

Nano Iron Oxide with the Neural-Network Morphology

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To improve network-functioning, an arc discharge method was developed for the synthesis of nano iron oxide with “neural-network” morphology. Iron wires with diameters of 0.01-0.05 cm were subjected to currents of 50-200 A, until explosions occurred in the open air. The XRD and RAMAN spectra of the as-prepared-products indicate formation of nano-Fe₂O₃ (tetragonal and monoclinic) crystals. Their SEM images show fabrication of nano iron oxide with three different morphologies: spheres, chains, and a “neural-network” biological form. While the latter is unprecedented, our fabrications of nano iron oxide with both sphere and chain morphologies are reproductions of previously reported results. The sphere shaped nanoparticles show a uniform distribution with sizes in the range of 50-250 nm. The specifications of the chain nano products appear consistent with those reported.

Keywords: Nano, Iron oxide, Morphology, Neural network, Arc discharge

INTRODUCTION

Nanoparticles have attracted considerable attention for their novel physical and chemical properties [1-5]. Many techniques are developed to prepare metal nanoparticles including: Gas-phase chemical reaction [6], spray pyrolysis [7], water-heating reaction [8], laser ablation [9], flame processing [10], vapor deposition [11], microwave plasma synthesis [12], sol-gel method [13], anodic arc plasma [14], and the exploding wire in dense media [15].

Among nanoparticles, nano iron oxides show potential applications in high-density recording media [16]. This is in addition to their usage in medicine, biomedicine, geochemistry, mineralogical processes, diagnostics, pigments, catalysts, gas sensors, *etc.* [17-21]. Interaction of functionalized super-paramagnetic iron oxide nanoparticles with brain structures is recently reported [22]. The characterization of the modified nano sized magnetic iron

oxide particles by various techniques is described [23]. Recently, the possibility of human nervous system to exchange information with electronic devices is studied [24]. Hence, cell patterning is of significance in order to study the relationship between network-function and form [25], as well as to learn about networks repair and brain activity [26]. A new approach is reported here for the formation of engineered, electrically viable neuronal networks consisting of ganglion-like clusters of neurons. The clusters are formed as the cells migrate on low affinity substrate towards high affinity, lithographically defined as carbon nanotube templates onto which they adhere and assemble [27]. In this work a modified arc discharge method was used to synthesize a compatible nano iron oxide neural-network.

EXPERIMENTAL

A modified arc discharge method was selected from among many others [6-15]. Synthesis was carried out in the open air, requiring very short times (0.01-1 s). Currents of 50-

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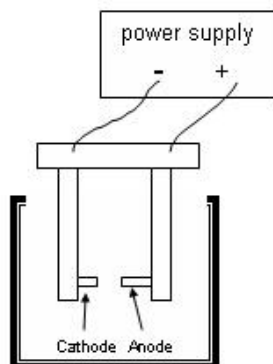


Fig. 1. Schematic representation of the arc discharge equipment.

200 A were passed through thin iron wires with different diameters (0.01-0.05 cm) attached to a wire guide (Fig. 1). The nanostructures, produced in high yields, were characterized by a Holland Philips Xpert X-ray powder diffraction (XRD) diffractometer using monochromatic high-intensity Cu K α radiation ($\lambda = 0.154056$ nm), at a scanning speed of $2^\circ/\text{min}$ from 10° to 70° (2θ). The particle size and morphology shape were investigated by scanning electron microscopy (SEM) of a Holland Philips XL30 microscope with an accelerating voltage of 25 kV. Micro Raman spectroscopy was performed at room temperature using a thermo Nicolet Almega Dispersive Raman Spectrometer equipped with a second harmonic 532 nm laser line in a back scattering configuration. The slit width was set to 20 micrometer and Raman spectrum resolution of about 4 cm^{-1} .

