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To cite this article: L Rohman et al 2020 J. Phys.: Conf. Ser. 1491 012013

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# **Magnetic Properties of FePt Material Influenced** by Heat-Assisted Using Micromagnetic Simulation

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Abstract: Platinum (FePt) is a ferromagnetic material that has a Face Centered Cubic (FCC) crystal structure. FePt material is classified as a hard magnetic material that can be applied as a magnetic storage medium. The composition of the material used in this study was  $Fe_{0.85}Pt_{0.15}$ . This study examined the magnetic properties of nano-sphere shaped FePt materials against the coercivity fields under the effect of heat-assisted variations in laser power values. The difference in magnetic properties due to the influence of laser power was seen based on the hysteresis curve. Micro-magnetic simulations were carried out to obtain Curie-temperature values, hysteresis curves, and configuration of the direction of spin of FePt material. This simulation found the Curie-temperature of the material as 650 K. The direction of the magnetization reversed by the power laser-assisted so quickly. With a small coercivity field; magnetic recording media can carry out the writing and recording process in high capacity. Based on the simulation results, laser power that has the potential to be applied to  $Fe_{0.85}Pt_{0.15}$ material. When the computer works at temperatures 0 K, the laser power 0 W to 0.0026 W can be applied. We use the suitable laser power 0 W to 0.016 W at temperatures of 298 K and 318. While the temperature of 339 K cannot be applied with laser power because it gets an overheat temperature.

#### 1. Introduction

Current technological developments cannot be separated from the role of material physics, especially in the magnetic sector. In this era, magnetic materials are desirable for application in digital information storage, such as the Hard Disk Drive (HDD). Heat Assisted Magnetic Recording (HAMR) is a system that assists the process of reading and writing data on the HDD. HDD storage capacity can be increased by used ferromagnetic materials, that have high magnetic anisotropy, but they have a high value of coercivity and saturated field. Laser power is used to provide heat energy in the storage area to reduce the coercivity field as the main factor of heat-assisted. The mechanism for applying the HAMR system, in general, is a high-power pulse laser that is given to the storage cell memory of magnetic materials so that the temperature approaches the Curie temperature. To be technologically useful, HAMR recording must be able to sustain sufficiently high data rates. The presence of the high temperature during recording results is a new set of challenges. It is well known that high-density recording requires narrow magnetization transitions, which can only be created by the temperature

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profile of the heat spot. Heat-assisted magnetic recording (HAMR) based on FePt media is regarded to be the most promising option to extend HDD beyond 1.5 Tb/in<sup>2</sup> [1].

This research used composition  $Fe_{0.85}Pt_{0.15}$  material with size of material 5 nm, and the shape is nanosphere. Heat Assisted in this case used laser power that was applied to reverse the direction of magnetization so that the coercivity field got decrease. The result of the hysteresis curve was expected to show the amount of laser power that could be applied to magnetic recording media. FePt material has a good chance to be utilized as a data storage medium with up to terabytes of storage capacity using the Heat Assisted Magnetic Recording (HAMR) method. The illustration of precision motion from magnetization is shown in Figure 1.



**Figure 1.** The precision motion of magnetization under the effect of magnetic field  $H_{eff}$  (a) $\alpha = 0$ , (b)  $\alpha \ll 1$  [2]

FePt alloy material is a material that received a lot of attention from the magnetic research community because it has very high magnetocrystalline anisotropy, which are about  $10^7$  joules / m<sup>3</sup>. Because the material has high anisotropy, the coercivity, and has good stability of corrosion resistance, then the material potentially applied in magnetic storage media [3]. FePt material has a Face Centered Cubic (FCC) crystal structure at high temperatures [4]. An illustration of the atomic structure of the FePt material is shown in Figure 2.



Figure 2. Atomic structure of the FePt material with a=c= 0,376 nm [5]

Previous research of influenced power laser that was applied to the material has been investigated by Evans *et al.* [6] The sudden increase in temperature led to demagnetization of the material. Therefore fit the time-dependent demagnetization dynamics with the function:

$$m(t) = A \exp\left(-\frac{t}{\tau}\right) \tag{1}$$

In which the demagnetization time constants  $\tau$  was intrinsic timescales and A constant was fitting parameters. The basic media structure for HAMR recording is shown in Figure 3.



Figure 3. HAMR writing scheme with laser integrated into the write pole [1]

#### 2. Method

The micromagnetic simulation of FePt material was carried out using the Vampire software program. The simulation was carried out in two stages. First, a simulation to create a magnetization curve and susceptibility to temperature to determine the Curie temperature. Second, a simulation to generate a hysteresis curve with variations of temperature and variations of laser power. Magnetic properties analyzed the output files of running to Curie temperature graph and hysteresis curves under the influence of laser power and be visualized the orientation of the spin direction.

