

# Magnetic behaviour of Polyaniline/BaFe<sub>12</sub>O<sub>19</sub> composites synthesised by two different pathways

Tayssir BEN GHZAIEL<sup>a</sup>, Wadia DHAOUI<sup>a</sup>, Frédéric MAZALEYRAT<sup>b</sup>

<sup>a</sup> Laboratory of Applied Mineral Chemistry, Department of Chemistry, University Tunis El Manar, Faculty of Sciences, Campus 2092, Tunis, Tunisia

<sup>b</sup> SATIE, UMR 8029, ENS Cachan, France

**ABSTRACT – Polyaniline/BaFe<sub>12</sub>O<sub>19</sub> composites synthesised by two different polymerisation pathways: chemical polymerization and solid-state polymerization, were studied. The influence was explored by the type of polymerization synthesis on the microstructure and on the magnetic properties of the composites. The powders obtained by solid-state polymerization had better magnetic characteristics (for 70% Polyaniline/BaFe<sub>12</sub>O<sub>19</sub> composite, saturation magnetization 25.37 emu/g and coercivity field 1026 Oe) than those obtained by chemical polymerization.**

**KEY WORDS: Polyaniline, Barium ferrites, solid state polymerisation, magnetic measurements.**

## 1. Introduction

The hybrid materials composed of both organic and inorganic units, offer wide opportunities for new materials with increased functionalities relative to that achievable with organic and inorganic materials alone [1-4].

Recently, a great attention has been focused on studying of the synthesis of composites consisting of Polyaniline (Pani) with various inorganic nanomaterial such as oxide, metal and clay [5-7]. One of the most prevalent type of these composites is composed of materials containing Pani and barium ferrite (BaFe<sub>12</sub>O<sub>19</sub>) which have potential application in antennas [8], radar absorbers [9], tunable filters [10], electromagnetic shielding materials for low and high frequency [11]...

The present work was aimed at comparing the structural and magnetic properties of Polyaniline/BaFe<sub>12</sub>O<sub>19</sub> composites synthesised following chemical and solid state polymerization processes at room temperature.

## 2. Synthesis and characterization of Polyaniline/BaFe<sub>12</sub>O<sub>19</sub> composites

Polyaniline/BaFe<sub>12</sub>O<sub>19</sub> composites were prepared by solid-state polymerization (SP) of aniline chloride in the presence of 10, 30, 50, 70 wt% of BaFe<sub>12</sub>O<sub>19</sub> particles (with respect to aniline monomer) by ammonium peroxodisulfate in an agate mortar for 20 min. Likewise, Polyaniline/BaFe<sub>12</sub>O<sub>19</sub> composites were synthesized by chemical polymerization (CP) of aniline in hydrochloric acid with the same barium ferrite ratio and reagents as above.

The XRD Spectra of Polyaniline/BaFe<sub>12</sub>O<sub>19</sub> composites synthesised by the two methods are presented in Fig.1. The composites synthesised by chemical and solid-state polymerization contained the barium ferrite phase [12]. It was observed that the intensity of peaks for BaFe<sub>12</sub>O<sub>19</sub> increases with the increase of the amount of ferrite in the composite which is explained by the coating of Polyaniline of barium ferrite.

