JPPIPA 9(1) (2023)

Jurnal Penelitian Pendidikan IPA

Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

Ceramic Oxide MgO-SiO_2-Al_2O_3 as Capacitor

Maryati Doloksaribu[1*], Pintor Simamora[1], Mukti Hamjah Harahap[1], Kristin[1], Puspita Sari[1]

[1] Physics Department, Medan State University, Medan, Indonesia

Received: November 29, 2022
Revised: January 12, 2023
Accepted: January 25, 2023
Published: January 31, 2023

Corresponding Author:
Maryati Doloksaribu
maryatidoloksaribu@unimed.ac.id

DOI: 10.29303/jppipa.v9i1.2532

Abstract: This study aims to analyze the effect of the composition MgO-SiO_2-AL_2O_3 on dielectric constant, hardness, and microstructure. Good ceramics can be produced from an alloy of ceramic materials with a certain composition that is hard and able to store electric charge. Magnesium Oxide (MgO) ranked as the most heat-resistant insulating material for application practice. Silica (SiO_2) is known for its hardness, besides that silica can also reduce plasticity and reduce dry shrinkage. The addition of alumina (AL_2O_3) to the ceramic resulted in a reduction in the mass of the ceramic. However, the hardness value obtained is increasing. So that the alloy between MgO-SiO_2-AL_2O_3 is expected to produce ceramics that have superior mechanical and electrical properties. This study varied the composition of MgO-SiO_2-AL_2O_3 with a composition ratio of 50%:50%:0%, 80%:15%:5%, 60%:32%:8%, 30%:63%,12%, 10%:75%:15%. Sintering was carried out at 1200^0C with a holding time of 8 hours. Then the sample's capacitance was measured using a capacitance meter and calculated the value of the dielectric constant, and hardness test using the Rockwell Hardness Tester type. The samples that have been tested for hardness are then taken three hardness values, namely low, medium, and high hardness to be tested for microstructure by SEM. The results show the MgO content increases, the value of the dielectric constant will increase but cause more pores. The level of SiO_2-AL_2O_3 increases the higher the hardness value and the smaller the number of pores. Of the 5 samples that have been studied, the best sample used is sample 3 which has a good dielectric constant value, moderate hardness value, and the microstructure of the number of pores is not too much.

Keywords: Dielectric constant; Hardness; MgO-SiO_2-AL_2O_3; Microstructure

Introduction

Ceramics continues to develop into an essential material today. This is due to the rapid development of science and technology which has influenced and changed many aspects of life. With the existence of science and technology in ceramics, it has been possible to identify the structure and chemical composition of its constituents and other mixing materials that can improve the properties of ceramics, so that a ceramic product can be produced for various needs of the mechanical, electronic, filter industries and even used in the field of space technology space (Arazaq et al., 2021; Barsoum, 2016; Nurzal et al., 2013).

Ceramics are found in almost every part of technology products. The development of technology based on ceramic materials is increasingly advanced, as seen from the many studies on these materials. Ceramic materials are structurally attractive materials seen from their characteristics, for example, good heat capacity, low heat conductivity, and good corrosion resistance, their electrical properties can be insulators, semiconductors, conductors, and even superconductors, and their magnetic properties can be magnetic and non-magnetic, their mechanical properties can be hard and strong, but brittle which allows it to be used for various applications (Atmoko, 2015; Carter et al., 2017; Sobirin et al., 2016).

One of the ceramic materials that have wide applications both in industry and research is magnesium oxide (MgO). Magnesium Oxide is one of the main ingredients in the manufacture of ceramics because Magnesium Oxide has a very high melting point which is around 2000^0C (Carp et al., 2014; Damayanti et al., 2015; Kosasih, 2016). Magnesium oxide is ranked as the