Source of data parameters that were used in the simulation were cell units at 3.76 Å, constant exchange (A)  $3,0 \times 10^{-21}$  J/m, Fe atomic spin moment  $2.22 \,\mu\text{B}$  / atom and Pt of  $0.35 \,\mu\text{B}$  / atom, unit cell and anisotropy (K) constant  $1,0 \times 10^{-23}$  J/atom. Determination of Curie temperature was analyzed the y-axis curve for magnetization (M) and susceptibility, while the x-axis was for temperature. The amount of temperature showed the highest value of susceptibility was an indicator of the value Curie temperature material. Determination of the magnetic properties coercivity field of the material was based on the results hysteresis curve. Hysteresis curve was analyzed the y-axis curve for magnetization (M) and the x-axis for external magnetic field (H) Illustration of determination the coercivity field based on the hysteresis curve is shown in Figure 4, and the extent of imprint in the sample is estimated by the shift in the mean coercive field as follows [7]:

$$\Delta Hc = \frac{1}{2} \left( Hc_{+} + Hc_{-} \right) \tag{2}$$



Figure 4. Illustration of the coercivity field determination of a hysteresis curve [7]

The temperature was based on the CPU heat sink condition of the computer device during operation. The determined temperature variations included 0 K, 298 K, 318 K and 339 K. Temperature variation 298 K was the initial temperature or environment, 318 K was the setpoint temperature and at 339 K is the maximum temperature that can be accepted by the processor (overheat). Meanwhile, the

laser power given were 0 W, 0.008 W, 0.012 W, 0.016 W, 0.022 W and 0.026 W. The hysteresis curve with laser power was expected to reduce the value of the coercivity field so that it could be analyzed the potential of the laser power that could be applied to magnetic recording media. Determination of the magnetic spin configuration of the material is determined for several points on the hysteresis curve to determine the direction of the spin on the influence of the given external magnetic field.

### 3. Results and Discussion

The results of this study describe the magnetic properties of the FePt material with the composition of the material Fe0.85Pt0.15. The magnetic properties included the value of the Curie temperature, the magnitude of the coercivity field, and the saturation field based on hysteresis curve analysis. Curie temperature determination was based on the concept of magnetization change that was the location of magnetization, which was close to zero. This was a prediction relative to the observer. According to (Evans et al.[8], magnetic susceptibility can be used to determine the Curie temperature of a material by reviewing the highest magnetic susceptibility. Therefore, to determine the Curie temperature of a material can be determined using the highest magnetic susceptibility and magnetization value that close to zero [3]. The results of the Curie temperature determination process is shown in Figure 5.



Figure 5. Graph of Curie temperature determination process

The large Curie temperature indicates the limit change in magnetization. Curie temperature is a magnetic property of a material that serves as a limit to the evolution of material from ferromagnetic material to paramagnetic material [3]. Ferromagnetic material will turn into paramagnetic material if given heat above the Curie temperature of the material. Based on Figure 5 above, the Curie temperature of the nanosphere Fe0.85Pt0.15 material was 650 K.

The result of the hysteresis curve shows the magnitude of the external influence field on the change in the magnetization process. The hysteresis curve then analyzed to determine the magnetic properties of the Fe0.85Pt0.15 material, including the coercivity field and the saturation field of each temperature variation and the laser power applied. Figure 6 shows that there was a change in the shape of the hysteresis curve in each temperature variation. In this figure, if the temperature of Fe0.85Pt0.15 material increase, the area bounded by the magnetization curve getting smaller. This was used as evidence there was a change in the coercivity field.



Figure 6. The hysteresis curve of Fe0.85Pt0.15 material with temperature variation

Based on the effect of temperature on the hysteresis curve, the addition of laser power as a heatassisted effect will be more influence the hysteresis curve. The addition of laser power aimed to reduce the magnetization energy so that the coercivity field of the hysteresis curve decreased.



