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Effect of Silicon Rubber (SIR) in Fabrication of $NdFeB/BaFe_{12}O_{19}$-based Hybrid Magnet

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Abstract

The purpose of this study was to determine the effect of physical properties (density), magnetic properties (magnetic flux), and mechanical properties (tensile strength) of NdFeB- $BaFe_{12}O_{19}$ hybrid magnets with silicon rubber adhesive. NdFeB - $BaFe_{12}O_{19}$ permanent magnet has been made with a silicon rubber (SIR) adhesive mixture. The percentage variations of magnetic powder materials used are NdFeB: $BaFe_{12}O_{19}$ (95%: 5%) and NdFeB: $BaFe_{12}O_{19}$ (90%: 10%) mixed with a weight percentage of silicone rubber with variations of 20%, 40%, 60% and 80%. Characterization includes physical properties in the form of density where the sample with 20% SIR variation has the largest bulk density value of 3.28 g/cm^3 for NdFeB: BaFe12O19 (95%: 5%) and 3.24 g/cm^3 for NdFeB: $BaFe_{12}O_{19}$ (90%: 10%), and mechanical properties in the form of tensile strength where the most optimum elasticity value is at 80% silicone rubber. Meanwhile, the most optimum magnetic properties of materials are owned by material samples with variations of SIR at a concentration of 20% for sample variations of 95% NdFeB and 5% $BaFe_{12}O_{19}$, which is 602.8 Gauss.

Introduction

Magnets are an integral part of human life today. Starting from electrical equipment to non-electrical equipment utilizing permanent magnets, for example, loudspeakers, water meters, KWH-meter, rice cookers, transformers, and generators. The characteristics of magnetic materials are determined by magnetic quantities such as susceptibility, remanent magnetization, saturation magnetization, and coercivity field [1,2].

The development of permanent magnets is currently highly focused on high-energy permanent magnets. One of the permanent magnet materials that can produce high energy is NdFeB. NdFeB magnets have high saturation magnetic induction reaching 1.6 T or 16 kG, remanence 0.5-0.9T or about 5 - 9 kGauss, NdFeB magnets have higher magnetic properties but lower corrosion resistance, stable at lower temperatures. To overcome the corrosion factor, NdFeB magnets are plated on the surface as corrosion protection. Permanent magnet products consist of two kinds, namely: sintered and bonded magnets, bonded magnets are composite materials with a polymer matrix and the reinforcement is magnetic particles such as Ba-ferrite and NdFeB [3,4]. The advantages of sintered magnets compared to bonded magnets include stronger and denser magnetic material and greater magnetic properties. However, the disadvantage of NdFeB is its poor thermal properties so it cannot be used at high temperatures. Ferrite-based permanent magnets such as barium ferrite are ceramic-type commercial permanent magnets. Ceramic magnets are made from calcined magnetic powder that has been pulverized, molded, and sintered. The characteristics of ceramic magnets are highly dependent on their microstructure characteristics. Barium Ferrite has been an interesting reference in the world of magnetic materials and has been widely used as a permanent magnet. This is due to its considerable magnetocrystalline anisotropy (1.07 x 105 erg/cm3 at 77 K) and high Curie temperature (450^{o}C), with relatively large saturation magnetization (96.27 emu/g), good chemical stability and corrosion resistance [4]. Barium ferrite magnets have a high coercivity field and are resistant to corrosion. Although their energy characteristics are lower compared to other hard magnets such as neodymium iron boron (NdFeB) magnets, ferrite hard magnets are still widely used for permanent magnet applications due to their abundant and cheap materials [5][6]. Magnets produced from the process of mixing NdFeB with Barium ferrite material are called Hybrid Magnets, which have better thermal properties than pure NdFeB and can work at higher temperatures (120 - 200^{o}C) [7][8]. Mixing NdFeB with Barium Ferrite and iron powder can provide the advantage of producing magnets that have an impact on reducing production costs even though the magnetic properties decrease [8]. Because $BaFe_{12}O_{19}$ material has lower magnetic properties than NdFeB alloy material, the advantages of $BaFe_{12}O_{19}$ are cheap and more stable in atmospheric conditions.