How to Cite:
Doloksaribu, M., Simamora, P., Harahap, M.H., Kristin, K., & Sari, P. (2023). Ceramic Oxide MgO-SiO2-Al2O3 as Capacitor. *Jurnal Penelitian Pendidikan IPA*, *9*(1), 216–220. https://doi.org/10.29303/jppipa.v9i1.2532

most heat-resistant insulating material for practical applications. Magnesium oxide has fairly good thermal conductivity, and magnesium oxide has very good electrical resistance, so it is widely used as an insulator material with characteristics that tend not to change when heated, magnesium oxide is also a material that is safe for the human body (Hull, 2016; Mills, 2017). Putra et al. (2012) researched making ceramics with the composition MgO sintered at 1200^0C. The results showed that when the MgO level decreased, the dielectric constant value decreased. Silica is the name given to a group of minerals consisting of oxygen and silicon with the chemical formula SiO_2. The two most abundant elements in the earth's crust. Silica has coarse particles and contributes greatly to the hard mechanical properties of the material because the material does not soften easily and is resistant to penetration on its surface (Callister Jr, 2017; Gurbuz et al., 2018; Nurzal et al., 2013). Putra et al. (2012) researched making ceramics with SiO_2 composition sintered at 1200^0C. The results showed that if the SiO_2 content increases, the hardness value will increase. Furthermore, according to Tamalia et al. (2017), the addition of alumina (Al_2O_3) to ceramics reduces the mass of ceramics. However, the hardness value obtained is increasing. This is of course very much needed in the manufacture of light, strong and stable ceramics when heated to a temperature of 1000^0C. Good ceramics can be produced from an alloy of ceramic materials with a certain composition that has several properties, including mechanical properties and dielectric properties.

Magnesium oxide (MgO) is an electronic ceramic whose material has dielectric properties and is capable of storing electric charges. Silica (SiO_2) is an important material in the manufacture of ceramics and the formation of glass. Silica has coarse particles and contributes greatly to its mechanical properties, namely hardness. The addition of alumina (Al_2O_3) to ceramics supports increasing the hardness value of ceramics. So that the alloy between MgO, SiO_2, and Al_2O_3 is expected to be able to determine the effect on the characteristics of the formation of phase structures, crystal size, and physical properties as well as hardness and produce ceramics that have advantages and resistance, including having hard properties and being able to store electric charges which are applied as ceramic capacitor materials (Matthews et al., 2019; Maulana, 2018). Based on the background above, the researchers conducted research to determine the effect of the composition of $MgO–SiO_2–Al_2O_3$ on oxide ceramics.

Method

Preparing raw materials for ceramic $MgO-SiO_2-Al_2O_3$ according to the variation of the composition that has been determined, the mixing process is carried out using a spatula carefully so that it is not contaminated with other materials. Then pressing the sample in the form of tablets. Pressing is done with a vertical force of 5 tons. Then the Sintering process is a process of heat treatment of the sample to increase the bonding of the particles so that the strength and hardness increase. The sintering temperature was used 1200^0C withholding time for 8 hours. The next step is to calculate the value and test the ceramics that have been made. Hardness testing using the Vickers Hardness method using a Rockwell-type Hardness Tester, dielectric constant values using a capacitance meter. Samples with the lowest, medium, and highest hardness values were examined for their microstructure using the SEM (Scanning Electron Microscope) tool.

Result and Discussion

Hardness test

Based on the data in Table 1, the relationship between hardness and variations in the composition of the $MgO-SiO_2-Al_2O_3$ ceramics is made. The increase in the hardness value of the variation in the $MgO-SiO_2-Al_2O_3$ ceramic composition is due to the more significant variation in the design of $SiO_2-Al_2O_3$. Because Silica Oxide has coarse particles and contributes greatly to the mechanical properties of the material and is resistant to penetration on its surface. Alumina (Al_2O_3) is a material that is often used in various applications because of its high physical and chemical properties, such as very high strength and very hardness (Inkson, 2016; Mujib et al., 2013; Rahaman, 2017; Raharjo, 2015). In this case, we can see that if the $SiO_2-Al_2O_3$ level increases, the hardness value increases, and the number of pores decreases. And if the number of pores decreases in the microstructure, the hardness value tends to increase.

