Available online at www.rajournals.in

RA JOURNAL OF APPLIED RESEARCH
ISSN: 2394-6709
DOI:10.47191/rajar/v8i12.08
Volume: 08 Issue: 12 December-2022

International Open Access

Impact Factor- 7.108

Page no.- 893-896

The Importance of Magnetic Force Microscopy Method in the Study of Magnetic Nanomaterials and its Comparison with Electron Microscopy Methods

Abdulrabi Atif[1], Bashir ullah Safi[2], Khalid Jawad[3]
[1]Nangarhar University, Department of Physics, Nangarhar University campus, Nangarhar University, Nangarhar, Afghanistan.
[2]Nangarhar University, Department of Physics, Nangarhar University, campus, Nangarhar University,Nangarhar, Afghanistan.
[3]Laghman University, Department of Physics, laghman University campus, laghman University, laghman, Afghanistan.

ARTICLE INFO
Published Online:
14 December 2022

Corresponding Author
Bashir ullah Safi

ABSTRACT
In recent years, magnetic nonmaterial's have been utilized in the different fields due to their unique magnetic properties. There are various methods to investigate and study the properties of magnetic nonmaterial's. Magnetic force microscope (MFM) belongs to a family of scanning probe microscope methods based on atomic force microscopy for the study of the magnetic properties of the sample surface and its topography at the nanoscale. In this paper, the importance of the MFM method in the study of magnetic materials, the operation principles, MFM modes and their applications was investigated. Also, the advantages and limitations of the MFM method compared to the scanning electron microscope (SEM) and transmission electron microscope (TEM) methods were evaluated. The presented information in this paper reveals that the MFM method is a more appropriate technique for probing the properties of magnetic nonmaterial's. Additionally, due to the higher sensitivity of the dynamic method of the magnetic force microscope than its static state, more favourable images of the surface of the magnetic sample can be obtained.

KEYWORDS: Magnetic nonmaterial's, magnetic force, microscope, scanning, transmission.

1. INTRODUCTION

Nowadays, the application of magnetic nonmaterial's in different fields such as environmental field, catalysis and biomedical nanotechnology is developing. Among these practical applications, cell isolation, drug delivery, and magnetic resonance imaging (MRI) has been attracted by many researchers. The wide usage of these nonmaterial's is due to the unique magnetic properties of them[2]. Magnetic nanoparticles are a class of particles with independent nature. While their maximum size is about 100 nm, they consist of magnetic components. Having large specific surface area and simple separation with an external magnetic field, these particles have unique physical and chemical properties which make them significantly different from other states of nanoscale particles[3].Therefore, studying the properties of these nonmaterial's can largely assists researchers to understand the applications of these materials.

Using magnetic force microscopy method (MFM) would be one of the most suitable tools for imaging and examining the properties and also the structure of these materials[6].Magnetic force microscopy (MFM) is an atomic force microscopy (AFM) based technique by which one can obtain different information about topography of the sample surface, distribution of the turbulent magnetic field, the comparison of its changes on the sample, roughness and sample size. The images obtained from these microscopes are two and three-dimensional. While other methods, scanning electron microscopes (SEM and TEM) despite having a high resolution in imaging materials, have limitations compared to the MFM method[1]. In this paper, first we explain how the MFM method operates and how it can helps researchers to study magnetic nanoparticles. Then, the comparison between the electronic methods of SEM and TEM with MFM method are briefly introduced.

2. MAGNETIC FORCE MICROSCOPE

The MFM method is a special case of scanning force microscopes which have been applied specially in studies related to local magnetic properties and also measurements of sample magnetic changes. Using this microscope, one can obtain 2-d images of magnetic fields which are created in magnetic materials (Figure 1).

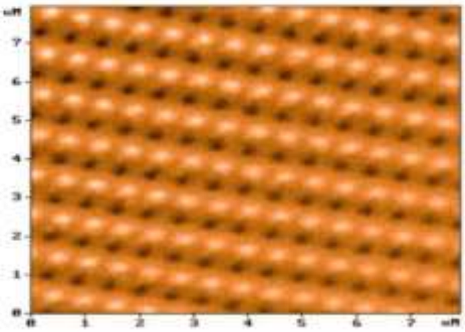

Fig 1. MFM image of an array of magnetic nanoparticles

Components of this microscope generally include a magnetic sharp tip, a piezoelectric scanner, a cantilever, a detector and an information processing unit[4-7]. In the MFM method, the sharp tip coating with a thin layer of ferromagnetic material such as nickel or cobalt, which is attached to the end of the beam is placed near the sample surface. By scanning the surface of the sample with the sharp tip, a small magnetic force is measured between the tip and the sample [1]. which by changing the vertical movement of this tip on the surface of the specimen, the generated local magnetic force makes a measurable deviation during scanning. Most magnetic force microscopes use the optical technique to determine the position of the cantilever. As shown in Figure 2, a laser beam is radiated on the back of the cantilever at the beginning of the scan. The interaction of the tip and the surface of the specimen causes the cantilever to bend and the laser light is reflected towards a position-sensitive detector (PSPD) so that displacement of the beam or cantilever is recorded. This detector can measure the displacement of the tip which is about an angstrom. The displacement recorded by the detector is used to reconstruct the magnetic structure and obtain an image of the force gradient on the surface. In the magnetic force microscopy method, magnetic images and data are generated by changes in the frequency, amplitude, or phase of the beam created by the magnetic field around the surface of the specimen [5]. In magnetic force microscopy, using both static and dynamic (oscillating) methods, the magnetic interactions created between the tip and the surface of the sample can be examined [11].

