Supplementary Material

Anti-Bacterial Iron Oxide Magnetic Nanoparticles based on Orange Peel Extract

David Giancarlo García Vélez 1, Cristina C. Garzón-Romero3,Mateo Alejandro Salazar Salazar3,Karina J. Lagos1, Kleber Orlando Campaña Cruz1, Alesis Debut5, Karla Vizuete5, Miryan Rosita Rivera 3, Dario Niebieskikwiat4,Maria J. Benitez2, María Paulina Romero Obando1\*.

1Department of Materials, Escuela Politécnica Nacional (EPN), Quito, Ecuador

2Departmento de Física, Escuela Politécnica Nacional (EPN), Quito, Ecuador

3Laboratorio de Investigación en Citogenética y Biomoléculas de Anfibios (LICBA), Centro de Investigación para la Salud en América Latina (CISeAL), Facultad de Ciencias Exactas y Naturales, Pontificia Universidad Católica del Ecuador (PUCE), Quito, Ecuador

4Department of Physics, Colegio de Ciencias e Ingenierías, Universidad San Francisco de Quito, Quito, Ecuador.

5 Centro de Nanociencia y Nanotecnología, Universidad de Las Fuerzas Armadas ESPE, Sangolquí 171103, Ecuador

**\* Correspondence:**María Paulina Romero Obando  
maria.romerom@epn.edu.ec

# Supplementary Figures



**Figure S1.** a) Initial and final pH measured in the green synthesis, b) initial and final pH measured in the microwave synthesis, c) initial and final pH measured in the coprecipitation synthesis.



**Figure S2**. SEM micrographs of the samples a) 0GS-MNPs-Fe, b) 50GS-MNPs-Fe, c) 75GS-MNPs-Fe and d) 100CO-MNPs-Fe. Filters used: Smooth, Gaussian blur (sigma radius: 1.0) and Median (Radius 0.8 pixels).



**Figure S3a.** Indexed diffractograms of the samples; a) 0GS-MNPs-Fe, b) 25GS-MNPs-Fe, c) 50GS-MNPs-Fe, d) 75GS-MNPs-Fe and e) 100GS-MNPs-Fe



**Figure S3b**. Indexed diffractograms of the samples; a) 25MW-MNPs-Fe, b) 50MW-MNPs-Fe and c) 75MW-MNPs-Fe.



**Figure S3c.** Indexed diffractograms of the samples; a) 25CO-MNPs-Fe, b) 50CO-MNPs-Fe, c) 75CO-MNPs-Fe and d) 100CO-MNPs-Fe

Diagrama, Esquemático

Descripción generada automáticamente

**Figure S4**. EDS spectra of the samples a) 0GS-MNPs-Fe, b) 25GS-MNPs-Fe, and c) 75GS-MNPs-Fe.



**Figure S5.** Full Raman spectra (100-2000 cm-1) of the samples; a) 100CO-MNPs-Fe, b) 75GS-MNPs-Fe, c) 50GS-MNPs-Fe, d) 25GS-MNPs-Fe and e) 0GS-MNPs-Fe



**Figure S6**. ZFC/FC curve of the samples a) 50GS-MNPs-Fe, b) 50CO-MNPs-Fe and c) 50MW-MNPs-Fe



**Figure S7.** Size distribution of the MNPs-Fe corresponding to the samples; a) 50Gs-MNPs-Fe, b) 100CO-MNPs-Fe and c) 50MW-MNPs-Fe