Table 1. Data Hardness Test

Various Composite $MgO-SiO_2-Al_2O_3$	Hardness Test
50%-50%-0%	41.89 Kgf/mm^2
80%-15%-5%	28.54 Kgf/ mm^2
60%-32%-8%	45.98 Kgf/ mm^2
30%-63%-12%	60.83 Kgf/ mm^2
10%-75%-15%	74.76 Kgf/ mm^2

Dielectric Constant Testing

From the five samples tested, the capacitance value data obtained from the measurement results with a capacitance meter were then carried out to calculate the dielectric constant.

Table 2. Data Dielectric Constant

Various composite $MgO-SiO_2-Al_2O_3$	Capacitance	Diameter (m)	Large (m^2)	$\varepsilon = c\frac{d}{A}$	$K = \frac{\varepsilon}{\varepsilon_0}$
50%-50%-0%	$4.53.10^{-12}$	15.10^{-3}	$1.17.10^{-4}$	$38.39.10^{-11}$	43.37
80%-15%-5%	$4.74.10^{-12}$	15.10^{-3}	$1.17.10^{-4}$	$40.17.10^{-11}$	45.39
60%-32%-8%	$4.61.10^{-12}$	15.10^{-3}	$1.17.10^{-4}$	$39.07.10^{-11}$	44.15
30%-63%-12%	$3.79.10^{-12}$	15.10^{-3}	$1.17.10^{-4}$	$32.12.10^{-11}$	36.30
10%-75%-15%	$3.00.10^{-12}$	15.10^{-3}	$1.17.10^{-4}$	$25.42. 10^{-11}$	28.72

$MgO-SiO_2-Al_2O_3$ ceramic composition is caused by the more significant variation in the MgO composition. A type of ceramic material used for electrical insulators (Sidabutar, 2017; Utomo, 2013). In this case, we can see that if the MgO level increases, the value of the dielectric constant will increase. However, rising levels of MgO cause many large pores to appear, causing more pores and lower hardness values.

Morphology Testing

Observation of the morphological structure was carried out to see the wide pores found on the surface of the sample. There were 3 samples selected. The three samples were chosen because they have a hardness value that can represent other samples, namely the sample with the smallest hardness (sample 2), medium hardness (sample 3), and the highest hardness value (sample 5). Calculation of the length of the pore area using the Image application.

From the results of the SEM test, the surface microstructure of the oxide ceramics was obtained as shown below:

