

# Peningkatan sifat kemagnetan nanokomposit SrFe<sub>12</sub>O<sub>19</sub>/CoFe<sub>2</sub>O<sub>4</sub> melalui rekayasa struktur menggunakan metoda gabungan pemanfaatan mekanik dan perlakuan ultrasonik daya tinggi = Magnetic properties enhancement of nanocomposite SrFe<sub>12</sub>O<sub>19</sub>/CoFe<sub>2</sub>O<sub>4</sub> by mechanical alloying method combined with high power ultrasonic treatment

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## Abstrak

Dalam lebih seratus tahun belakangan, fokus riset dan pengembangan magnet permanen terletak pada pencarian fasa magnetik baru sehingga ditemukannya berbagai senyawa material magnet permanen. Tercatat dalam sejarah pengembangannya, fasa magnetik Nd<sub>12</sub>Fe<sub>14</sub>B yang ditemukan pada tahun 1993 merupakan fasa magnetik magnet permanen terkuat sampai saat ini. Sejak dimulainya abad 21, ternyata pengembangan riset magnet permanen tidak lagi fokus pada pencarian fasa magnetik baru, tetapi lebih kepada rekayasa struktur diantaranya magnet permanen berbasis nanokomposit. Magnet nanokomposit adalah jenis magnet permanen baru yang merupakan hasil penggabungan dua atau lebih fasa magnetik keras dan lunak dengan struktur yang mengizinkan terjadinya efek interaksi antar butir atau grain exchange interaction. Efek interaksi antar grain dalam struktur nanokomposit menghasilkan karakteristik baru magnet permanen berupa peningkatan nilai magnetisasi remanen (Mr), magnetisasi saturasi (Ms), dan produk energi maksimum (BH)maks. Pada penelitian ini, telah dipelajari magnet nanokomposit terbuat dari fasa magnet permanen stronsium heksaferit (SrFe<sub>12</sub>O<sub>19</sub>) dan fasa magnet lunak kobalt ferit (CoFe<sub>2</sub>O<sub>4</sub>) dengan menerapkan metode pemanfaatan mekanik dilanjutkan dengan perlakuan ultrasonik daya tinggi. Serbuk halus material magnetik SrFe<sub>12</sub>O<sub>19</sub> dipersiapkan dari bahan baku oksida besi (Fe<sub>2</sub>O<sub>3</sub>) dan stronsium karbonat (SrCO<sub>3</sub>) dengan teknik pemanfaatan mekanik, demikian juga serbuk halus CoFe<sub>2</sub>O<sub>4</sub>. Kedua jenis serbuk material magnetik tersebut juga menerima perlakuan ultrasonik daya tinggi agar terjadi destruksi lanjut ukuran serbuk masuk kedalam ukuran skala nanometer. Magnet nanokomposit yang dipelajari pada penelitian ini memiliki rasio fraksi massa SrFe<sub>12</sub>O<sub>19</sub>/CoFe<sub>2</sub>O<sub>4</sub> masing-masing adalah 70:30, 75:25, 80:20, dan 85:15. Rekayasa struktur komposit dilakukan dengan menggunakan ukuran serbuk bervariasi, baik ukuran serbuk senyawa SrFe<sub>12</sub>O<sub>19</sub> maupun senyawa CoFe<sub>2</sub>O<sub>4</sub>. Temperatur sintering 1000–1200 °C diterapkan pada magnet komposit untuk mengetahui suhu sintering optimal terjadinya difusi pembentukan magnet nanokomposit terbaik. Sifat kemagnetan empat variasi kombinasi ukuran serbuk SrFe<sub>12</sub>O<sub>19</sub> dan CoFe<sub>2</sub>O<sub>4</sub> dalam struktur komposit masing-masing kombinasi antara serbuk berukuran mikron dan nano menunjukkan bahwa efek interaksi butir antara fasa magnetik keras SrFe<sub>12</sub>O<sub>19</sub> dan fasa magnetik lunak CoFe<sub>2</sub>O<sub>4</sub> telah meningkatkan nilai Mr dan Ms magnet nanokomposit. Karakteristik magnet optimal yang didapat dari hasil penelitian ini adalah nilai Mr =34,55 emu/g, Ms =66,44 emu/g, Hc =3,11 kOe dan nilai (BH)maks hasil kalkulasi berdasarkan nilai Mr sudah melebihi nilai (BH)maks magnet SHF tunggal yaitu 1,12 MGOe (8.96 kJ.m<sup>-3</sup>) yang diperoleh dari magnet nanokomposit komposisi 80:20.

