, making them very appropriate for applications in a.c. of higher frequencies (500 – 1000 kHz). Figure 3 illustrates the form of

hysteresis curves for the two types of materials. It can be seen that small quantities of organic binder significantly modify this form.

Table 2.

The physico-mechanical characteristics of the composite materials from Fe-P powders agglomerated with 0.5% polyethylene or 0.5% epoxy resin, pressed at 6 tf/cm<sup>2</sup> and curried at 150°C

Powder type	Resine	Pressing		Curring		
		Density g/cm <sup>3</sup>	Tensile strength N/mm <sup>2</sup>	Density g/cm <sup>3</sup>	Tensile strength N/mm <sup>2</sup>	Hardness HV
DP200+ 0,03%P	ER	6.80	9.7	6.80	25.0	91.8
	PE	6.97	9.9	7.00	69.1	95.3
DP200HD+ 0,03%P	ER	6.95	11.3	6.98	25.0	92.9
	PE	6.98	12.2	7.00	69.2	94.6

Table 3.

The magnetical characteristics of the composite materials from Fe-P powders agglomerated with 0.5% polyethylene or 0.5% epoxy resin, pressed at 6 tf/cm<sup>2</sup> and curried at 150°C

Type of powder	Type of resine	B <sub>max</sub> (H <sub>max</sub> =100Oe) Gs	B <sub>r</sub> Gs	H <sub>c</sub> Oe	μ (H <sub>c</sub> =20 Oe) Gs/Oe
DP200+ 0.03%P	ER	9.800	1.100	5	160
	PE	11.900	1.700	5	290
DP200HD+ 0.03%P	ER	9.900	800	4.5	145
	PE	12.200	1.500	4	323

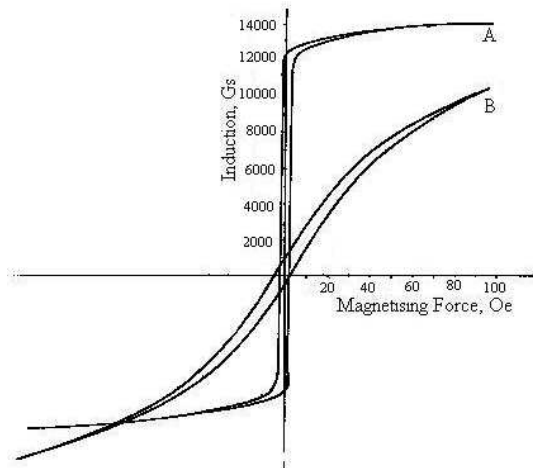


Fig. 3 - Hysteresis curves for: (A) Fe-0.03%P and (B) Fe-0.03%P-0.5%ER composite materials  
(DP 200 iron powder sort)

In the figure 4 the microstructural aspects of the two agglomerated composite materials Fe-0.03%P-0.5%PE and Fe-0.03%P-0.5%ER are presented. The uniform and homogenous structures assure the uniformity of magnetic properties..

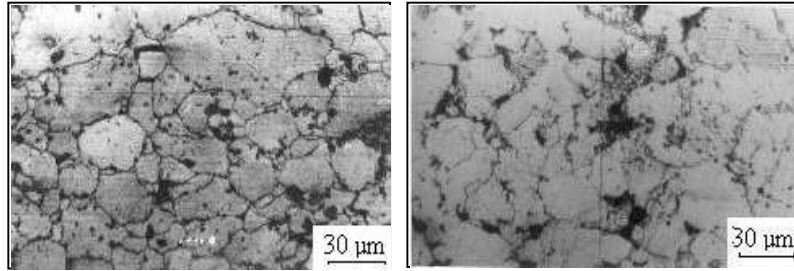


Fig. 4 - The microstructural aspect of: a) Fe-0.03%P-0.5%PE and b) Fe-0.03%P-0.5%ER agglomerated composite materials

#### 4. CONCLUSIONS

This paper presents the results of our experiments for elaboration of composite materials from inorganic and inorganic/organic insulated iron powders. The two Romanian iron powders used as raw materials presented quiet similar behaviour, lightly more performante for DP 200 HD sort.

Based on the measured magnetic characteristics, it can be concluded that the composite materials obtained from inorganic insulated iron powders, Fe-0.03%P, are adequate for utilisation in low frequencies a.c. applications, while the agglomerated materials from inorganic/organic insulated iron powders can be used both in medium frequencies, Fe-0.03%P-0.5%ER, and high frequencies, Fe-0.03%P-0.5%PE, a.c. applications.

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