Computational and Experimental Research in Materials and Renewable Energy (CERiMRE)
Volume 3, Issue 2, page 53-57
eISSN : 2747-173X

Submitted : August 22, 2020
Accepted : October 15, 2020
Online : November 24, 2020
doi : 10.19184/cerimre.v3i2.23545

Analysis Curie Temperature and Hysteresis $La_{0.7}Sr_{0.3}MnO_3$ with Micromagnetic Simulation

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Abstract. Simulation reseach has been carried out to obtain the characteristic of material $La_{0,7}Sr_{0,3}MnO_{3.}$ The simulation method used atomistic of magnetic materials. Simulations were carried out using Vampire software Micromagnetic simulation were determine Curie temperature and Hysterisis Curve. The monte carlo algorithm was used in this reseach. Simulation were carried out by variation nanocube size 22 nm, 27 nm, and 32 nm. The simulation result show, Curie temperature show in 27 nm have the biggest value and stuck in that value. The characteristics of the Hysterisis curve 32 nm bigger than the others.From the simulation, it is found that the between the temperature and Hysteris curve. More temperature value, the smaller the Hysterisis curve.

Keywords: LSMO, Curie Temperature, Micromagnetic Simulation, Hysteristic Curve

Introduction

Currently, The development of technology results in higher human needs for data storage. All data storage and retrieval is done using the device. such as laptops, computers and cell phones. This activity is stored in a storage device. Hard Disk Drive (HDD) is a digital data storage device that uses a disk (disk) coated with magnetic material [1]. HDD with strong power and heat resistance provides good magnetic characteristics at high temperatures. The approach that can be proposed in this case is to make a magnetic recording medium in the form of patterned media. The magnetic material is formed in a very small size so as to increase the bit density of the magnetic recording medium [2]. CMR materials can be a solution with larger data storage capacities and low power usage [3]. CMR materials such as $La_{0,7}Sr_{0,3}MnO_3$ [LSMO] are predicted to have half-metal properties with high critical temperatures.

The research on $La_{0,7}Sr_{0,3}MnO_3$ was carried out by means of a micromagnetic simulation. This research was conducted to investigate its magnetic properties. Parameter determination is done by looking for references and adjusting the software used. Determining the sides of the cube is done by finding the critical diameter value and adjusting it. Determination of the critical diameter is carried out to show changes in the properties of the domain. The critical diameter was found to be about 27 nm. The method used in this research is Monte Carlo. This method is used because the application is easier for data retrieval.

Theoretical Background

Magnetic materials are materials that have magnetic properties. Magnetic property is the ability of a material to attract or repel other materials around it. Examples of magnetic materials are iron, steel, nickel, cobalt and their alloys [4]. A material magnetic have magnetic moment in the same direction. Metals that are non-magnetic can be seen whose magnetic moments have an irregular direction so that the effects cancel each other out which results in no magnetic poles at the ends of the metal.

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Kittle describes the critical diameter of a single domain by comparing the energy required to make the domain wall against the reduction in magnetostatic energy or demagnetostatic energy during the creation or manufacture of the domain structure [5].

The critical diameter equation is given:

$$DC = 7.221\sqrt{\frac{2A}{\mu\, Ms^2}} \tag{1}$$

$$DC = 7.221\, I_{ex} \tag{2}$$

With , $I_{ex} = \sqrt{\frac{2A}{\mu\, Ms^2}}$, I_{ex} is *exchange length and* μ is permeability of the material.

This study uses micromagnetic simulation software, namely Vampire. Vampire 4.0 is an atomistic model simulation application for nanometer-sized magnetic materials [6]. This study uses a vampire to simulate the Curie temperature and hysteresis curve which will be analyzed to determine the characteristics of the magnetic material.

Materials and Methods

This reseach was using vampire software with LSMO nanocube form to determine its magnetic properties. In this study, the relationship between magnetization and temperature was analyzed, the relationship between susceptibility and temperature at various material sizes of 22 nm, 27 nm and 32 nm. The size 27 nm is used because it is the result of a critical diameter calculation. Meanwhile, other measurements are above the critical material size and below the critical diameter. The analysis results will provide information about magnetic properties such as magnetic sensitivity, Curie temperature and hysteresis curves in ferromagnetic with various side sizes of the cube. The simulation produces the output that is processed using origin and Povray. This research uses micromagnetic simulation, by creating input script files and material script files (Table 1).

