International Journal of Computational and Experimental Science and ENgineering (IJCESEN)
Vol. 6-No.3 (2020) pp. 173-175
http://dergipark.org.tr/en/pub/ijcesen

ISSN: 2149-9144

Research Article

Magnetic Nanoparticles Synthesized By Green Chemistry and Investigation of Its Application in the Material Industry

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Article Info:

DOI: 10.22399/ijcesen.733423
Received : 07 May 2020
Accepted : 15 November 2020

Keywords

Green tea
Iron nanoparticles
Non Destructive Testing (NDT)

Abstract:

In the past decade, the use of plants for synthesis of nanoparticles has been intensively studied. Various plants have been employed to synthesize nanomaterials in all fields of science and industry. Particularly, magnetic nanoparticles (MNPs) are emerging as new subjects of research for their application in different fields of industry. Conventional techniques for nanoparticles synthesis require hazardous chemicals that have many risks due to their toxicity and serious concerns for environment and health. On the other hand, plant-mediated synthesis of nanoparticles seems to be having an effective way in developing inexpensive, nontoxic and eco-friendly materials.
The aim of this study is to examine the use of iron magnetic nanoparticles synthesized by green chemistry as a liquid penetrant for investigating potential of detection micro surface flaws on industrial materials. For this purpose, green tea extract (GTE) was used as a reduction agent for synthesis of iron (Fe_3O_4) nanoparticles. GTE has high concentration phenolic and carbonyl groups of polyphenol compounds can be responsible for the formation Fe_3O_4 nanoparticles. The synthesized nanoparticles (Fe_3O_4-GTE NPs) were characterized by X-ray Photoelectron Spectroscopy (XPS), Transmission Electron Microscopy (SEM) and Vibrating-Sample Magnetometer (VSM). The experimental results showed that plant-mediated iron nanoparticles have great potential as a new penetrant for fluorescent penetrant inspection (FPI) applications.

1. Introduction

Recent advancements of green nanotechnology have been changing most of the existing processes and products. This transformation is making a remarkable impact on diverse science, engineering, industry, and commercial sectors. The unique physical and chemical properties of the nanoparticles can lead to significant enhancements in conductivity, mechanical strength, and optical sensitivity. Their unique properties are enables to use of advanced materials and sensors for engineering applications in industry. The use of metal nanoparticles and nanocomposites in various applications such as electronics, biology, biomedical applications, and material science depends on its features such as size, shape and composition [1-3].

Nondestructive testing (NDT) is the process of inspecting and evaluating parts or components for discontinuities, or differences in characteristics without destroying the serviceability of the part or system. In other words, when the inspection is finished, the parts can still be reused. Magnetic particle inspection (MPI) is a common NDT technique for detecting flaws on the surface or subsurface of the ferromagnetism material. MPI is an industry standard used extensively from raw to processed materials. Inspection of surface and subsurface crack using magnetic particle has been widely used in the field of railroad, metallurgy, automobile and aircraft [4]. It is used for the detection of surface defects to evaluated according to predefined quality standards. This method aims at verifying the structure of a part without any damage [5]. The increase of small and micro scale manufacturing has increased the need for advanced NDT techniques. From this perspective, aim of our study is to develop herbal synthesized magnetic nanoparticle penetrant which can be used in NDT. Thus, the use of plant-based nanoparticle applications particularly will be increased its application in the field of NDT.

2. Materials and methods

2.1 Magnetic Nanoparticles Synthesized by Green Chemistry

The Green tea leaves were washed with double-distilled water. Dry tea residue was added to a solution of distilled water, and $FeCl_3 \cdot 6H_2O$ was dissolved in it by stirring for 4 h and then left overnight. By filtration, $FeCl_3 \cdot 6H_2O$-treated tea residue was obtained and was dried in an oven. Then, in a muffle furnace, it was heated for 6 h at 450 °C, washed, and dried. The resultant product was a crystal structure of Fe_3O_4 (magnetite) [6]. FITC-labeled Fe_3O_4-GTE NPs as penetrant was applied to the surface of the test material. The synthesis of Fe_3O_4-GTE NPs was performed as shown in Figure 1.