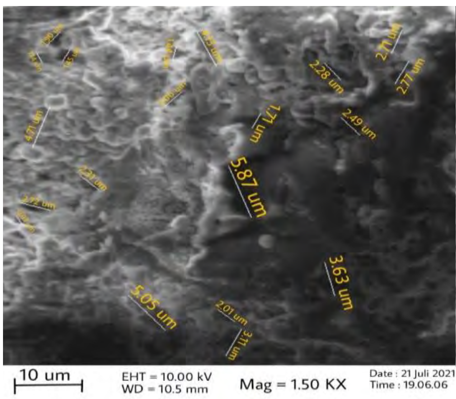

Figure 1. SEM sample 2

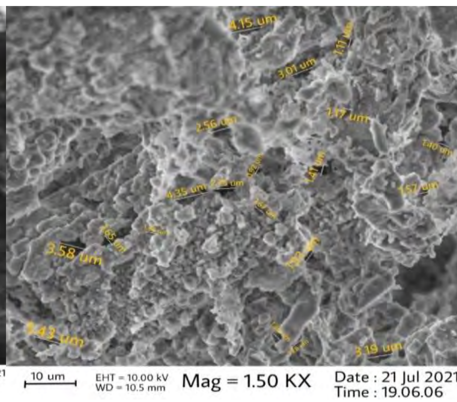

Figure 1. SEM sample 3

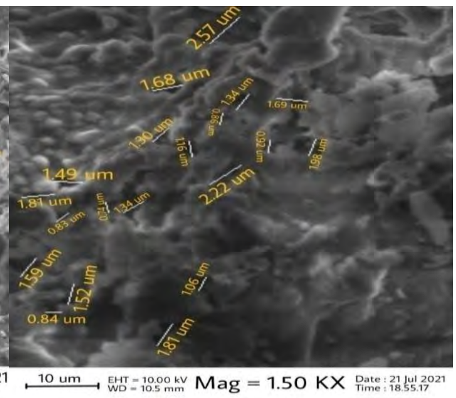

Figure 3. SEM sample 5

In Figure 1, $MgO-SiO_2-Al_2O_3$ oxide ceramics with the smallest hardness have an average pore length of 2.72 µm. In this image, many large pores appear due to the addition of many MgO elements (Maharani et al., 2017) which causes more pores and lower hardness values. In Figure 2, $MgO-SiO_2-Al_2O_3$ oxide ceramics with moderate hardness have an average pore length of 2.22 µm. It can be seen in the image that the homogenization of the material is quite good, although from the observations in the picture there are still visible pores, but not too many. In Figure 3, $MgO-SiO_2-Al_2O_3$ oxide ceramics with moderate hardness have an average pore area of 1.40 µm. In this picture, there are not many pores that appear because of the many additions of $SiO_2-Al_2O_3$ elements which contribute significantly to the mechanical properties, hardness, and high strength (Raharjo, 2015) causing the hardness value in sample 5 to be the highest among other samples.

Conclusion

The increase in the dielectric constant value of the variation in the $MgO-SiO_2-Al_2O_3$ ceramic composition is caused by the more significant variation in the composition of MgO, when the MgO level increases, the value of the dielectric constant increases, it has the potential to store electric charge. However, increasing levels of MgO cause many large pores to appear, causing more pores and lower hardness values. The increase in the hardness value of the variation in the composition of the $MgO-SiO_2-Al_2O_3$ ceramics was due to the increased levels of $SiO_2-Al_2O_3$ and a decrease in the number of pores. And if the number of pores decreases in the microstructure, the hardness value tends to increase. Of the 5 samples that have been studied, the best sample used to be applied as a ceramic capacitor material which has a hardness value of 45.98 and a dielectric constant value of 44.15 is sample 3, because it has a fairly good dielectric constant value, moderate hardness value, and the microstructure of the number of pores that are not too many.

Acknowledgments

This research was funded by the DIPA of Medan State University for 2022. Under the Decree of the Chancellor of UNIMED No. 0141/UN33.8/PPKM/PT/2021 Dated 18 April 2022.

References

Arazaq, T., Safentry, A., & Husnah, H. (2021). Perbandingan pengolahan air limbah karet antara dua membran keramik. *Jurnal Pedoks*, *6*(1), 72–79. https://doi.org/10.31851/redoks.v6i1.5201

Atmoko, R. (2015). *Pengaruh Fraksi Volume terhadap Kekuatan Tarik Komposit Berpenuat Serat Rami dengan Matrik Polyester*. Teknik Universitas Lampung.

Barsoum, M. W. (2016). *Fundamentals of Ceramics*. McGraw Hill Companies, Inc.

Callister Jr, W. (2017). *Materials Science and Engineering: An Introduction 5th Edition*. John Wiley & Sons Incorporated.

Carp, O., Huisman, C. L., & Reller, A. (2014). Photoinduced Reactivity of Titanium Dioxide. *Progress in Solid State Chemistry*, *32*(1–2), 33–177. https://doi.org/10.1016/j.progsolidstchem.2004.08.001

Carter, C. B., & Grant., N. (2017). *Ceramic Materials Science and Engineering*. Princeton University Press.

Damayanti, H., Masturi, Y., & I. (2015). Pemanfaatan Limbah Daun Jambu dan Polimer Alami Getah Karet sebagai Bahan Alternatif Furniture. *Jurnal Fisika*, *5*(1), 23–30. https://doi.org/10.15294/jf.v5i1.7368

Gurbuz, M., Mahmut, C., & Erdem, K. (2018). Pengaruh waktu sintering suhu, dan penambahan graphene terhadap kekerasan dan struktur mikro komposit aluminium. *Jurnal Bahan Komposit*, *52*, 4.

Hull, D. (2016). *An Introduction to Composite Material*. Cambridge University Press.

