Supplementary Information

Magnetic Liposomes based on Nickel Ferrite Nanoparticles for Biomedical Applications

Ana Rita O. Rodrigues,[a] I. T. Gomes,[a,b] Bernardo G. Almeida,[a] J. P. Araújo,[b] Elisabete M. S. Castanheira,[a] Paulo J. G. Coutinho[a]

[a] *Centro de Física (CFUM), Universidade do Minho, Campus de Gualtar, 4710-057 Braga, Portugal*

[b] *IFIMUP/IN - Instituto de Nanociência e Nanotecnologia, R. Campo Alegre, 4169-007 Porto, Portugal*

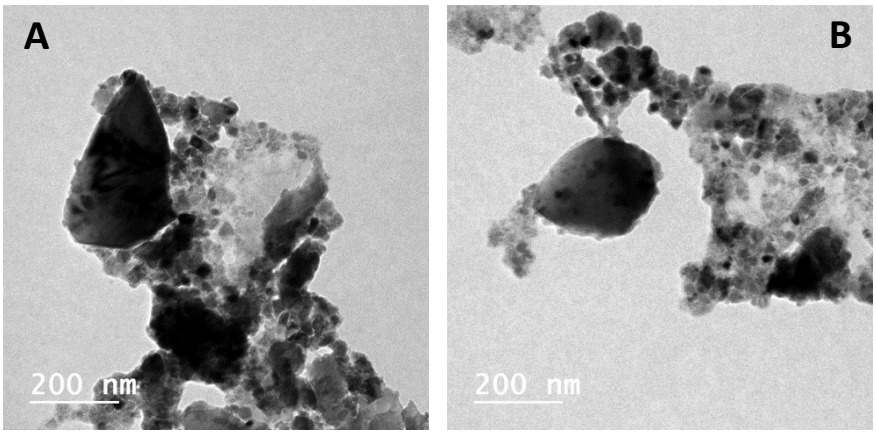

Fig. S1 TEM images of the synthesized $NiFe_2O_4$ NPs, containing NiO-rich particles (the larger ones).

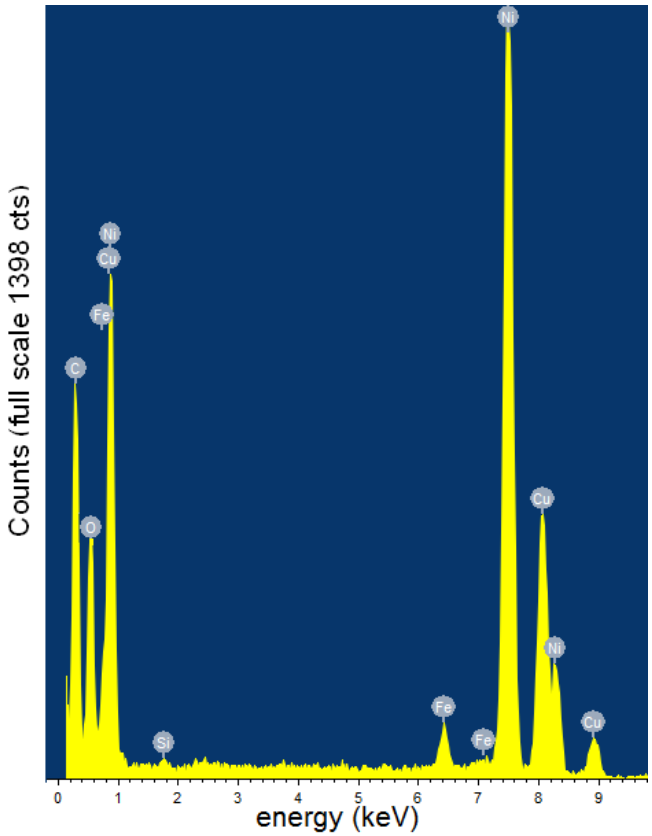

Fig. S2 EDAX elemental analysis of area corresponding to figure S1A.

Table S1. EDAX atomic percentages considering only Ni, Fe and O contributions and comparison with the values predicted for NiO NPs.