RESULTS AND DISCUSSION

To improve network-functioning requires a compatible form of super-paramagnetic recording media with “neural network” morphology. This was prepared from nano iron oxide, through a modified arc method, in the open air (Fig. 2). Sphere, chain, and “neural network” shaped iron oxide nanoparticles were produced in high yields (Fig. 2a, b and c, respectively). The times required for the formation of nanoparticles appear proportional to the square of current (I^2) and the logarithm of the length of the wire (L) over its thickness (D) (Eq. 1) [15].

$$F = I^2 \log(L/D) \quad (1)$$

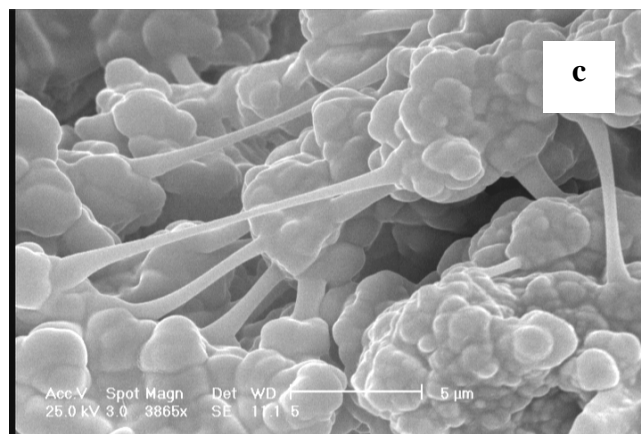
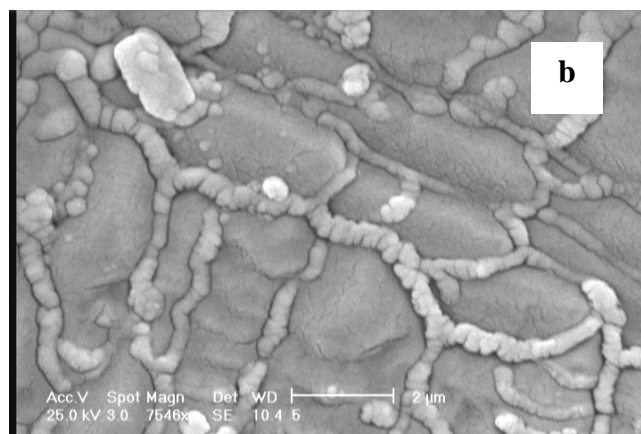
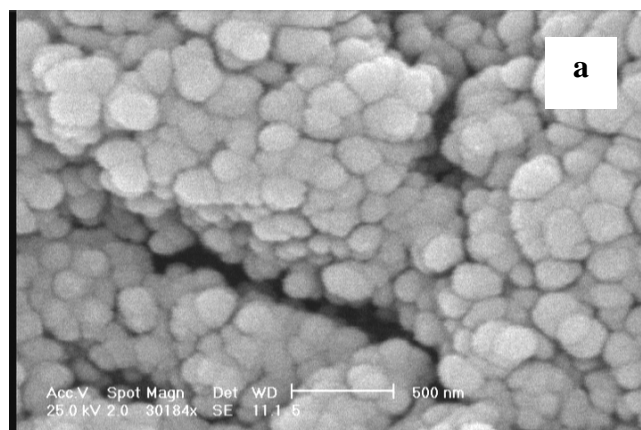


Fig. 2. Scanning electron microscopy (SEM) of (a) Sphere, (b) Chain, and (c) Neural network shapes of the iron oxide Nanoparticle.

Several particles were investigated to infer particle sizes. A typical particle was chosen for the size measurement by drawing a line across it, and the diameter measured. The SEM image of sphere shaped nanoparticles shows a uniform distribution of the nano sphere clusters with sizes in the range of 50-250 nm, which are formed at 100 A (Fig. 2a). Such a wide range is not unprecedented [28-32]. Similarly, the SEM image of chain type nanoparticles, formed under the above conditions, is not unique (Fig. 2b) [33].

This work is distinct from previous reports [27] for fabricating a new morphology of nano iron oxide, with a biological shape, which appears both unique and unprecedented (Fig. 2c). In order to obtain the desired morphology, very careful attention was focused on the optimization of current, as well as the length and thickness of the iron rods. Increasing the current and the diameter of iron wires translated into the increases in the size of Fe_2O_3 nanoparticles [1]. The optimum condition to reach the neural network morphology was the application of 100 A on iron wires with 0.03 cm diameters.