# Supplementary Tables

**Table S1.** Yield by weight of MNPS-Fe obtained by GS, MW and CO

|  |  |  |
| --- | --- | --- |
| **Samples** | **Average weight (mg)** | |
| 0GS-MNPs-Fe | 8.97 | ± 2.32 |
| 10GS-MNPs-Fe | 13.43 | ± 5.26 |
| 25GS-MNPs-Fe | 25.93 | ± 6.23 |
| 50GS-MNPs-Fe | 88.13 | ± 13.33 |
| 75GS-MNPs-Fe | 95.03 | ± 9.85 |
| 100GS-MNPs-Fe | 84.20 | ± 3.10 |
| 10CO-MNPs-Fe | 79.63 | ± 6.20 |
| 25CO-MNPs-Fe | 79.73 | ± 5.61 |
| 50CO-MNPs-Fe | 72.33 | ± 8.96 |
| 75CO-MNPs-Fe | 68.67 | ± 5.70 |
| 100CO-MNPs-Fe | 64.73 | ± 8.90 |
| 10MW-MNPs-Fe | 79.30 | ± 3.87 |
| 25MW-MNPs-Fe | 79.97 | ± 6.85 |
| 50MW-MNPs-Fe | 80.10 | ± 4.61 |
| 75MW-MNPs-Fe | 85.87 | ± 5.56 |

**Table S2.** Average roughness, obtained from the AFM topographies, for the samples obtained by GS.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Average roughness - Ra (pm)** | | | | | |
| **ID** | **0GS-MNPs-Fe** | **25GS-MNPs-Fe** | **50GS-MNPs-Fe** | **75GS-MNPs-Fe** | **100GS-MNPs-Fe** |
| 1 | 153 | 186 | 122 | 139 | 81 |
| 2 | 74 | 181 | 78 | 70 | 42 |
| 3 | 118 | 105 | 61 | 116 | 69 |
| 4 | 93 | 107 | 63 | 50 | 53 |
| 5 | 110 | 66 | 90 | 56 | 59 |
| 6 | 75 | 131 | 102 | 94 | 42 |
| 7 | 73 | 119 | 51 | 61 | 62 |
| 8 | 86 | 143 | 102 | 57 | 61 |
| 9 | 117 | 183 | 71 | 51 | 46 |
| 10 | 68 | 132 | 45 | 67 | 47 |
| 11 | 62 | 113 | 96 | 71 | 50 |
| 12 | 172 | 97 | 103 | 86 | 66 |
| 13 | 105 | 115 | 66 | 84 | 48 |
| 14 | 166 | 75 | 74 | 52 | 47 |
| 15 | 78 | 85 | 64 | 63 | 63 |
| 16 | 183 | 146 | 77 | 61 | 54 |
| 17 | 86 | 117 | 54 | 92 | 69 |
| 18 | 65 | 132 | 56 | 52 | 49 |
| 19 | 101 | 108 | 72 | 65 | 74 |
| 20 | 78 | 134 | 112 | 99 | 75 |
| **Average** | 103 | 124 | 78 | 74 | 58 |
| **DS** | 38 | 33 | 22 | 24 | 12 |

**Table S3a.** Active Raman bands of functional groups found in the Raman spectra of the 0GS-MNPs-Fe, 25GS-MNPs-Fe, 50GS-MNPs-Fe, 75GS-MNPs-Fe and 100Co-MNPs-Fe samples

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Active Raman bands of functional groups (cm-1) - HORIBA** | **Raman bands in samples (cm-1)** | | | | |
| **0GS-MNPs-Fe** | **25GS-MNPs-Fe** | **50GS-MNPs-Fe** | **75GS-MNPs-Fe** | **100CO-MNPs-Fe** |
| 550-800, (C-Cl) (strong) | 564,6  (strong) | - | - | - | - |
| 600-1300, C-C) aliphatic (medium)  630-790, (C-S) aliphatic (strong)  800-970,(O-C-O) (medium) | 628,4  (strong) | - | - | - | - |
| 645,7  (strong) | - | 710  (strong) | - | - |
| 798,2  (medium) | - | 854  (medium) | - | - |
| 600-1300, (C-C) aliphatic (medium)  800-970, (O-C-O) (medium)  1000, (C-C) aromatic (medium) | 952  (medium) | - | 950-1015  (medium) | 1004  (weak) | - |
| 600-1300, C-C) aliphatic (medium)  1080-1100, C-S) aromatic (strong) | 1100  (strong) | - | 1131  (medium) | - | - |
| 600-1300, C-C) aliphatic (medium)  1060-1150, (C-O-C) (weak)  1000-1250, C=S) (strong) | 1172  (strong) | 1162  (weak) | 1165  (medium) | 1160  (weak) | - |
| 600-1300, C-C) aliphatic (medium)  1000-1250, C=S) (strong) | 1274  (strong) | 1307  (medium) | 1300  (medium) | 1305  (media) | - |
| 1400-1470, (CH3),(CH2) (medium)  1450,1500, C-C) aromatic (medium) | 1486  (medium) | 1479  (medium) | 1486  (medium) | 1477  (medium) | - |
| ~1600, (H2O) (weak wide)  1500-1900, C=C) (strong) | 1604  (strong) | 1598  (medium) | 1591  (strong) | 1592  (medium) | 1608  (weak) |
| 1500-1900, C=C) (strong)  1680-1820, C=O) (medium) | 1676  (strong) | - | 1696  (medium) | - | - |
| 1500-1900, C=C) (strong)  1680-1820, C=O) (medium) | 1808  (strong) | - | 1805  (medium) | - | - |
| 1500-1900, C=C) (strong) | 1904  (strong) | - | 1905  (medium) | - | - |
| Stretching symmetrical (), asymmetric (), symmetrical bending (), asymmetric () | | | | | |