The formation of bonded magnets is a combination of NdFeB- $BaFe_{12}O_{19}$ magnetic particles with polymer particles, where the polymer material functions as an adhesive for magnetic particles [9]. The types of polymers used vary, including Polyvinyl Butyral [10], epoxy resin[11], silicon rubber[12], Bakelite, and others[13–17]. In this case, silicon rubber as the adhesive. The connection is stronger, more hybrid magnetic, and has superior heat resistance than before.

Therefore, in this study we try to investigate the effect of physical properties (density), magnetic properties (magnetic flux), and mechanical properties (tensile strength) of NdFeB-$BaFe_{12}O_{19}$ hybrid magnets with silicon rubber adhesive.

Experimental Method

The raw materials used in this research are NdFeB powder type MQB + and commercial $BaFe_{12}O_{19}$ powder. Furthermore, the materials were weighed respectively with a predetermined weight percent composition (NdFeB: $BaFe_{12}O_{19}$ 95%: 5% and 90%: 10% respectively) with silicone rubber variations of 20%, 40%, 60%, and 80%. Mixing commercial NdFeB as much as 18.95 grams and 17.80 grams, barium hexaferrite as much as 1.05 grams and 2.20 grams, silicone rubber as much as 5 grams, 13.3 grams, 30 grams and 80 grams into a glass jar for each variation, the material is stirred evenly for further printing. Next, the drying process will be carried out in a desiccator or at room temperature where the sample is allowed to dry until it becomes a solid. The sample-making stage more clearly can be seen in Figure 1 research flow chart.