The XRD scanning from 10° - 70° shows the lines (150) and (315), at $2\theta = 44.930^\circ$ and 61.010° , respectively for Fe_2O_3 (monoclinic) and lines (204), (206), (109), (313), (0012), (1012), (2212), (0015), and (2114) at $2\theta = 25.275^\circ$, 30.355° , 33.415° , 35.695° , 43.265° , 44.930° , 53.590° , 54.365° and 57.210° , respectively for Fe_2O_3 (tetragonal) (Fig. 3). The observation of a diffraction peak for the iron oxide nanoparticles indicates that these are tetragonal and monoclinic. However, the predominance of the (150) and (315) line in XRD indicates reorientation of the Fe_2O_3 (monoclinic) nanoparticle preferentially in two directions as against the random orientation of grains in the bulk material. For Fe_2O_3 (tetragonal) nanoparticles have the predominance of the (204), (206), (109), (313), (0012), (1012), (2212), (0015), and (2114) line in XRD indicates reorientation of the nanoparticle preferentially in nine directions. From the full width at half maximum, the average crystalline size can be estimated with the (315), and (0012) diffraction peaks in the XRD spectra according to the Scherrer formula $d = KA/(B\cos\theta)$ [34]. d is the crystallite size; $K = 0.89$, which is the Scherrer approximate constant related to the shape and index (hkl) of the crystals; A is the wavelength of the X-ray (Cu $K\alpha$, 0.154 nm); θ is the diffraction angle; and B is the

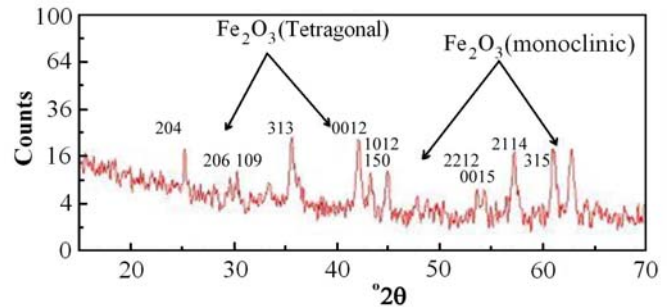


Fig. 3. XRD pattern of Fe_2O_3 nanoparticles.

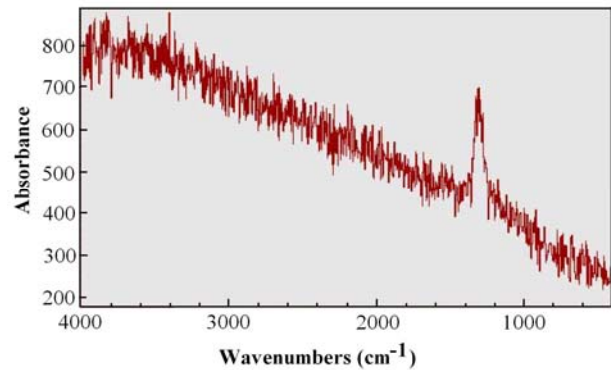


Fig. 4. Raman spectrum of Fe_2O_3 nanoparticles.

corrected half-width of the diffraction peak (in radians) given by $B^2 = B_m^2 - B_s^2$; where B_m , is the measured half-width and B_s , is the half-width of a standard sample with a known crystal size greater than 100 nm. The effect of geometric (instrumental) broadening on the reflection peaks was calibrated. The calculated average crystallite sizes are around 33.5 nm for Fe_2O_3 (monoclinic) nanoparticle and 24.7 nm for Fe_2O_3 (tetragonal). These are consistent with the average particle diameters obtained from the SEM images. Moreover, Raman absorptions appear consistent with those of Fe_2O_3 nanoparticles (Fig. 4).

CONCLUSIONS

To improve network functioning requires a compatible form which is prepared from nano iron oxide, through a modified arc method, in the open air. The SEM images, XRD and RAMAN spectra show formation of nano- Fe_2O_3 (tetragonal & monoclinic) crystals.

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