OPEN ACCESS

Saudi Journal of Engineering and Technology
Abbreviated Key Title: Saudi J Eng Technol
ISSN 2415-6272 (Print) | ISSN 2415-6264 (Online)
Scholars Middle East Publishers, Dubai, United Arab Emirates
Journal homepage: https://saudijournals.com

Original Research Article

New Compounds for Electromagnetic Interference Shielding

Samir A Hamouda[1*], Naji S Amneenah[1]

[1]Department of Physics, University of Benghazi, Libya

DOI: 10.36348/sjet.2024.v09i03.005 | **Received:** 25.01.2024 | **Accepted:** 07.03.2024 | **Published:** 12.03.2024

***Corresponding author:** Samir A Hamouda
Department of Physics, University of Benghazi, Libya

Abstract

The impact of electromagnetic wave interference on electronic devices and the danger that can arise from it has become a problem that is being discussed at the international level. This paper discusses research on important and effective materials and compounds to be used for EMI shielding. In this paper, three basalt samples (A12, A14, and B12) have been selected and analyzed for reflection and absorption for RF and microwave frequencies.

Keywords: EMI, electrical conductivity, magnetic permeability, compounds, EMI shielding.

INTRODUCTION

The electromagnetic interference (EMI) is dangerous for our daily lives. It produces vital electronic failures. These problems are due to bad shielding materials for electronic systems. The classifications and properties of electromagnetic spectrum have been published elsewhere [1]. A detailed account of EMI impacts on our daily lives can be found in [2, 3].

The profound impacts of EMI and its consequences on critical functions of electronic systems are well established knowledge. It can be stated that, all electrical equipment using radio communication contains intentional emitters and sensitive receivers. Therefore, it was suggested that the study of the optical properties of materials is a central task for reducing the effect of EMI on the proper function of electronic devices. Since electrical and magnetic materials have different properties, the objective of this paper is to explore the shielding effectiveness of some new compounds that satisfies the effective shielding requirements.

Studying the EMI problem requires two important optical mechanisms for materials that should be taken into account. One is the absorption mechanism and the other is the reflection mechanism. The absorption mechanism is related to relative magnetic permeability (u_r) and the reflection mechanism is related to electrical conductivity (σ) and are given [4] as:

$$\text{Absorption loss} = \sigma.\mu_r \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$\text{Reflection loss} = \frac{\sigma}{u_r} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

For compounds and mixtures the Voigt model [5] has been used to estimate the electrical conductivity (σ) of compounds, given as.

$$\sigma_{total} = f_1\sigma_1 + f_2\sigma_2 + f_3\sigma_3 + \ldots\ldots\ldots\ldots (3)$$

Where σ_{total} is the total electrical conductivity, f_1, f_2, f_3…are the corresponding volume fractions and $\sigma_1, \sigma_2, \sigma_3$…are the conductivities constituents 1, 2, 3….. However, Equation 3 has been applied to verify the accuracy of the estimate values for electrical conductivity of several compounds comparing with the experimental data [6]. Table 1, Gives a Comparison between experimental and calculated values for electrical conductivity.

Table 1: Gives figures of merit for some calculations

Compound	σ (experimental)[6] (s/m)	$\sigma_{total}=f_1\sigma_1+f_2\sigma_2$ (s/m)
Cu (50%) Ag (50%)	6.4×10^{7}	6.1×10^{7}
Ag (99.75%) C (0.25%)	5.5 to 5.97×10^{7}	6.1×10^{7}
Cu (70%) Zn (30%)	1.6×10^{7}	4.6×10^{7}
Sn (62%) Pb (36%) Ag (2%)	8.1×10^{6}	8.6×10^{6}
Sn (60%) Pb (40%)	6.7×10^{6}	7.3×10^{6}
Ag (95%) Ni (5%)	4.6 to 5.5×10^{7}	5.9×10^{7}
Ag (48%) W (51.75%) C (0.25%)	3.8×10^{7}	4.0×10^{7}
Ag (90%) Fe (10%)	5.0 to 5.3×10^{7}	5.6×10^{7}
Ag (90%) W (10%)	5.2 to 5.5×10^{7}	5.7×10^{7}
Ag (10%) W (90%)	1.6 to 2.0×10^{7}	2.4×10^{7}
Cu (50%) W (50%)	2.6 to 3.7×10^{7}	3.9×10^{7}
Ag (35%) Mo (65%)	2.3 to 2.6×10^{7}	3.5×10^{7}
Sn (95%) Sb (5%)	6.9×10^{6}	8.7×10^{6}