**Table S3b.** Active bands found in the samples 0GS-MNPs-Fe, 25GS-MNPs-Fe, 50GS-MNPs-Fe, 75GS-MNPs-Fe and 100CO-MNPs-Fe by FT-IR

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **FT-IR Bands, Functional Group** | **Bands obtained in the FT-IR spectra / sample** | | | | |
| **0GS-MNPs-Fe** | **25GS-MNPs-Fe** | **50GS-MNPs-Fe** | **75GS-MNPs-Fe** | **100CO-MNPs-Fe** |
| (3700-3584) (O-H), alcohols | 3866  (weak) | 3886  (weak) | 3800  (weak) | --- | --- |
| (3700-3584) (O-H), alcohols | 3662  (weak) | 3706  (weak) | 3700  (weak) | 3690  (weak) | 3650  (weak) |
| (3000-2840), (C-H) alkanes (CH3)  (~2872), (C-H), (CH3)  (~2853), (C-H), (CH2) | --- | --- | 2856  (weak) | 2862  (weak) | --- |
| (2600-2550), (S-H), compounds S | 2576  (weak) | 2586  (weak) | 2532  (medium) | --- | --- |
| (2700-2250), (N-H), amine salts | 2336  (weak) | 2334  (weak) | 2350  (medium) | 2348  (weak) | 2354  (weak) |
| (2000-1900), (C=C=C), alkenes  (1870-1540), (C=O) ketones  (~ 1640), (H2O) | 1960  (weak) | 1932  (weak) | 1886  (medium) | --- | 1776  (weak) |
| (1670-1600), (C=C), (lineal, cíclicos)  (1600-1585), (C-C), (aromatic)  (1870-1540), (C=O), ketones  (1710-1685), (C=O), aldehydes  (~ 1640), (H2O) | 1698  (medium) | 1580  (medium) | 1600  (medium) | 1638  (weak) | --- |
| (1350-1150), (C-H), (CH2)  (1300-1000), (C-H), (aromatic)  (1260-1000), (C-O), alcohols  (1300-1000), (C-C-C),(C-C(=O)), ketones  (1070-1030), (S=O), compounds S  (1096-1089), (C-Cl), halogens | 1180  (medium) | 1156  (medium) | 1120  (medium) | 1158  (medium) | --- |
| (850-550), (C-Cl), halogens  (~850), (=CH2), alkenes  (900-675), (C-H), aromatic | 870  (medium) | 868  (medium) | 822  (medium) | 828  (medium) | --- |
| (850-550), (C-Cl), halógens  (700-450), (Fe-O) | 578 | 546 | 640 | 578 | --- |
| (700-450), (Fe-O) | 508 | 502 | 536 | 520 | 550 |
| Stretching symmetrical (), asymmetrical (), symmetrical bending (), asymmetrical (), Scissoring (), Rocking (), Wagging (), Twisting (). | | | | | |