Element	EDAX Atomic (%)	Calculated atomic (%)
Ni	54.2	50.0
Fe	2.5	0
O	43.3	50.0

Details of Rietveld XRD analysis using FullProf Software

Bragg-Brentano (X-rays) geometry

March-Dollase model for preferred orientation with

G_1=0 and G_2=1 which corresponds to **no preferred orientation** (P_h=1)

Background defined by a 6 coefficient polynomial centered at 2Θ=40°

Profile function used was T-C-H Pseudo-Voigt function convoluted with asymmetry due to axial divergence, as formulated by van Laar and Yelon.[S1]

Instrumental Resolution Function obtained with a XRD pattern of a reference sample

U-inst	V-inst	W-inst	X-inst	Y-inst	Z-inst
-0.02522	0.00705	0.02608	0.00000	0.00000	0.00000

where U, V, W, X, Y and Z define the variation of Gaussian and Lorentzian widths of the peaks profile with diffraction angle.[S2,S3]

Zero point fixed to -0.0608 (obtained from the XRD pattern of a reference sample)

Displacement peak-shift parameter: SyCos = 0.0122 ± 0.0006 (Fit 1)
0.0113 ± 0.0007 (Fit 2)
0.0118 ± 0.0006 (Fit 3)

$$\Delta(2\theta) = - \text{SyCos} \times \text{Cos}(\theta)$$

Transparency peak-shift parameter: SySin = 0.020 ± 0.003 (Fit 1)
0.012 ± 0.003 (Fit 2)
0.023 ± 0.003 (Fit 3)

$$\Delta(2\theta) = \text{SySin} \times \text{Sin}(2\theta)$$

Phase 1: $NiFe_2O_4$

Number of Space group: 227
Hermann-Mauguin Symbol: F d -3 m
Hall Symbol: -F 4vw 2vw 3
Atom coordinates, occupation and isothermal factors (Bs)

Atom	x/a	y/b	z/b	Occ	B
Fe_T	0.125	0.125	0.125	1	-1.272±0.007
	0.125	0.125	0.125	1	0
	0.125	0.125	0.125	0.76±0.03	-1.282±0.007
Fe_Oh	0.5	0.5	0.5	1	-1.150±0.007
	0.5	0.5	0.5	1	0
	0.5	0.5	0.5	1.24±0.03	-1.132±0.007
Ni_Oh	0.5	0.5	0.5	1	-1.150±0.007
	0.5	0.5	0.5	1	0
	0.5	0.5	0.5	0.76±0.03	-1.132±0.007
O	0.2515±0.00003	0.2515±0.00003	0.2515±0.00003	4	-1.861±0.015
	0.2512±0.00003	0.2512±0.00003	0.2512±0.00003	4	0
	0.2517±0.00003	0.2517±0.00003	0.2517±0.00003	4	-1.88±0.015
Ni_T	0.125	0.125	0.125	0	-1.272±0.007
	0.125	0.125	0.125	0	0
	0.125	0.125	0.125	0.24±0.03	-1.282±0.007

Profile parameters

Overall scale factor: 0.0000001722 ± 0.0000000001 (Fit 1)
0.00000019887 ± 0.00000000009 (Fit 2)
0.00000001723 ± 0.0000000001 (Fit 3)

Cell parameters:

a=8.3350 ± 0.0001 (Fit 1)
8.3339 ± 0.0001 (Fit 2)
8.3352 ± 0.0001 (Fit 3)

b=8.3350 ± 0.0001 (Fit 1)
8.3339 ± 0.0001 (Fit 2)
8.3352 ± 0.0001 (Fit 3)

c=8.3350 ± 0.0001 (Fit 1)
8.3339 ± 0.0001 (Fit 2)
8.3352 ± 0.0001 (Fit 3)

Preferred orientation: $G_1 = 1$
$G_2 = 0$

X (strain enlargement) and Y (size enlargement) parameters:

X = 0
Y = 0.4263 ± 0.0003 (Fit 1)
0.4195 ± 0.0003 (Fit 2)
0.4258 ± 0.0003 (Fit 3)