Table 1. Source of micromagnetic simulation data

Parameter	Value
Crystal Structure	*Simple Cube*
Atomic Spin Moment (μS)	3.6 μB
Anisotropy energy (ku)	-3.38 x 10^{-25} J/link
Unit cell lattice vector (a)	3.9 A
Exchange energy (J_{ij})	3.45 x 10^{-21} J/K
Anisotropy constant (Ku)	-0.3 x 10^3 J/m^3
Hard axis	1,1,0
Coordinat number (Z)	6
Spin number (s)	$^3/_2$
Spin wafe correction (ϵ)	0.751

Determination of Curie temperature. The LSMO simulation results produced an output file which was then taken to a graph plot using Origin software. The method is carried out combining a graph of the relationship between magnetic susceptibility and temperature based on the LSMO material. From this magnetic susceptibility graph, a more specific Curie temperature can be determined by combining temperature to magnetization and susceptibility temperatures. The way to determine the Curie temperature (Tc) via a graph is to examine the

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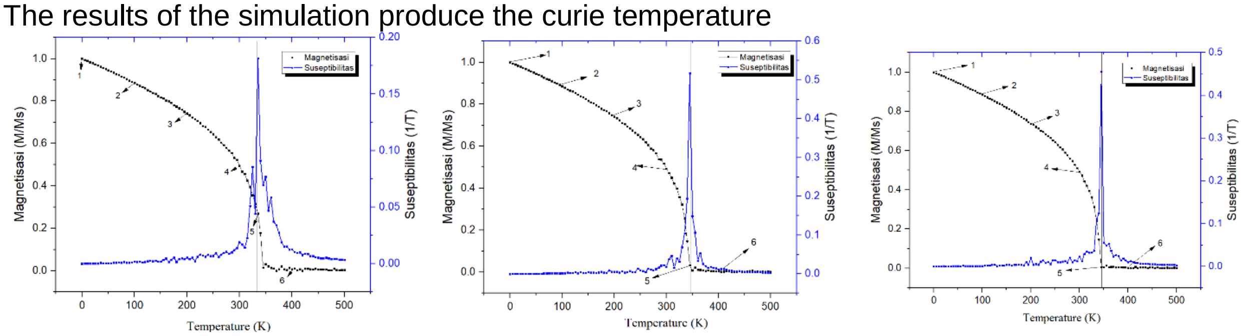
point between the temperature curve against magnetization and the temperature curve for susceptibility. When this point is close to zero on the magnetization axis, and the highest magnetic susceptibility value at that point can be said to be the Curie temperature point of the ferromagnetic material. Furthermore, it can be seen the effect of the side size of the cube material on the respective magnetic properties.

Determination of hysterisis curve. Hysteresis curve determination. The hysteresis curve simulation results were analyzed using Origin software. The analysis is carried out by making a graph of the magnetic relationship with the magnetic field. Hysteresis curve analysis is carried out to see the properties or values of the saturation field and the coercivity field formed from the LSMO material based on its temperature. Hysteresis curve analysis was performed using temperature variations on each side of the cube, namely the size of 0K, 100K, 200K, 300K and 400K. Determination of the temperature was carried out using reference studies which showed that the material had a curie temperature of about 350K. take values above and below the curie temperature. The hysteresis curve shape can show the characteristics of the ferromagnetic material itself. Furthermore, the material spin domain direction was visualized using Povray software.

Results and Discussion

The results of the simulation produce the curie temperature



(a) (b) (c)

Figure 1. Magnetic magnetization and susceptibility graph against temperature in LSMO material (a) size 22 nm, (b) size 27 nm, (c) size 32 nm.

Table 1. Curie temperature values in material LSMO

Size cubed (nm)	Curie temperature (K)
22	335
27	345
32	345

In ferromagnetic materials the spin is oriented in one direction without any external fields. This situation occurs only when the temperature does not exceed the transition temperature. Figure 1 shown, When the temperature is above the transition temperature, the spin orientation of the material becomes random and causes its state to change to a paramagnetic material. The simulation results show that the Curie temperature value does not change when the size of the material LSMO 27 nm in the form of nancube. Table 1 shown The Curie temperature value does not increase when it is above the critical side size. Determination of the size of the critical side makes the material usable as efficiently as possible. A material larger than the critical size will