.....In the last hundred years, research and development of permanent magnets have been in the search for new magnetic phases. Hence, various compounds of permanent magnet materials have been discovered. During the story of its evolution, the magnetic phase Nd<sub>12</sub>Fe<sub>14</sub>B which was identified in 1993 remains the strongest permanent magnet to date. Nevertheless, since the start of the 21st century, it works out that the

growth of permanent magnet research is no longer concentrating on finding new magnetic phases, but rather on structural engineering, including nanocomposite-based permanent magnets. Nanocomposite magnets are a new type of permanent magnet which is the result of combining two or more hard and soft magnetic phases with a structure that allows grain exchange interactions to occur. The interaction effect between grains in the nanocomposite structure produces new characteristics of permanent magnets in the form of an increase in the value of remanent magnetization ( $M_r$ ), saturation magnetization ( $M_s$ ), and maximum energy product ( $(BH)_{max}$ ). In this research, nanocomposite magnets made of hard phase strontium hexaferrite ( $\text{SrFe}_{12}\text{O}_{19}$ ) and soft phase cobalt ferrite ( $\text{CoFe}_2\text{O}_4$ ) prepared through the mechanical alloying method followed by high power ultrasonic treatment have been studied. The fine powder of  $\text{SrFe}_{12}\text{O}_{19}$  was prepared from iron oxide ( $\text{Fe}_2\text{O}_3$ ) and strontium carbonate ( $\text{SrCO}_3$ ) by a mechanical alloying technique likewise, the fine powder  $\text{CoFe}_2\text{O}_4$ . Both types of magnetic material powders also received high power ultrasonic treatments to allow further destruction of the powder size into the nanometer scale. The nanocomposite magnets understudied had mass fraction ratios of  $\text{SrFe}_{12}\text{O}_{19}/\text{CoFe}_2\text{O}_4$ , respectively 70:30, 75:25, 80:20, and 85:15. The structural engineering of the composite was carried out using various powder sizes, both the size of  $\text{SrFe}_{12}\text{O}_{19}$  and  $\text{CoFe}_2\text{O}_4$ . The sintering temperature of 1000–1200 °C was applied to the composite magnets to determine the optimal sintering temperature for the best diffusion of nanocomposite magnet formation. The magnetic properties of nanocomposite magnets with four size combinations of  $\text{SrFe}_{12}\text{O}_{19}$  and  $\text{CoFe}_2\text{O}_4$  powders in the composite structure of each combination of micron and nano-sized powders showed that the grain interaction effect between the hard magnetic phase  $\text{SrFe}_{12}\text{O}_{19}$  and the soft magnetic phase  $\text{CoFe}_2\text{O}_4$  had increased the  $M_r$  and  $M_s$  values of the nanocomposite magnets. The optimal magnetic characteristics obtained from the results of this study are the value of  $M_r = 34.55 \text{ emu/g}$ ,  $M_s = 66.44 \text{ emu/g}$ ,  $H_c = 3.11 \text{ kOe}$ . The value of  $(BH)_{max}$  calculated from  $M_r$  has exceeded that of the single-phase SHF magnet which is 1.12 MGoe (8.96 kJ.m<sup>-3</sup>).