Phase 2: $FeNaO_2$

Number of Space group: 33
Hermann-Mauguin Symbol: P n a 21
Hall Symbol: P 2c -2n
COD ID = 1008191

Atom coordinates, occupation and isothermal factors (Bs)

Atom	x/a	y/b	z/b	Occ	B
Fe	0.062	0.13	0	1	0.33 ± 0.03
	0.062	0.13	0	1	0
	0.062	0.13	0	1	0.37 ± 0.03
Na	0.416	0.151	0.489	1	-2.40 ± 0.03
	0.416	0.151	0.489	1	0
	0.416	0.151	0.489	1	-2.41 ± 0.03
O1	0.043	0.084	0.339	1	2.15 ± 0.08
	0.043	0.084	0.339	1	0
	0.043	0.084	0.339	1	2.26 ± 0.08
O2	0.38	0.153	0.927	1	-2.60 ± 0.05
	0.38	0.153	0.927	1	0
	0.38	0.153	0.927	1	-2.52 ± 0.05

Profile parameters

Overall scale factor: 0.0003173 ± 0.0000005 (Fit 1)
0.0003247 ± 0.0000004 (Fit 2)
0.0003172 ± 0.0000005 (Fit 3)

Cell parameters:

a= 5.61077 ± 0.00008 (Fit 1)
5.60964 ± 0.00009 (Fit 2)
5.61087 ± 0.00008 (Fit 3)

b= 7.1917 ± 0.0001 (Fit 1)
7.1909 ± 0.0001 (Fit 2)
7.1919 ± 0.0001 (Fit 3)

c= 5.37289 ± 0.00008 (Fit 1)
5.37188 ± 0.00009 (Fit 2)
5.37294 ± 0.00008 (Fit 3)

Preferred orientation: G_1=1
G_2= 0

X (strain enlargement) and Y (size enlargement) parameters:

X = 0
Y = 0.1500 ± 0.0003 (Fit 1)

0.1483 ± 0.0004 (Fit 2)
0.1497 ± 0.0003 (Fit 3)

Phase 3: NiO

Number of Space group: 225
Hermann-Mauguin Symbol: F m -3 m
Hall Symbol: -F 4 2 3
COD ID : 1010381

Atom coordinates, occupation and isothermal factors (Bs)

Atom	x/a	y/b	z/b	Occ	B
Ni	0	0	0	1	0.55 ± 0.02
	0	0	0	1	0
	0	0	0	1	0.61 ± 0.02
O	0.5	0.5	0.5	1	-1.66 ± 0.05
	0.5	0.5	0.5	1	0
	0.5	0.5	0.5	1	-1.68 ± 0.05

Profile parameters

Overall scale factor: 0.00000044 ± 0.00000001 (Fit 1)
0.000000450 ± 0.000000007 (Fit 2)
0.00000044 ± 0.00000001 (Fit 3)

Cell parameters:

a= 4.1783 ± 0.0006 (Fit 1)
4.1777 ± 0.0007 (Fit 2)
4.1784 ± 0.0006 (Fit 3)

b= 4.1783 ± 0.0006 (Fit 1)
4.1777 ± 0.0007 (Fit 2)
4.1784 ± 0.0006 (Fit 3)

c= 4.1783 ± 0.0006 (Fit 1)
4.1777 ± 0.0007 (Fit 2)
4.1784 ± 0.0006 (Fit 3)

Preferred orientation: $G_1 = 1$
$G_2 = 0$

X (strain enlargement) and Y (size enlargement) parameters:

X = 0
Y = 0.296 ± 0.008 (Fit 1)
0.321 ± 0.009 (Fit 2)
0.296 ± 0.008 (Fit 3)