The authors have also used the Voigt model, for the first time, to estimate the relative magnetic permeability (μ_r) of compounds as:

$$\mu_{rtotal} = f_1\mu_{r1} + f_2\mu_{r2} + f_3\mu_{r3}\ldots\ldots\ldots (4)$$

Where μ_{total} is the bulk relative magnetic permeability, $f_1, f_2, f_3\ldots.$ are the corresponding volume fractions and the relative magnetic permeability $\mu_{r1}, \mu_{r2}, \mu_{r3}\ldots$are the relative magnetic permeability constituents 1, 2, 3….

MATERIALS AND METHODS

In this study, three basalt rocks samples (A-14, A-18, B-12) as shown in figure1, were taken from the Gharyan Volcanic Province NW Libya area. Description of samples and method of analysis were described elsewhere [7].

Figure 1: Shows the basalt rock samples

Elemental composition and concentration analysis of basalt samples (A12, A14, and B12) are shown in table 2, the results of the elemental composition analyses were carried out using (TXRF) system at The Nuclear Research Center at Tripoli's Atomic Energy Organization.

Table 2: Elemental composition and concentration analysis of basalt samples

Element Z	Magnetic [8] Type	A-18 (ppm)	A-14 (ppm)	B-12 (ppm)
K	Paramagnetic	2660.00	7498.00	8726.98
Ca	Paramagnetic	31390.00	45257.59	32836.26
Mn	Paramagnetic	1560.00	1607.43	1331.07
Fe	Ferromagnetic	128130.00	120016	120017.97
Ni	Ferromagnetic	338.00	505.19	326.26
Zn	Diamagnetic	203.00	223.64	167.133
Sr	Paramagnetic	478.00	457.27	242.193
Ba	Paramagnetic	24200.00	30071.88	---
Mg	Paramagnetic	26946.00	28942.00	22854.20
Na	Paramagnetic	168662.00	203592.00	101796.00

The Bulk Vol. (A-18) 17.762, (A-14) 16.817, (B-12) 32.962 cm^3. The conversions from (ppm) to grams are calculated according to [9] as:

$$PPM = \frac{G}{T} \times 10^6 \text{ ……………………. (5)}$$

Where G is the mass of the substance in grams (g) and T is the total mass or volume of mixture. Table 3 summarizes the processes of calculations.

RESULTS AND DISCUSSION

Table 3: Calculations of electrical conductivities and relative magnetic permeability of three basalt rocks samples (A-14, A-18, B-12).