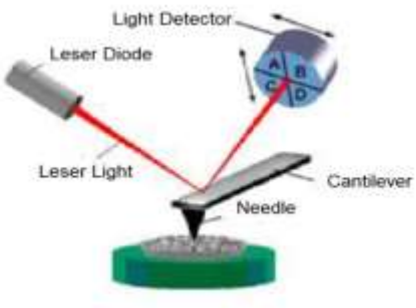

Fig 2. Schematic of the cantilever positioning optical system

3. STATIC METHOD

In this method, the force acting on the tip is measured from the static deviation of the beam. The tip scrubs the surface of the specimen at a constant height. As the tip moves on the surface of the specimen, due to the interaction between the tip and the surface of the specimen, the beam connected to the tip bends. Detector by recording the bending or deflection of the beam scans a two-dimensional image of the sample surface. However, In the static stage, the surface of the sample is scanned in two steps [8-9].

- In the first step, as it can be seen in Figure 3, the MFM image is obtained in contact or quasi-contact mode. The tip is then raised from the surface to a height of h and the sweeping operation is repeated.
- In the second step, the local distance between the tip at each fixed point and the local heterogeneity of the magnetic field cause the beam to bend during the movement of the probe on the specimen.

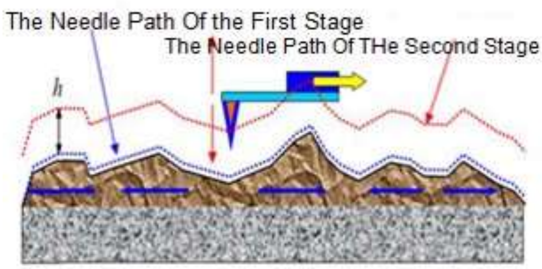

Fig 2. Stages of static MFM method

4. ELECTRONIC MICROSCOPES

Electronic microscopes are one of the most suitable tools for studying materials on a micro or nanoscale. These microscopes are used in various fields such as physics, chemistry, crystallography, materials and biology which by using them, one can obtain information about the structure, morphology and size of nonmaterial's. These microscopes can be categorized in some different types which two of more important ones are transmission electron microscopes (TEM) and scanning electron microscopes (SEM) [10]. The transmission electron microscope (TEM) operates similar to light microscopes. However, in TEM, electrons are used instead of light rays. Therefore, the resolution and magnification of these kinds of microscopes are a thousand times higher than of light microscopes. As it mentioned above, scanning electron microscopy (SEM) is another kind of electron microscope is using to study the structure of materials[6]. The operation of this microscope is based on the impact of a high-energy beam on the surface of the sample, which causes the electron to be excited from the surface of the sample, and the reflected beam is received by the detector. In scanning electron microscopy, the impact While in transmission electron microscopy, a thin layer of the sample must pass through the sample to produce a beam image[9].

5. COMPARISON OF MAGNETIC FORCE MICROSCOPE WITH SEM AND TEM

Compared to scanning and transmission electron microscopy, magnetic force microscopes have more advantages and capabilities specially in the study of magnetic materials. Among the most important privileges of MFM one can note that it requires minimal sample preparation. Also, the possibility of imaging in air, vacuum and liquid environments makes these microscopes much interesting. Angstrom accuracy, the possibility of creating a three-dimensional image of the magnetic sample and the ability of checking the material roughness in different points of sample surface are other properties which make this method more well-established[1,2]. While Table1 reports the capabilities and limitations of the MFM method compared to the SEM and TEM, figure 4 represents some images obtained from TEM, MFM and SEM of the crystal arrays which are formed by the magnetic nanoparticles of cubic iron oxide.

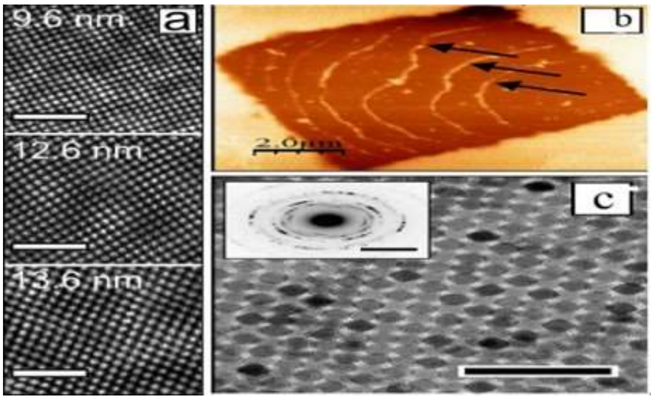

Fig 3. crystalline representations formed by magnetic cubic iron oxide nanoparticles a) SEM, b) MFM, c) TEM.

