International Journal of Innovative Scientific & Engineering Technologies Research 13(1):1-14, Jan-Mar., 2025

© SEAHI PUBLICATIONS, 2025 www.seahipublications.org ISSN: 2360-896X

10.5281/zenodo.14598154

Development of an Electromagnetic Interference (EMI) Shielding Material Using Local Rice straw for an Industrial Application

[*1]Garba Anas Abubakar, [2]Shehu Ibrahim Gajo, [1]Musa Lawal, [3]Bashir Salisu

[1]Department of Electrical And Electronics Engineering
Katsina State Institute of Technology and Management, Katsina, Katsina State Nigeria

[2]Department of Computer Engineering Technology
Katsina State Institute of Technology and Management, Katsina, Katsina State Nigeria

[3]Department of Basic and Applied Sciences,
College of Science and Technology,
Hassan Usman Katsina Polytechnic, Katsina, Katsina State Nigeria

***Corresponding Author: fatminmed@gmail.com,**

ABSTRACT

The rapid proliferation of electronic devices and industrial technologies has amplified the challenge of electromagnetic interference (EMI), which disrupts the functionality and reliability of sensitive equipment. This study investigates the development of an innovative EMI shielding material derived from locally sourced rice straw, an abundant agricultural by-product. The primary goal is to provide a sustainable, cost-effective, and lightweight alternative to conventional shielding materials. Rice straw was processed and incorporated into polymer matrices with conductive fillers to create composite materials in the ratio of rice husk (RH)-Polymer (P) of 90:10, 80:20,70:30, 60:40 and 50:50. The series composites were characterized for their structural, thermal, electrical, and EMI shielding properties using techniques such as X-ray diffraction (XRD), scanning electron microscopy (SEM), fourier transform microscopy (FTIR) and vector network analysis. Results demonstrated that rice straw-based composites achieve shielding effectiveness (SE) values ranging from 20 dB to 40 dB in the frequency range of 8 GHz to 12 GHz, depending on the filler concentration. The 50:50 ratio was found to have highest shielding effectiveness due to the stability of the composite. The materials also exhibited excellent electrical conductivity and lightweight properties, making them ideal for applications in electronics, telecommunications, automotive, and aerospace industries. This research highlights the potential of agricultural residues to address critical industrial challenges, paving the way for eco-friendly and scalable solutions.

Keywords: Electromagnetic interference, Electronic devices, Shielding material, Rice straw, Conducting polymer

1.0 INTRODUCTION

The increasing prevalence of electronic devices has led to a significant rise in electromagnetic interference (EMI), which can adversely affect electronic equipment and human health **[1]**. This necessitates the development of an effective EMI shielding materials. Recent research has explored various natural materials, including rice straw, as potential candidates for EMI shielding due to their sustainability, cost-effectiveness, and availability **[2]**. This research, provide a novel procedure for the development of EMI shielding materials using local rice straw, focusing on their properties, mechanisms, and potential industrial applications.

1.1 Background on Electromagnetic Interference (EMI)

Electromagnetic interference refers to the disruption caused by electromagnetic radiation emitted from electronic devices **[3]**. This interference can lead to malfunctions in sensitive equipment and pose health risks [4]. The primary methods for mitigating EMI include reflection, absorption, and transmission loss through the use of shielding materials [5]. Effective EMI shielding materials must possess high electrical conductivity, appropriate thickness, and low weight to be viable for industrial applications [6]. The effectiveness of EMI shielding materials is determined by their ability to reflect and absorb electromagnetic waves [7]. For rice straw-derived materials, the mechanisms include: Reflection where conductive components in the composite reflect incoming electromagnetic waves, the absorption in which the porous structure of the carbonized rice straw allows for energy dissipation through thermal conversion and multiple Scattering by which the fibrous nature of the material leads to multiple scattering events that enhance overall shielding performance [8].