Element	B-12 (gm)	Atomic wt.	# of atoms	Vol. fraction f	σ (s/m)	μ_r
K	0.2876	39.09	4.43x1021	0.063	$1.4x10^7$	1.00
Ca	1.0823	40.07	1.6x1022	0.12	$2.9x10^7$	1.00
Mn	0.0438	54.93	4.8x1020	$1.99\ x10^{-3}$	$6.2x10^5$	1.00
Fe	3.9560	55.84	4.26x1022	0.16	$1x10^7$	5500
Ni	0.0107	58.69	1.1x1020	$3.60\ x10^{-4}$	$1.4x10^7$	300
Zn	0.0055	65.38	5.1x1019	$1.45\ x10^{-4}$	$1.7x10^7$	0.999
Sr	0.0079	87.62	5.5x1019	$5.74\ x10^{-4}$	$7.7x10^6$	1.000
Mg	0.7533	24.305	1.9x1022	0.058	$2.3x10^7$	1.000
Na	3.3553	22.989	8.8x1022	0.6	$2.1x10^7$	1.000
Element	**A-14 (gm)**	**Atomic wt.**	**# of atoms**	**Vol. fraction f**	**σ (s/m)**	**μ_r**
K	0.1260	39.09	1.9x1021	0.031	$1.4x10^7$	1.00
Ca	0.7610	40.07	1.1x1022	0.091	$2.9x10^7$	1.00
Mn	0.0270	54.93	3x1020	$1.42\ x10^{-3}$	$6.2x10^5$	1.00
Fe	2.0183	55.84	2.2x1022	0.095	$1x10^7$	5500
Ni	0.0084	58.69	8.7x1019	$3.25\ x10^{-4}$	$1.4x10^7$	300
Zn	0.0037	65.38	3.5x1019	$1.14\ x10^{-4}$	$1.7x10^7$	0.99
Sr	0.0076	87.62	5.3x1019	$6.31\ x10^{-4}$	$7.7x10^6$	1.00
Ba	0.5057	137.32	2.2x1021	0.041	$2.9x10^6$	1.00
Mg	0.4867	24.305	1.2x1022	0.041	$2.3x10^7$	1.00
Na	3.4238	22.989	9x1022	0.7	$2.1x10^7$	1.00
Element	**A-18 (gm)**	**Atomic wt.**	**# of atoms**	**Vol. fraction f**	**σ (s/m)**	**μ_r**
K	0.0472	39.098	7.3x1020	0.013	$1.4x10^7$	1.00
Ca	0.5575	40.078	8.3x1021	0.077	$2.9x10^7$	1.00
Mn	0.0277	54.938	3.0x1020	$1.58\ x10^{-3}$	$6.2x10^5$	1.00
Fe	2.2758	55.845	2.5x1022	0.12	$1x10^7$	5500
Ni	0.0060	58.693	6.1x1019	$2.56\ x10^{-4}$	$1.4x10^7$	300
Zn	0.0036	65.381	3.3x1019	$1.20\ x10^{-4}$	$1.7x10^7$	0.99
Sr	0.0084	87.623	6x1019	$7.99x10^{-4}$	$7.7x10^6$	1.000
Ba	0.4298	137.327	2x1021	0.041	$2.9x10^6$	1.000
Mg	0.4786	24.305	1.3x1022	0.050	$2.3x10^7$	1.000
Na	2.9957	22.989	8x1022	0.7	$2.1x10^7$	1.000

Table 4 lists the σ_{total} and $\mu_{r_{total}}$ for the three basalt rocks samples (A-14, A-18, B-12).

Table 4: The electrical conductivities and relative magnetic permeability for three basalt rocks samples (A-14, A-18, B-12) relative to copper

Sample	σ_{total} (s/m)	$\mu_{r_{total}}$	$\sigma_{total}/\mu_{r_{total}}$	$\cdot\ \mu_{r_{total}}\sigma_{total}$
B-12	0.34	880.95	$3.9x10^{-4}$	299.5
A-18	0.33	660.96	$5.0x10^{-4}$	218.1
A-14	0.34	523.50	$6.5x10^{-4}$	178.0

It can be stated that the absorption property of shielding material is characterized by the term skin depth (δ). The skin depth δ is defined as the minimum thickness or the distance over which the magnitude of the electric and magnetic field is attenuated to 1/e ≅0.3681 (37%) of its initial strength. The skin depth (δ) is given [10, 1 1] as:

$$\delta = \frac{1}{\sqrt{\pi\sigma\mu f}} \text{ ……………………….(6)}$$

Where: f is frequency, μ is magnetic permeability ($\mu_0\mu_r$), μ_r is relative magnetic permeability, $\mu 0 = 4\pi\ x10^{-7}$ H/m, and σ is the electrical conductivity (Ω^{-1}. m^{-1}). It can be seen from equation that it depends on conductivity, magnetic permeability and frequency of the incident wave. As these parameters increase, the thickness of the shielding material decreases.