Inkson, B. J. (2016). Scanning electron microscopy (SEM) and transmission electron microscopy (TEM) for materials characterization. *Materials Characterization Using Nondestructive Evaluation (NDE) Methods*, 17–43. https://doi.org/10.1016/B978-0-08-100040-3.00002-X

Kosasih, D. P. (2016). Analisis Material Isolotor Busi Panas Dengan Busi Dingin Menggunakan Perangkat Lunak Match Powder Diffraction. *Mesa Jurnal Fakultas Teknik Universitas Subang*, *2*(2), 23–55–9241. https://garuda.kemdikbud.go.id/documents/detail/2173982

Maharani, A., Sembiring, S., & Suroto, B. J. (2017). Pengaruh Penambahan Periclase (0,10,15)% terhadap Karakteristik Struktur dan Kekerasan Kordierit. *Jurnal Teori Dan Aplikasi Fisika*, *5*(1), 77–82. https://jurnal.fmipa.unila.ac.id/jtaf/article/view/1363

Matthews, F. L., & Rawlings, R. D. (2019). *Composite Material Engineering And Science*. Imperial College Of Science. Technology And Medi-cine.

Maulana, N. B. (2018). Pengaruh variasi beban indentor vickers hardness tester terhadap hasil uji kekerasan material aluminium dan besi cor. *Jurnal Teknik Mesin MERC*, *1*(1). https://jom.untidar.ac.id/index.php/merc/article/view/131

Mills, J. F. M. (2017). *The Pergamon Dictionary of Art*. Pergamon Press Ltd.

Mujib, S., & Muntini, M. S. (2013). Perancangan Sensor Kelembaban Beras Berbasis Kapasitor. *Jurnal Sains Seni Pomits*, *1*(1), 1–6. https://adoc.pub/perancangan-sensor-kelembaban-beras-berbasis-kapasitor.html

Nurzal, & Saputra N, A. E. (2013). Pengaruh komposisi fly ash dan suhu sinter terhadap kekerasan pada manufacture keramik lantai. *Jurnal Teknik Mesin*, *3*(1), 25–28.

Putra, A. M., Hartatiek, & Nasikhudin. (2012). *Pengaruh komposisi terhadap konstata dielektrik, kekerasan, dan mikrostruktur keramik oksida SiO2-MgO*. Universitas Negeri Malang. https://mill.onesearch.id/Record/IOS5407.slims-53505

Rahaman, M. N. (2017). *Pengolahan keramik dan sintering : edisi ke-2*. Pers CRC.

Raharjo. (2015). Pengaruh tingkat kemurnian bahan baku alumina terhadap temperatut sintering dan karakteristik keramik alumina. *Pengembangan Teknologi Kimia Untuk Pengelolahan SDM Indonesia*, 1693–4393. http://jurnal.upnyk.ac.id/index.php/kejuangan/article/view/404

Sidabutar, T. E. (2017). Pembuatan dan karakterisasi keramik magnesium alumina silika dari abu vulkanik gunung sinabung. *Jurnal Teknik Mesin*, *06*(1), 28–35. https://core.ac.uk/download/pdf/194442353.pdf

Sobirin, M., Nita Rosita, Fitriawan, M., Usriyah, F., Faizal, R., & Yulianto, A. (2016). Sintesis nanokomosit stronsium ferit-keramik porselin alumina sebagai peningkat struktur dielektrik kapasitor berbahan dasar pasir besi. *Journal of Creativity Students*, *1*(1), 1–5.

https://doi.org/10.15294/jcs.v1i2.7796

Tamalia, N., Sembiring, S., & Simanjuntak, S. (2017). Pengaruh Penambahan Alumina (0 dan 10 wt%) terhadap Karakteristik Termal (DTA-TGA) dan Konduktivitas Termal Bahan Keramik Kordierit Berbasis Silika Sekam Padi. *Jurnal Teori Dan Aplikasi Fisika*, *5*(1), 91–95. https://jurnal.fmipa.unila.ac.id/index.php/jtaf/article/viewFile/1365/1195

Utomo, H. P. (2013). *Pengaruh Lama Penggerusan terhadap Konstanta Dielektrik, kekerasan, dan Mikrostruktur Keramik Oksida SiO2- MgO*. Skripsi Jurusan Fisika-Fakultas MIPA UM.