1.2 Properties of Rice Straw as an EMI Shielding Material

Rice straw is an abundant agricultural byproduct that can be transformed into valuable materials for EMI shielding. Its advantages include: Biodegradability: Rice straw is a natural fiber that decomposes easily, making it environmentally friendly. Cost-effectiveness: As a waste product, rice straw is inexpensive compared to synthetic materials [9]. Thermal Stability: Treated rice straw can withstand high temperatures without degrading. Processability: Rice straw can be processed into various forms, including fibers and biochar, enhancing its versatility in applications [10].

2.0 MATERIAL AND METHOD

The development of EMI shielding materials from rice straw involves the collection and preparation of local rice straw to remove impurities, followed by chemical treatment where by the straw undergoes chemical treatment (I.e., alkali treatment) to enhance its properties by removing lignin and hemicellulose, resulting in cellulose-rich fibers [11]. The treated fibers were then carbonized at high temperatures to produce biochar, which exhibits improved electrical conductivity suitable for EMI shielding applications [11]. The carbonized rice straw was then combined with conductive polymers fillers to form composites in different ratios to identified the correct stoichiometry for an enhance EMI shielding effectiveness.

2.1 Characterization

The fabricated composites were subjected to the following tests: Structural Analysis: X-ray diffraction (XRD), fourier transform microscopy (FTIR) and scanning electron microscopy (SEM) were used to analyze the microstructure and particle distribution. Also, four-point probe measurements were conducted to evaluate the electrical conductivity of the composites.

2.2 Performance Evaluation

To assess the performance of rice straw-based EMI shielding materials, the shielding effectiveness (SE) of the materials was measured using a vector network analyzer in the frequency range of 8 GHz to 12 GHz.

3.0 RESULT AND DISCUSSION

3.1 X-ray diffraction (XRD)

X-ray diffraction (XRD) is a powerful technique used to analyze the crystallographic structure of materials by measuring the diffraction pattern produced when a sample is exposed to X-rays. the fabricated series EMI shielding material obtained from rice husk, was analyzed using XRD to understand their crystalline structure and composition **[13]. Rice Husk**: Rice husk is primarily composed of cellulose, hemicellulose, lignin, and silica. When analyzing rice husk using XRD, the diffraction pattern will primarily show peaks corresponding to the crystalline structure of silica. This is because silica (SiO_2) is one of the major components of rice husk and exists in a crystalline form known as α-cristobalite or β-cristobalite [1]. The XRD analysis can provide valuable information about the crystalline phases present in rice husk, which can be useful for various applications such as agricultural research and biomass utilization. The analysis can help in understanding the structural properties and potential uses of these agricultural byproducts.

Figure 1, shows the XRD pattern of the crushed powder of the series EMI shielding materials. The XRD pattern shows that at 2θ = 22.01° the broadening peak of silica peak diffraction was identified throughout the samples series as supported by ICDD # 00-003-0226 [4]. It is assumed that silica has an amorphous-like structure obtained from rice husk (RH). The XRD pattern shows the silica phase with a narrower peak compared to the broad peak at 2θ = 16.33° obtained from polymer. These results were found to be of high purity as there is no additional peak of impurity was detected throughout the EMI shielding materials **[5].** In the XRD diffractogram, there is no significant change on the silica phase, but the cellulose intensity reduces to the normal level carbon line peaks. It concludes that the RH 50%: polymer 50% ratio was the best combination due to its smooth nature of crystal peaks **[5]** and the broadening peaks diffraction in the silica was due to the pores formed as seen in the SEM images. So also, the result explained that the wide-angle x-ray diffraction (WAXRD) had amorphous-like pattern that corresponded to the existence of a large porous in the material. The same pattern has been shown in the SEM spectroscopy **[5].**