Table 5 gives the skin depth (δ) values for the three basalt rocks samples (A-14, A-18, B-12), using equation6.

Table 5: Calculated skin depth (δ) for basalt rocks samples. Parameters are shown

Sample	at 1kHzδ(mm)	(μm) at 1MHzδ	at 1GHzδ(μm)
A-14	0.16	4.9	0.16
A-18	0.13	4.42	0.14
B-12	0.120	3.8	0.12

It can be seen from table4 that the electrical conductivity for the compound samples are almost the same, due to the magnetic nature of the compounds constitutes (i.e ferro and paramagnetic, see table2). Also the magnetic permeability of the compound samples depends strongly on the elemental concentrations which possess magnetic properties.

It can also be seen from table4, that for such basalt rock samples (A-14, A-18, B-12) have strong absorption mechanism for electromagnetic waves. On the other hand, the electrical conductivities for these basalt rock samples are very small, which implies very low reflection mechanism for electromagnetic waves. Therefore, it can be concluded that basalt rock samples (A-14, A-18, B-12) are excellent materials for absorption of Rf signals and are very good shielding materials for electromagnetic interference (EMI).

CONCLUSION

Analysis of basalt rock samples (A-14, A-18, B-12) that were taken from the Gharyan Volcanic Province NW Libya area have shown that these rocks have good property of absorbing RF waves and can be designed as a radio frequency (RF) effective shielding materials. They have light weights and easy to form and fabricate and cost effective.

Acknowledgement

We would wish to express our gratitude to the Head of The Nuclear Research Center in Tripoli's Atomic Energy Organization for his kind support. Special thanks also to Dr.Hamza Break Hamza at The Nuclear Research Center at Tripoli's Atomic Energy Organization for carrying out the analysis and for his fruitful discussions about this work.

REFERENCES

1. Hamouda, S. A., Ibrahim, M. K., & Mohamed, M. B. (2021). The Electromagnetic Spectrum: Knowledge and Experimental Techniques. *Engineering and Scientific International Journal*, *8*(4).
2. Hamouda, S. A., & Amneenah, N. S. (2024). Electromagnetic Interference Impacts on Electronic Systems and Regulations. *International Journal of Advanced Multidisciplinary Research and Studies*, *4*(1), 124-127.
3. Samir, A. H. (2024). "Electrical and Magnetic Properties of Materials for Electromagnetic Interference"., *International Journal of Advanced Multidisciplinary Research and Studies*, *4*(1), 1249-1252.
4. Chung, D. D. L. (2000). Materials for Electromagnetic Interference Shielding. *Journal of Materials Engineering and Performance*, *9*(3), 350-354.
5. Han, K., & Clark, S. M. (2021). Review of calculating the electrical conductivity of mineral aggregates from constituent conductivities. *Solid Earth Sciences*, *6*(2), 111-128.
6. Charles, M. (2000). "Electrical and Magnetic Properties of Metals"., ASM Ready Reference, www.asminternational.org
7. Hamouda, S. A., Abdelmalik, M. B., & al-Talhi, E. A. Q. (2014). Porosity measurements for some basalt rocks from the Gharyan Volcanic Province NW Libya. *Earth Science*, *3*(1), 26-30. http://www.sciencepublishinggroup.com/j/earth
8. https://periodictable.com/Elements/016/data.html
9. Grams To Ppm Calculator - Calculator Academy
10. Chung, D. D. L. (2000). Materials for electromagnetic interference shielding. *Journal of Materials Engineering and performance*, *9*, 350-354.
11. Weibler, J., & Enclosures, L. R. (1993). Properties of Metals used for RF shielding. *EMC Test and Design*, 100.