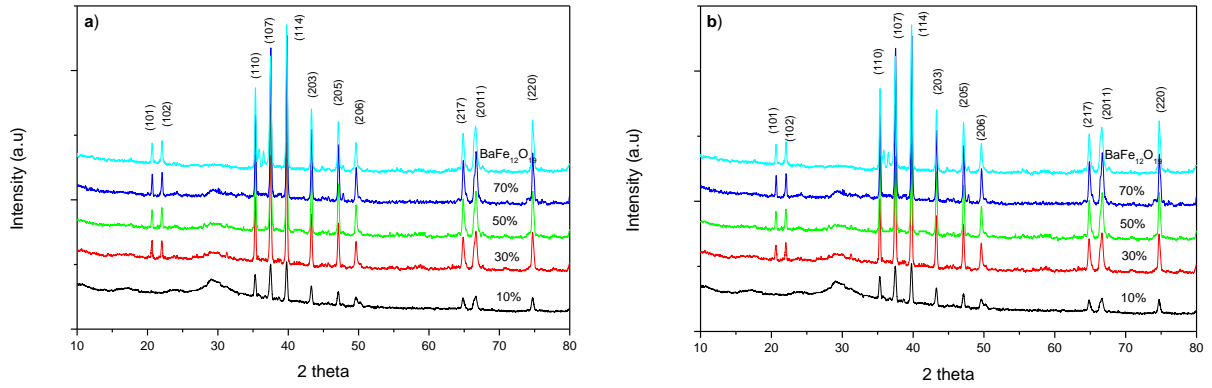


Fig.1 X-Ray diffraction patterns of Polyaniline/BaFe<sub>12</sub>O<sub>19</sub> composites obtained by:

a) Chemical polymerization and b) solid –state polymerization

Scanning electron microscopy was used to examine the morphology of different Polyaniline/BaFe<sub>12</sub>O<sub>19</sub> composites obtained by chemical polymerization and solid- state polymerization (Fig.2 and 3).SEM micrographs consist of aggregated particles due to the coating of BaFe<sub>12</sub>O<sub>19</sub> by Polyaniline in the two syntheses. In fact, with the increase of Polyaniline in the composites, it produces a bigger segregation of the magnetic grain.

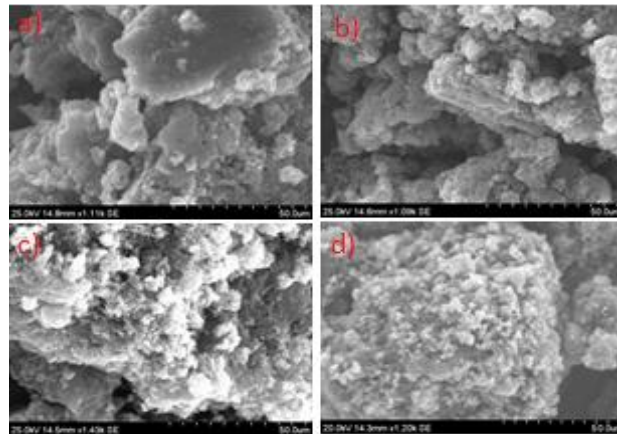


Fig. 2 SEM microphotographs of Polyaniline/BaFe<sub>12</sub>O<sub>19</sub> composites synthesised by chemical polymerization:

a) 10%; b) 30%, 50% and 70%

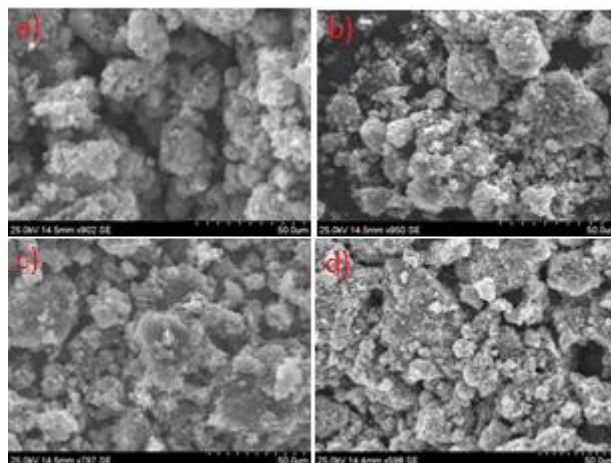


Fig. 3 SEM microphotographs of Polyaniline/BaFe<sub>12</sub>O<sub>19</sub> composites synthesised by solid-state polymerization:

a) 10%; b) 30%, 50% and 70%

The hysteresis loops of the composites at room temperature at a maximum applied field at 24 KOe are shown in Fig.4. The magnetization under applied magnetic field for the as-prepared Polyaniline/barium ferrite composites exhibits clear hysteresis behaviour. The analysis of the experimental data shows that the method synthesis of the composites has an effect on the magnetic properties.