Table 1. comparison between MFM method with SEM and TEM

SEM	TEM	MFM	Method
Nanometer	Angstrom (in high resolution type) (HRTEM)	Angstrom	High accuracy
It takes several hours to reach the vacuum	-Examination of bulk specimens requires several weeks till specimen reach a certain thickness -It requires a very high vacuum, so this requirement takes several hours as the minimum image preparation.	- Scanning speed is longer than SEM - Normally the sample does not require any preparation.	measurement and sample preparation
- The surface must be conductive. Insulation surfaces should be covered with a thin top surface of conductive material.	Produces images only in two dimensions (no depth)	The only limitation of this method is the inability to study the structure of holes with a depth greater than the length of the tip (about 10 micrometers)	Limitations

6. CONCLUSION

In this paper, magnetic force microscopy, its applications in the study of local magnetic properties and changes in magnetic force at the sample level have been discussed. The results show that the dynamic method (oscillation) in which the sharp tip is in a position closer to the sample surface, consists a higher sensitivity than the thermodynamic method. Therefore, using the dynamic method, better two-dimensional images of the surface of the magnetic sample can be obtained. Comparison of MFM method with scanning and transmission electron microscopy methods has been explained in the last part. According to this comparison one can note that MFM method has more advantages make it more appropriate for studying the properties of magnetic nanomaterials. Its capabilities such as minimal sample preparation, angstrom accuracy and the possibility of preparing a two-dimensional image of magnetic fields in air, vacuum and liquid environments have been noted. However, we mention the limitations of the MFM method. For instance, the impossibility of imaging samples with porosity deeper than the tip length. Therefore, magnetic force microscopy is one of the most appropriate method to study the surface of nonmagnetic materials.

REFERENCES

1. Passeri, D., Dong, C., Angeloni, L., Pantanella, F., Natalizi, T., Berlutti, F., ... & Rossi, M. (2014). Thickness measurement of soft thin films on periodically patterned magnetic substrates by phase difference magnetic force microscopy. Ultramicroscopy, 136, 96-106.
2. Jun, Y. W., Seo, J. W., & Cheon, J. (2008). Nanoscaling laws of magnetic nanoparticles and their applicabilities in biomedical sciences. Accounts of chemical research, 41(2), 179-189.
3. Osaka, T., Matsunaga, T., Nakanishi, T., Arakaki, A., Niwa, D., & Iida, H. (2006). Synthesis of magnetic nanoparticles and their application to bioassays. *Analytical and Bioanalytical Chemistry, 384(3), 593-600.*
4. Koblischka, M. R., Kirsch, M., Pfeifer, R., Getlawi, S., Rigato, F., Fontcuberta, J., ... & Hartmann, U. (2010). Different types of ferrite thin films as magnetic cantilever coating for magnetic force microscopy. *Journal of magnetism and magnetic materials*, *322*(9-12), 1697-1699.
5. Saenz, J. J., Garcia, N., Grütter, P., Meyer, E., Heinzelmann, H., Wiesendanger, R., ... & Güntherodt, H. J. (1987). Observation of magnetic forces by the atomic force microscope. *Journal of applied physics*, *62*(10), 4293-4295.
6. Goodhew, P. J., Humphreys, J., & Beanland, R. (2000). *Electron microscopy and analysis*. CRC press.
7. Neves, C. S., Quaresma, P., Baptista, P. V., Carvalho, P. A., Araújo, J. P., Pereira, E., & Eaton, P. (2010). New insights into the use of magnetic force microscopy to discriminate between magnetic and nonmagnetic nanoparticles. Nanotechnology, 21(30), 305706.
8. Ellner, M., Pavlicek, N., Pou, P., Schuler, B., Moll, N., Meyer, G., ... & Peréz, R. (2016). The electric field of CO tips and its relevance for atomic force microscopy. *Nano Letters*, *16*(3), 1974-1980.
9. Liu, J. Y., Wang, Z. B., & Li, D. Y. (2017). A developed magnetic force microscope. In *EMBEC & NBC 2017* (pp. 362-365). Springer, Singapore.
10. Kazakova, O., Puttock, R., Barton, C., Corte-León, H., Jaafar, M., Neu, V., & Asenjo, A. (2019). Frontiers of magnetic force microscopy. *Journal of applied Physics*, *125*(6), 060901.
11. Sarid, D., Coratger, R., Ajustron, F., & Beauvillain, J. (1991). Scanning force microscopy-with applications to electric, magnetic and atomic forces. *Microscopy Microanalysis Microstructures, 2(6), 649-649.*