Figure 1. *Synthesis of Fe_3O_4-GTE NPs.*

2.2 Magnetic Particle Test Bar

The Magnaflux Magnetic Particle Test Bar is a test piece with artificial flaws, to establish field direction and determine adequate current levels using AC or DC currents in wet horizontal magnetic particle bench units. The bar contains both fine and coarse defects, surface and sub-surface defects and longitudinal and transverse indications [7]. Magnetic Particle Test Bar specifications are given in Table 1.

2.3 Application of Penetrant on Magnetic Particle Test Bar

FITC-labeled Fe_3O_4-GTE NPs as penetrant was

Table 1. *Specifications of the magnetic test bar.*

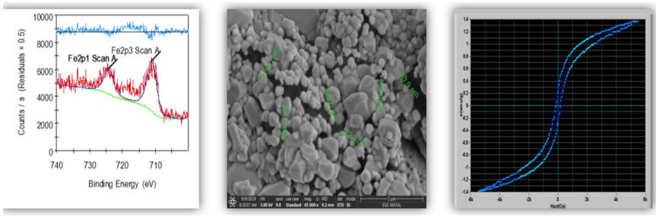
Dimesions	10"31m x 10mm
Weight	5 lbs.
Magnaflux Part #	- MT-MX-189838
MX Industrial (equivalent to Magnaflux's MPI Test Bar) Part #	- MT-MXI-MX3508 x 1.25" x 3/8" (approx. 254mm x

applied to the surface of the test material. The synthesized penetrant application is shown in Figure 2. We did our experimental work at Ege University, Aviation Higher Vocational School.

a) b)

Figure 2*. Application of penetrant on test material; a) Horizontal cracks, b)Vertical cracks.*

The experimental results showed that plant-mediated iron nanoparticles have great potential as a new penetrant for fluorescent magnetic particle inspection (MPI) applications. Experimental results showed that cracks ranging 254 mm x 31 mm x 10 mm in test block test materials were successfully identified.



a) b) c)

Figure 3. *Characterization of a) XPS spectrum related to the elemental survey scan of Fe_3O_4-GTE NPs, b) SEM images of Fe_3O_4-GTE NPs, c) The measured magnetic hysteresis of the MNPs by VSM.*

2.4 Characterization of Fe_3O_4-GTE NPs

The synthesized nanoparticles were characterized by X-ray Photoelectron Spectroscopy (XPS), Transmission Electron Microscopy (SEM) and Vibrating-Sample Magnetometer (VSM) in Figure 3.

According to the results of XPS analysis, percentage values of iron, carbon and oxygen in the green tea extract were found 6.64%, 21.31% and 48.76%, respectively. This result shows us that we synthesized Fe_3O_4 nanoparticles with a green synthesis. The Fe_3O_4@GTE NPs morphological structure was examined using SEM. Fig. 3b shows nanoparticle in the sample at 65000 x magnification under scanning electron microscopy. The size of Fe NPs synthesized using green tea extracts was found to be around 150 and 210 nm, as detected from SEM images. To better understand the magnetic properties of nanoparticles we tested magnetization measurements by using Vibrating Sample Magnetometer (VSM). The hysteresis loop of Fe_3O_4-GTE NPs magnetic behaviors is illustrated in Fig. 3c. VSM measurement showed that synthesized Fe_3O_4-GTE NPs nanoparticles exhibit soft magnetic behavior at room temperature. The Fig. 3c shows the saturation magnetization (Ms) and intrinsic coercivity (jHc) values have been measured 1.37 emu/g and 147.82 Oe respectively.

Conclusion

The synthesized magnetic particle has been developed and tested on a magnetic particle test bar. The preliminary studies demonstrate the usability of the synthesized penetrant. Our result shows that if the synthesized penetrant is optimized, it may be used in MPI applications. The study findings provide a new perspective on the development of a plant-based penetrant to be used in magnetic particle inspection.

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