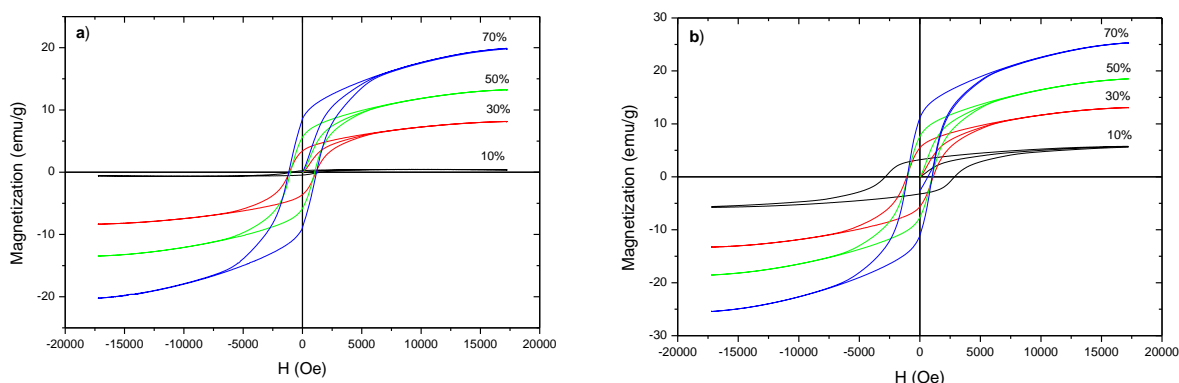


Fig. 4 Hysteresis loops of Polyaniline/BaFe<sub>12</sub>O<sub>19</sub> composites obtained by: a) Chemical polymerization and b) solid-state polymerization

The magnetic parameters, namely, the saturation magnetization ( $M_s$ ), the remanent magnetization ( $M_r$ ) and the coercivity field ( $H_c$ ) as obtained from the curves are listed in Table 1.

Table 1. Magnetic properties of Polyaniline/BaFe<sub>12</sub>O<sub>19</sub> composites prepared using chemical and solid-state polymerization

Sample	Synthesis pathway	$M_s$ (emu/g)	$M_r$ (emu/g)	$H_c$ (Oe)
10%	CP	0.55	0.35	1212
	SP	5.77	2.19	1083
30%	CP	8.25	3.5	1117
	SP	13.18	5.57	1094
50%	CP	13.36	5.76	1026
	SP	18.52	7.64	1010
70%	CP	20.06	8.72	1070
	SP	25.7	11.12	1026

The  $M_s$  values for all samples are lower than the theoretical one calculated for single-crystal barium hexaferrite, i.e. 72 emu/g, as reported by Shirk and Buessem [13]. This low saturation magnetization values can be explained by the interaction between Pani and magnetic nanoparticles, which contribute to magnetic anisotropy and consequently change the magnetic properties of nanoparticles [14]. The maximal saturation magnetization,  $M_s = 25.36$  emu/g, was measured for the composite of 70% of barium ferrite prepared by solid-state polymerization. As the amount of barium ferrite raised, the  $M_s$  of the two different syntheses of composites (prepared by chemical or solid-state polymerization) increased. The  $M_s$  values of the composites obtained by solid-state polymerization are higher than those obtained by chemical polymerization due to the effect of the synthesis method.

The coercive force of the composites has not any significant change. It is related to many factors such as microscopic structure, grain shape, components, magnetic anisotropy (magnetic crystal, stress, shape) and magnetic scalability, etc. In the polymerization process, Pani is deposited on the ferrite surface and crystallite boundary, which will reduce the magnetic surface anisotropy of ferrite particles.

### 3. Conclusion

Two types of polymerization methods were studied, namely, chemical and solid-state polymerization, in view of synthesizing Polyaniline/Barium ferrite composites. The particles have irregular shapes and are agglomerated. The powders produced by the solid-state polymerization exhibited a much higher degree of homogeneity than those obtained by chemical polymerization. The magnetic properties of the samples obtained by solid-state polymerization are better than those of the samples obtained by chemical polymerization; we believe that this is mainly due to the higher degree of homogeneity with respect to the amount of barium ferrite. It is thus demonstrated that the solid-state polymerization, which is less complicated and less expensive than the classical chemical polymerization, can be used to prepare powders of single-domain barium ferrite nanoparticles with good magnetic properties in view of possible applications.