Figures of merit

Fit 1

```
==>  RELIABILITY  FACTORS  WITH  ALL  NON-EXCLUDED  POINTS  FOR
PATTERN:  1

  => Cycle: 27 => MaxCycle:250
 => N-P+C:  3471
 =>  R-factors (not corrected for background) for Pattern:  1
 => Rp:   6.17      Rwp:   8.05      Rexp:     6.19 Chi2:   1.69
L.S. refinement
 => Conventional Rietveld R-factors for Pattern:  1
 => Rp:  11.7     Rwp:  13.0     Rexp:   10.00 Chi2:  1.69
 => Deviance:  0.589E+04     Dev*  :   1.694
 => DW-Stat.:    1.2601     DW-exp:     1.9117
 => N-sigma of the GoF:   28.699


==> RELIABILITY FACTORS FOR POINTS WITH BRAGG CONTRIBUTIONS FOR
PATTERN:  1

 => N-P+C:  3248
 =>  R-factors (not corrected for background) for Pattern:  1
 => Rp:   6.16      Rwp:   8.05      Rexp:     6.10 Chi2:   1.75
L.S. refinement
 => Conventional Rietveld R-factors for Pattern:  1
 => Rp:  11.3     Rwp:  12.8     Rexp:    9.68 Chi2:  1.75
 => Deviance:  0.569E+04     Dev*  :   1.750
 => DW-Stat.:    1.3033     DW-exp:     1.9093
 => N-sigma of the GoF:       30.026

 => Global user-weigthed Chi2 (Bragg contrib.):   1.80

     ----------------------------------------------------
     BRAGG R-Factors and weight fractions for Pattern #  1
     ----------------------------------------------------

 => Phase:  1     Nickel iron oxide 14174 Trevorite
 =>  Bragg  R-factor:     1.99           Vol:   579.048(  0.014)
Fract(%):   67.23( 0.27)
 => Rf-factor=   1.85                    ATZ:       1080076.500
Brindley:  1.0000

 => Phase:  2     IronIII sodium oxide - -beta
 =>  Bragg  R-factor:     9.20           Vol:   216.802(  0.006)
Fract(%):   19.03( 0.08)
 => Rf-factor=   4.77                   ATZ:            443.342
Brindley:  1.0000

 => Phase:  3     Nickel oxide
 =>  Bragg  R-factor:     4.44           Vol:     72.945(  0.019)
Fract(%):   13.74( 0.40)
 => Rf-factor=   2.50                    ATZ:         688429.688
Brindley:  1.0000
```

Fit 2

```
==>  RELIABILITY  FACTORS  WITH  ALL  NON-EXCLUDED  POINTS  FOR
PATTERN:  1

  => Cycle: 15 => MaxCycle:250
 => N-P+C:  3480
 =>  R-factors (not corrected for background) for Pattern:  1
 => Rp:   7.51      Rwp:   9.47      Rexp:     6.20 Chi2:   2.33
L.S. refinement
 => Conventional Rietveld R-factors for Pattern:  1
 => Rp:  14.4     Rwp:  15.4     Rexp:   10.05 Chi2:  2.33
 => Deviance:  0.814E+04     Dev*  :   2.337
 => DW-Stat.:    0.9106     DW-exp:     1.9065
 => N-sigma of the GoF:   55.568

 ==> RELIABILITY FACTORS FOR POINTS WITH BRAGG CONTRIBUTIONS FOR
PATTERN:  1

 => N-P+C:  3255
 =>  R-factors (not corrected for background) for Pattern:  1
 => Rp:   7.55      Rwp:   9.52      Rexp:     6.10 Chi2:   2.43
L.S. refinement
 => Conventional Rietveld R-factors for Pattern:  1
 => Rp:  14.0     Rwp:  15.2     Rexp:    9.73 Chi2:  2.43
 => Deviance:  0.794E+04     Dev*  :   2.436
 => DW-Stat.:    0.9332     DW-exp:     1.9037
 => N-sigma of the GoF:       57.806

 => Global user-weigthed Chi2 (Bragg contrib.):   2.49

     ------------------------------------------------------
     BRAGG R-Factors and weight fractions for Pattern #  1
     ------------------------------------------------------

 => Phase:  1     Nickel iron oxide 14174 Trevorite
 =>  Bragg  R-factor:     6.35           Vol:   578.819(  0.017)
Fract(%):   69.77( 0.15)
 =>  Rf-factor=   3.75                    ATZ:        1080076.500
Brindley:  1.0000

 => Phase:  2     IronIII sodium oxide - -beta
 =>  Bragg  R-factor:     11.7           Vol:   216.693(  0.006)
Fract(%):   17.51( 0.04)
 =>  Rf-factor=   7.03                   ATZ:             443.342
Brindley:  1.0000

 => Phase:  3     Nickel oxide
 =>  Bragg  R-factor:     8.43           Vol:     72.912(  0.021)
Fract(%):   12.72( 0.21)
 =>  Rf-factor=   3.62                    ATZ:         688429.688
Brindley:  1.0000
```