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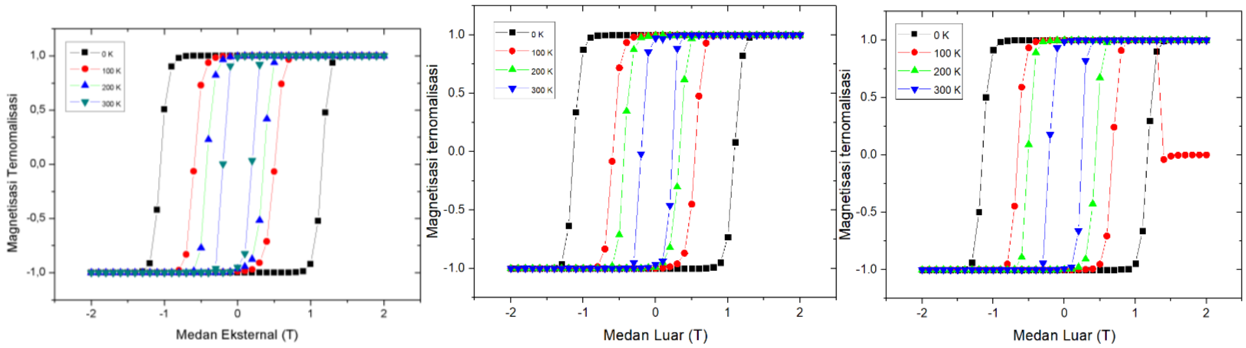
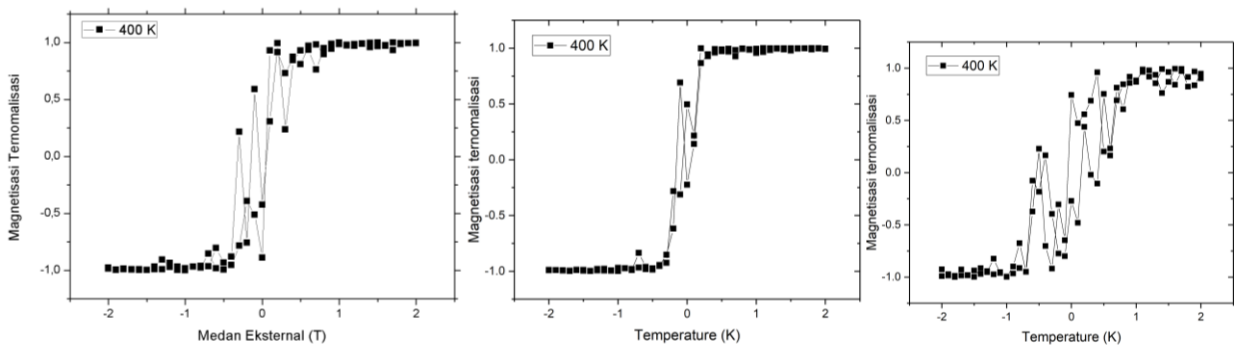
produce the same temperature value [7]. This occurs because the value of 27 nm is thought to have reached the critical side size of the material cube LSMO. LSMO material has a Curie temperature value which has reached the highest value when the material size is 27 nm.



(a) (b) (c)

Figure 2. LSMO hysterical curve against temperature variation (a) size 22 nm, (b) size 27 nm, (c) size 32 nm.



(a) (b) (c)

Figure 3. LSMO hysterical curve temperature 400 K (a) size 22 nm, (b) size 27 nm, (c) size 32 nm.

Table 2. The coercivity and saturation field values of the LSMO material temperature variations

Size cubed (nm)	Coercivity field (Tesla)					Saturation Field (Tesla)				
	0K	100K	200K	300K	400K	0K	100K	200K	300K	400K
22	1.05	0.55	0.35	0.2	-	1.5	0.8	0.6	0.4	-
27	1.05	0.6	0.35	0.2	-	1.5	0.9	0.6	0.4	-
32	1.2	0.7	0.45	0.2	-	1.5	0.9	0.7	0.4	-

The coercivity field value of the LSMO material at a size of 22 nm shows a value that decreases as the temperature increases. The saturation field value and the coercivity field also show the

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value that decreases as the temperature increases. This also occurs in the coercivity and saturation fields at the sizes 22 nm, 27 nm and 32 nm. The hysteresis curve of the LSMO material, the saturation field value and the coercivity field, increased the greater the size of the material. However, the hysteresis curve will narrow as the temperature rises. This causes the coercivity field and saturation field values to decrease as the temperature increases, but the coercivity and saturation field values increase as the size increases. The change in the value of the magnetization occurs due to the influence of the external field given by the ferromagnetic material.

Conclusions

The effect of cube side size variations on the LSMO material based on the simulation results, the cube side size variations affect the Curie temperature value. At a size of 22 nm in the LSMO material, the Curie temperature value is 335K, and for the 27 nm and 32 nm sizes the Curie temperature value is 345K. At 27 nm the Curie temperature value has reached the highest Curie temperature value, which is thought to have reached the critical size value. This makes the efficiency value of an LSMO nanocube form material of 27 nm. The characteristics of the hysteresis curve of the LSMO material based on the simulation results obtained changes in the value of the saturation field and coercivity field on the side size of the material cube and the variations given. In LSMO material, the highest coercivity and saturation field values were found on the side size of the cube 32 nm. This value can be used as information on the characteristics of LSMO material

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