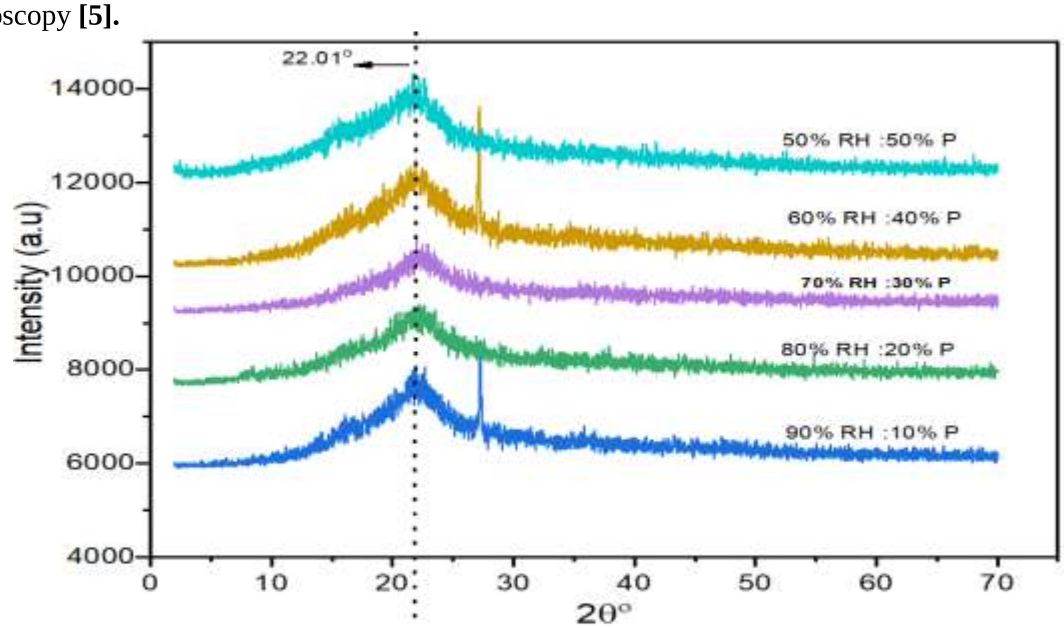


Figure 1: XRD Spectra for a Series EMI shielding material

3.2 Fourier Transform Infrared Spectroscopy (FTIR)

The fourier transform infrared spectroscopy (FTIR) is another analytical technique commonly used to characterize the chemical composition of materials based on their molecular vibrations. In this research the FTIR was applied to analyze rice husk EMI shielding material. FTIR can identify characteristic absorption bands for cellulose, hemicellulose, and lignin present in rice husk. So also, FTIR can identify characteristic absorption bands for various lipid components including triglycerides, fatty acids, and esters [6].

By employing FTIR analysis on rice husk sample intended for fuel production, researchers can make informed decisions regarding feedstock selection, process optimization, and overall feasibility of biofuel production from these agricultural residues. This helps in developing sustainable and efficient biofuel production processes [7]. The functional groups observed by FTIR in this research was tabulated along with their wavenumber in **Table 1.** And for understanding the functional groups were categorized in into regions as can be seen in **Figure 2**. The results obtained is in its pure form as no any peaks of impurity was detected and the sample is expected to be a good material for energy production as it was found to be in line with the reported literature [8].

Table 1: The FTIR Vibrational mode for EMI shielding material functional group

S/NO	Wavenumber (cm^{-1})	Vibrational Mode	Reference
1	1023	Si-O, stretching	[6]
2	1644	Si-OH, bending	[6]
3	2090	Si-O-Si, stretching	[7]
4	2921	OH, skeletal vibrations	[7]