Fit 3

```
==>  RELIABILITY  FACTORS  WITH  ALL  NON-EXCLUDED  POINTS  FOR
PATTERN:  1

  => Cycle: 70 => MaxCycle:250
 => N-P+C:  3470
 =>  R-factors (not corrected for background) for Pattern:  1
 => Rp:   6.16      Rwp:   8.04      Rexp:     6.19 Chi2:   1.69
L.S. refinement
 => Conventional Rietveld R-factors for Pattern:  1
 => Rp:  11.7     Rwp:  13.0     Rexp:   10.01 Chi2:  1.69
 => Deviance:  0.588E+04     Dev*  :   1.693
 => DW-Stat.:    1.2627     DW-exp:     1.9123
 => N-sigma of the GoF:   28.545

 ==> RELIABILITY FACTORS FOR POINTS WITH BRAGG CONTRIBUTIONS FOR
PATTERN:  1

 => N-P+C:  3247
 =>  R-factors (not corrected for background) for Pattern:  1
 => Rp:   6.15      Rwp:   8.04      Rexp:     6.09 Chi2:   1.74
L.S. refinement
 => Conventional Rietveld R-factors for Pattern:  1
 => Rp:  11.3     Rwp:  12.8     Rexp:    9.68 Chi2:  1.74
 => Deviance:  0.568E+04     Dev*  :   1.749
 => DW-Stat.:    1.3060     DW-exp:     1.9099
 => N-sigma of the GoF:       29.868

 => Global user-weigthed Chi2 (Bragg contrib.):   1.80

     ------------------------------------------------------
     BRAGG R-Factors and weight fractions for Pattern #  1
     ------------------------------------------------------

 => Phase:  1     Nickel iron oxide 14174 Trevorite
 =>  Bragg  R-factor:     2.03           Vol:   579.089(  0.015)
Fract(%):   67.18( 0.29)
 =>  Rf-factor=   1.85                   ATZ:        1080076.500
Brindley:  1.0000

 => Phase:  2     IronIII sodium oxide - -beta
 =>  Bragg  R-factor:     9.22           Vol:   216.814(  0.006)
Fract(%):   19.00( 0.09)
 =>  Rf-factor=   4.80                  ATZ:             443.342
Brindley:  1.0000

 => Phase:  3     Nickel oxide
 =>  Bragg  R-factor:     4.50           Vol:     72.954(  0.020)
Fract(%):   13.82( 0.43)
 =>  Rf-factor=   2.52                   ATZ:         688429.688
Brindley:  1.0000
```

Microstructural analysis was performed by Fullprof software using the broadening of the XRD peaks with an implementation previously described.[S2,S3]

References

S1. B. van Laar, W. B. Yelon, The peak in neutron powder diffraction, *J. Appl. Cryst.*, 1984, **17,** 47-54.

S2. J. Rodríguez-Carvajal, T. Roisnel, Line Broadening analysis Using FullProf: Determination of Microstructural Properties, *Materials Science Forum*, 2004, **443-444**, 123-126.

S3. J. Rodríguez-Carvajal, *Study of Micro-Structural Effects by Powder Diffraction Using the Program FULLPROF*, IV Congreso de la Sociedad Mexicana de Cristalografía, Morelia, Michoacan, México, Libro de Resúmenes, 2003, 66-75.
http://sdpd.univ-lemans.fr/DU-SDPD/pdf/Microstructural_effects.pdf