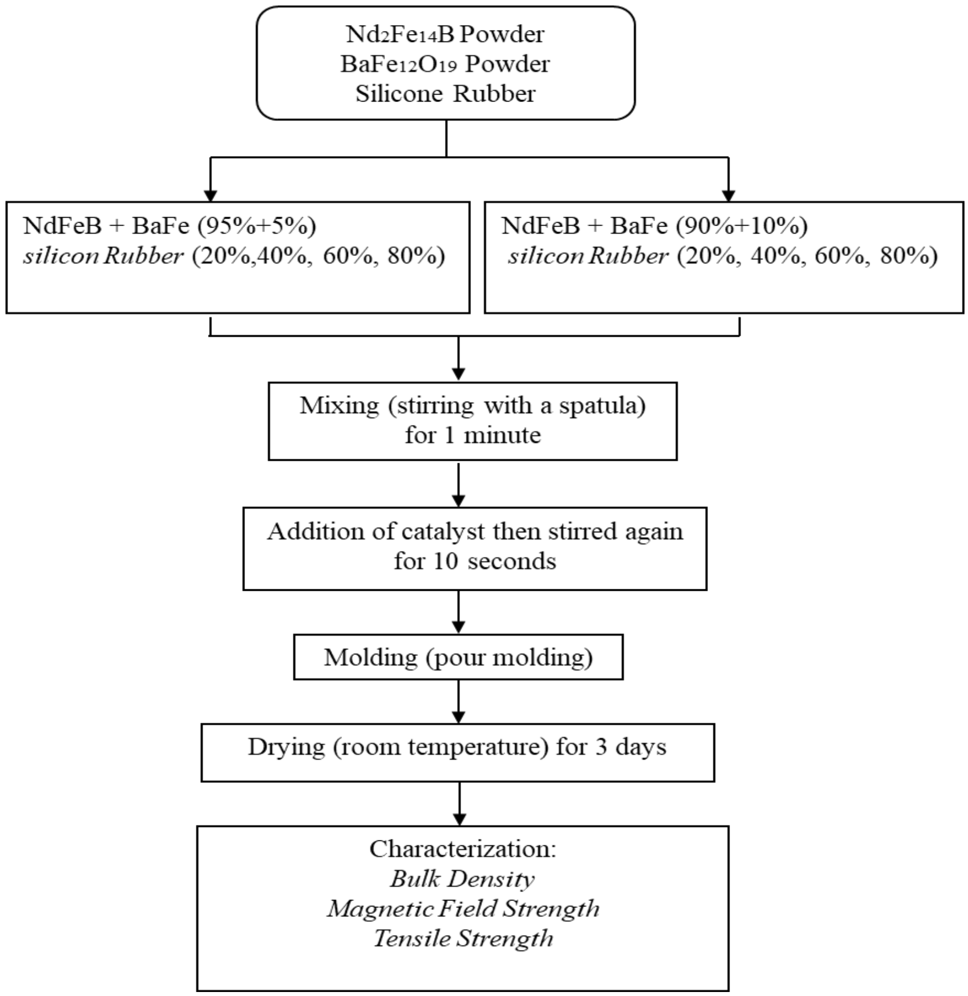

Figure 1. Flow chart of making NdFeB/$BaFe_{12}O_{19}$ hybrid magnet with silicone rubber adhesive

Density measurement using the Archimedes method with the equation:

$$\rho_s = \frac{m_a}{m_a - m_b} \text{ x } \rho_{water} \quad (1)$$

Where m_a is the dry mass of the sample (g), mb is the wet mass of the sample (g) and ρ_{water} is the density of water (g/cm^3). The magnetic field strength of the sample will be tested using a Gaussmeter with a voltage of 1.2kV. To determine the strength of the sample to withstand the given load, a tensile test is carried out using the WeiHeng tool.

Result and Discussion

Bulik Density

The graph of the bulk density test results of NdFeB - $BaFe_{12}O_{19}$ can be seen in the following Figure 2.

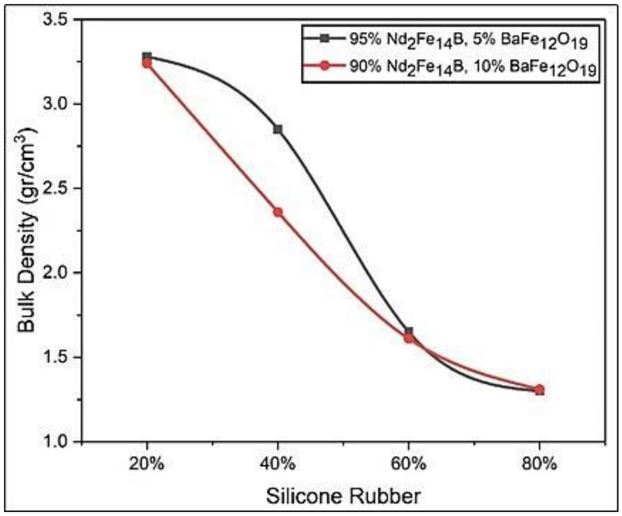

Figure 2. Graph of Bulk Density against Silicone Rubber Variation

From Figure 2, It can be seen that the bulk density value tends to decrease along with the addition of silicone rubber. The greater the percentage of silicone rubber given, the smaller the bulk density value. This is because the density of silicone rubber (1.35 g/cm^3) is smaller when compared to NdFeB (6 g/cm^3) and $BaFe_{12}O_{19}$ (4 g/cm^3) [18]. Therefore, the magnetic material used will float due to the increasing amount of silicone rubber given. Silicone rubber material also has properties that bind each other between particles and materials, so that the magnetic material used will be firmly attached and the pores of the sample will be smaller. The decrease in density in the manufacture of $BaFe_{12}O_{19}$ magnets using silicone rubber adhesives has also been carried out by Giyanto et al. [19]. The decrease in density is also influenced by the difference in density between NdFeB and $BaFe_{12}O_{19}$. Where along with the addition of Ba-Ferrite, the density will also decrease. This decrease in density indicates a decrease in cohesiveness in the sample due to the presence of a silicone rubber polymer mixture in the NdFeB bonded magnet composite and the density of silicone rubber is smaller than NdFeB [20].

Magnetic Field Strength

The magnetic field strength measurement results of NdFeB-$BaFe_{12}O_{19}$ can be seen in Figure 3.