Figure 7. The hysteresis curve of Fe<sub>0.85</sub>Pt<sub>0.15</sub> material with laser power variation in 0 K



Figure 8. The hysteresis curve of Fe<sub>0.85</sub>Pt<sub>0.15</sub> material with laser power variation in 298 K



**Figure 9.** The hysteresis curve of  $Fe_{0.85}Pt_{0.15}$  **Figure 10.** The hysteresis curve of  $Fe_{0.85}Pt_{0.15}$  material with laser power variation in 318 K material with laser power variation in 339 K

In Figure 11, a visualization of spin configuration results from observations of the hysteresis curve FePt material, where the analyzed temperature was 0 K with an additional laser power of 0.008 W. The orientation of the spin direction in figure 11 changed slowly but could be seen still dominantly leads to one direction. The change in orientation of the spin direction was influenced by high temperatures, which were caused by laser power radiation. The laser power of 0.008 W was considered to be of minimal value so that the orientation of the spin direction of the Fe0.85Pt0.15 material could undergo very rapid changes which could also be seen in the resulting hysteresis curve.



**Figure 11.** (a) The hysteresis curve of Fe<sub>0.85</sub>Pt<sub>0.15</sub> material with laser power variation 0,008 W in 0 K (b) orientation changes of spin direction on various external field values

Based on Table 1, it was shown that temperature variations and laser power variations gave affect the value of the coercivity field and the saturation field of the formed hysteresis curve. From the simulation, results obtained that the most significant value of the coercivity field was at 0 K temperature and 0 W laser power. At 339 K, the maximum temperature of the CPU was working so that the addition of lasers at this temperature could break the material as the damage of the hysteresis curve showed it. At laser power 0.026 W, the coercivity field could not be analyzed. It was assumed that when the laser power was above 0.010 W, the Fe0.85Pt0.15 material at environment temperature and the setpoint of CPU temperature had close Curie temperature, so the hysteresis curve was damage and irregular. In these situations, the material was difficult to be magnetization or become to paramagnetic material.

Laser Power	Coercivity Field (Hc) (T)				Saturation Field (Hs) (T)			
(W)	0 K	298 K	318 K	339 K	0 K	298 K	318 K	339 K
0	4.2	1.75	1.5	1.35	4.4	2.1	1.9	1.6
0.008	1.85	1.05	0.65	-	1.9	2.3	1.7	-
0.012	1.85	0.95	0.95	-	2.1	1.8	1.9	-
0.016	1.75	0.7	0.7	-	1.9	2.1	1.8	-
0.022	1.8	-	-	-	2.6	-	-	-
0.026	2	-	-	-	2.6	-	-	-

Table 1. Values of coercivity field (Hc) and saturation field (Hs) Fe0.85Pt0.15 material at 0 K, 298 K,318 K and 339 K temperature with laser power variation

The energy of material could also be obtained by determining the area of the hysteresis curve. If the coercivity field increased, the energy of material was getting more significant for one magnetization cycle from zero to positive external fields to negative external fields to zero. Hard magnetic materials had more energy than soft magnetic materials so that laser power was applied to reduce energy.

#### 4. Conclusion

The results of the analysis hysteresis curve showed that the coercivity and saturation fields decreased when the temperature of the Fe0.85Pt0.15 material increased. If laser power was applied to the Fe0.85Pt0.15 material expanded, the coercivity field of the material was getting smaller. Laser power had the potential to be applied to the material Fe0.85Pt0.15 when the computer works, among others, at a temperature of 0 K with a laser power of 0 W to 0.0026 W. For temperatures 298 K and 318 K, laser power that could be applied was 0 W to 0.016 W. Whereas the temperature of 339 K could not be used with laser power because it is an overheat temperature.

#### Reference

- [1] Weller D, Mosendz O, Pisana S, Richter H J, Reiner J W, Stipe B, Parker G, Santos T S, Hellwig, O, and Terris B 2015 *Ultrafast Magn. I. Springer Proc. Phys.* **159** 228
- [2] Purnama B, Ismail I, and Suharyana S 2013 J. Fis. Apl. 9 30.
- [3] Evans R F L, Fan W J, Chureemart P, Ostler T A, Ellis M O A, and Chantrell R W 2014 J. *Phys.: Condens.Matter* **26** 103202
- [4] Xing Y T, Barb I, Gerritsma R, Spreeuw R J C, Luigjes H, Xiao Q F, Rétif C, and Goedkoop J B 2007 J. Magn. Magn. Mater. 313 192
- [5] Bakhshayeshi A, Sebt S A, and Abolhassani M R 2014 J. Supercond. Nov. Magn. 27 163
- [6] Evans R F L, Ostler T, Chantrell R W, Radu I, and Rasing T 2014 Appl. Phys. Lett. 104 082410.
- [7] Bedoya-Hincapié C M, Ortiz-Álvarez H H, Restrepo-Parra E, Olaya-Flórez J J, and Alfonso J E 2015 Chin. Phys. B 24 117701
- [8] Sugiarto T D, Handayani I P, and Iskandar R F 2015 J. Meas. Electron. Commun. Syst. 1 C1