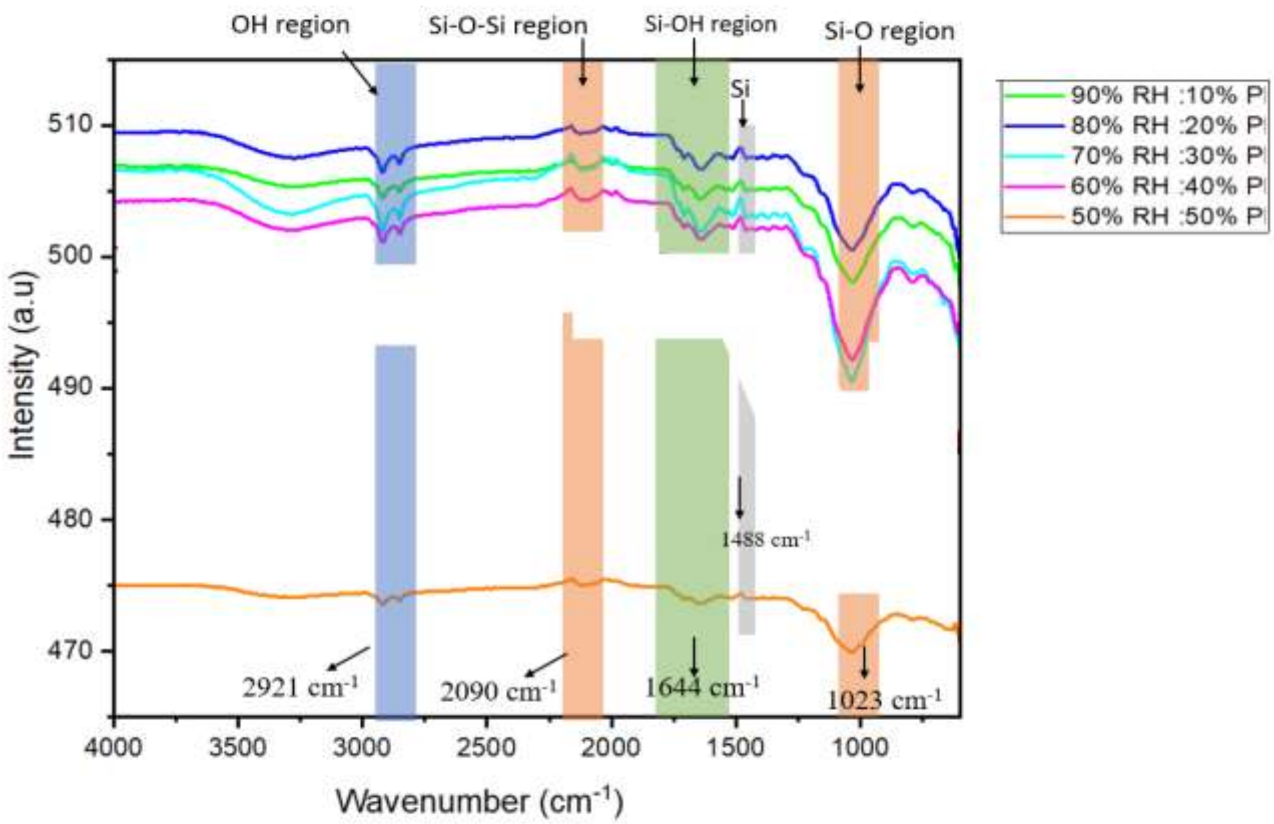


Figure 2: FTIR Spectra for the series Rice Husk EMI shielding material

3.3 Scanning Electron Microscopy (SEM)

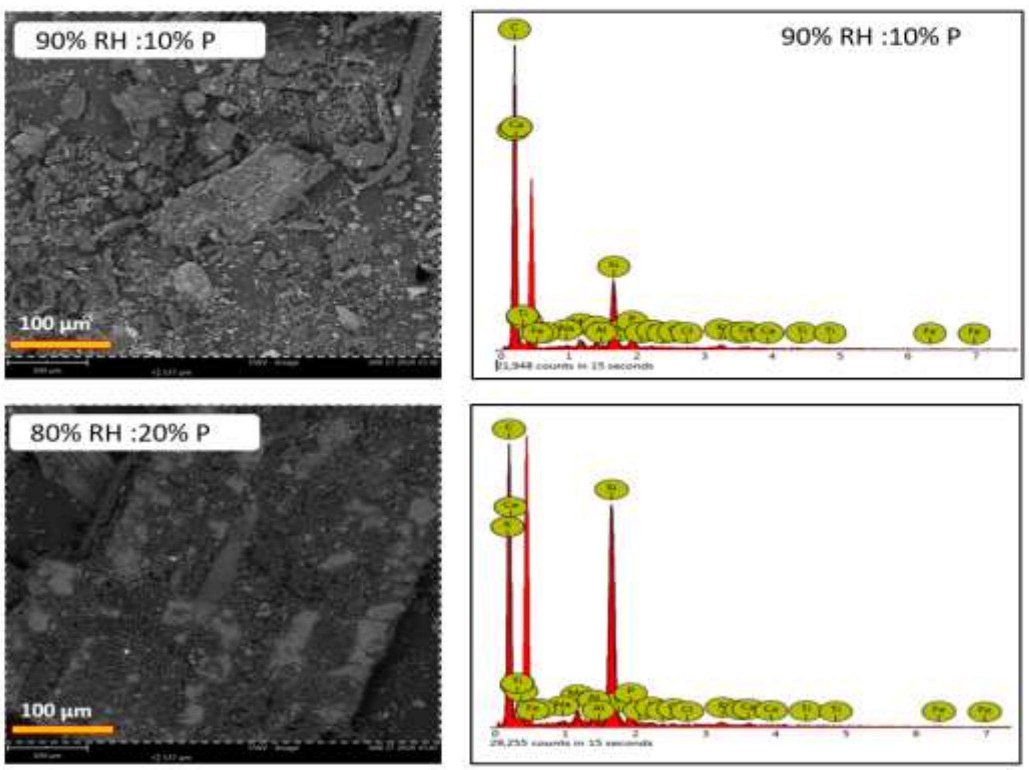
Scanning Electron Microscopy (SEM) is a powerful imaging technique that provides detailed surface morphology and microstructural information at high magnifications. In the context of fuel applications, SEM can offer valuable insights into the physical characteristics and structural properties of biomass feedstocks such as rice husk [9]. **Rice Husk**: Surface Morphology: SEM can reveal the surface morphology of rice husk particles, including their size, shape, and surface texture. This information is important for understanding the physical properties of rice husk as a potential fuel for bioenergy production. SEM can provide detailed images of the internal microstructure of rice husk, including the arrangement of cellulose, hemicellulose, lignin, and silica components. Understanding the microstructure helps in optimizing biomass conversion processes such as pyrolysis, gasification, or combustion. It can characterize the pore structure of rice husk, including the size, distribution, and connectivity of pores.

This information is relevant for assessing the accessibility of reactive sites and the diffusion of gases or liquids during biomass conversion processes (3).

Figure 3. shows scanning electron microscope (SEM) images of series EMI shielding material along with their EDX graphs, it is observed that the series EMI shielding material contained a sandwich of large and small particles with irregular shape that are uniformly distributed and the morphological structure of the series EMI shielding material is found to be inhomogeneous as it was mixed in different percentages of RH and polymer. The SEM micrographs for the studied sample are at 100 μm magnification. The samples surface appeared with a complex morphology showing randomly arranged small platelets ranging from 20 to 105 μm as revealed by the ImageJ software. On the other hand, some particles showed hexagonal corners and edges in their structure especially in the RH high concentration region.

The 100% rice husk (RH) was found to be large size particles and a rough surface. Meanwhile the 100% polymer was found to have a smooth surface. The 90%HR: 10% polymer was found to have high granules of silica due the high % of rice husk whereas the particles size of the decreases with the increase of polymer % that smoothen the surface morphologies of the 80%HR: 20% polymer, 70%HR: 30% polymer, 60%HR: 40% polymer, and 50%HR: 50% polymer. The result is good agreement with the reported literature [9].

The EDX results confirmed the XRD and chemical composition analysis, demonstrating that calcium, silicon and carbon are the predominant constituents in the series EMI shielding material samples as also depicted in Figure 3.