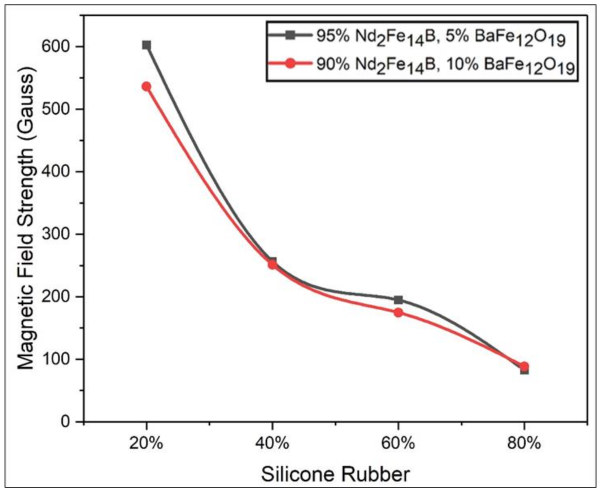

Figure 3. Graph of magnetic field strength against silicon rubber variation.

In Figure 3, the magnetic field strength decreases along with the more silicon rubber used, the smaller the resulting magnetic field strength. The relationship between magnetic field strength and silicon rubber variation is inversely proportional. This is due to the nature of the material from silicon rubber which is an insulating material. So that when given an electric current, the resulting magnetic field strength is not getting bigger or decreasing[12].

Tensile Strength

Tensile Strength test results can be seen in Figure 4.

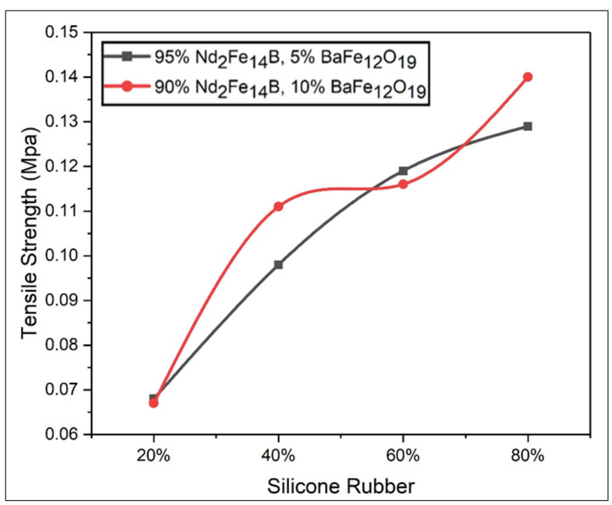

Figure 4. Ultimate tensile strength graph against silicone rubber variation.

From Figure 4, it can be seen that the more silicone rubber is used, the greater the ability of the material to increase in length. So that the material can withstand greater loads. This is due to the elastic nature of silicone rubber, so when the material is mixed with a strong material such as metal will make the material elastic and can withstand a given load or tensile force [12]. The highest value of elasticity is at the amount of silicone rubber as much as 80%. So, it can be interpreted that the greater the percentage of silicone rubber used, the greater the level of elongation obtained. Elongation is the ability of a metal material to increase in length when given a load or tensile force. In addition to the elongation value, the maximum or ultimate tensile strength (UTS) value is also obtained. UTS is the maximum load or tensile force that can be withstood by the material before experiencing a change in cross-section.

Conclusion

NdFeB - $BaFe_{12}O_{19}$ permanent magnets have been successfully made using silicone rubber adhesive. The physical properties of samples with silicon rubber variations at a composition of 20% have the highest bulk density value of 3.28 g/cm3. The highest material magnetic properties are owned by material samples with silicon rubber variations with a concentration of 20%. For sample variations 95%NdFeB and 5%BaFe have the highest value of 602.8 Gauss. The most Optimum elasticity value is at the amount of silicone rubber as much as 80%. Because it has a good level of flexibility, this material is very suitable to be applied to components on doors or windows as a lock or sealer, or as an adhesive material between two components, for example, such as on refrigerator doors and rice cookers.

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