## 4. References

- [1] G.R. PEDRO “Hybrid organic-inorganic materials-in search of synergic activity” *Adv. Mater.*13 (2001),p 163.
- [2] P.T. Nguyen, U. Rammelt, W. Plieth,“ Electrochemical impedance spectroscopy for characterization of coatings with intrinsically conducting polymers”, *Macromol.Symp.* 187 (2002), p929.
- [3] B. Garcia, A. Lamzoudi, F. Pillier, H. Nguyen Thi Le, C. Deslouis, Deslouis. “Oxide/Polypyrrole composite films for corrosion protection”, *J. of The Electrochem. Soc.* 149 (2002), p 560.
- [4] S. Tagmouti, A. Outzourhit, A. Oueriagli, M. Khaidar, M. Elyacoubi, R. Evrard, E.L. Ameziane, Electrical characteristics of W/P3MT/Pt diodes”, *Thin Solid Films* 379 (2000), p 272.
- [5] C. Danielle, S. Michelle, A. Ivo, and Z. Aldo, “Preparation and Characterization of Novel Hybrid Materials formed from (Ti,Sn)O<sub>2</sub> nanoparticles and Polyaniline”, *Chem. Mater.* 15 (2003), p 4658.
- [6] Y.Qiu and L. Gao,” Novel polyaniline/titanium nitride nanocomposite: controllable structures and electrical/electrochemical properties”, *J. Phys. Chem. B* 109, (2005), p 19762.
- [7] M. X. Wan and J. H. Fan, *J. Polym. Sci. Part A:*“Synthesis and ferromagnetic properties of composites of a water-soluble polyaniline copolymer containing iron oxide”,*Polym. Chem.* 36 (1998), p 2749
- [8] H. Nguyen Cong, V. de laGarzaGuadarrama, J.L. Gautier, P. Chartier, “Oxygen reduction on NixCo<sub>3</sub>-xO<sub>4</sub> spinel particles/polypyrrole composite electrodes: hydrogenperoxide formation”, *Electrochim. Acta* 48 (2003), p 2389.
- [9] H. Nguyen Cong, V. de la Garza Guadarrama, J.L. Gautier, P. Chartier,“ NixCo<sub>3</sub>-xO<sub>4</sub> mixed valence oxide nanoparticles/Polypyrrole composite electrodes for oxygen reduction”, *J. New Mater. Electrochem. Syst.* 5 (2002), p 35.
- [10] M.K. Song, Y.T. Kim, B.S. Kim, J. Kim, K. Char, H.W. Rhee, “Synthesis and characterization of soluble polypyrrole doped with alkyl benzenesulfonic acids”, *Synth. Met.*141 (2004), p 315.
- [11] D.A. Makeiff, T. Huber, “Microwave absorption by polyaniline-carbon nanotube composites”, *Synth.Met.*156 (2006), p 497.
- [12] M. Drogenik ,I. Ban,D. Makovec, A. Znidarsic, Z. Jaglicic, D. Lisjak, D Hanzel, “The hydrothermal synthesis of super-paramagnetic barium hexaferrite particles”, *Mater. Chem. Phys.* 127 (2011), p 415.
- [13] B. Shirk, W. Buessem, “Temperature dependence of Ms et K1 of BaFe<sub>12</sub>O<sub>19</sub> and SrFe<sub>12</sub>O<sub>19</sub>”, *J. Appl. Phys.* 40 (1969),p 1294.
- [14] P.Xu, X. Han, J. Jiang, X. Wang, X. Li, A. Wen, “Synthesis and characterization of novel coraloid Polyaniline/BaFe<sub>12</sub>O<sub>19</sub> nanocomposites”, *J. Phys. Chem. C*,1112007, p 12603.