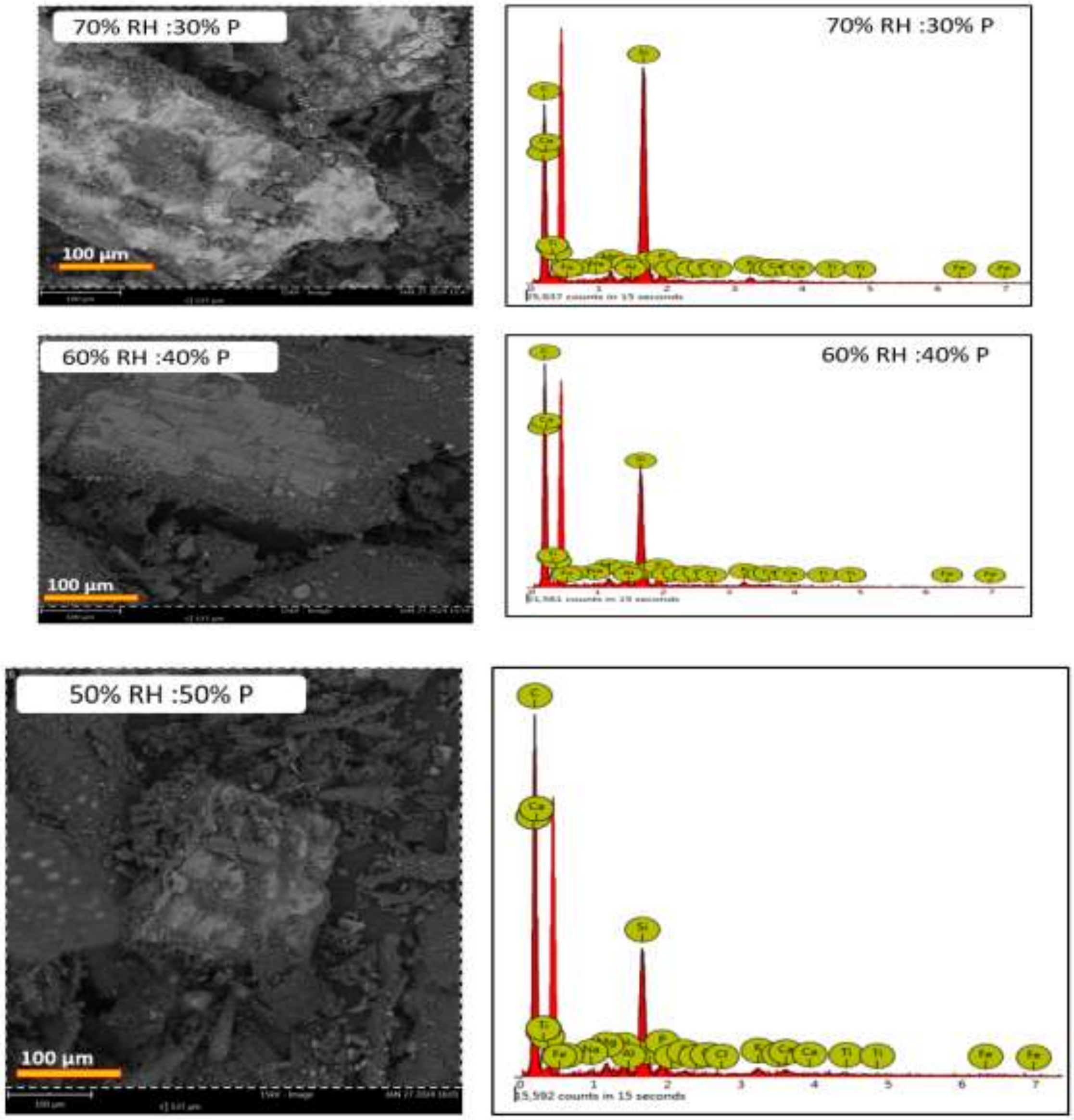


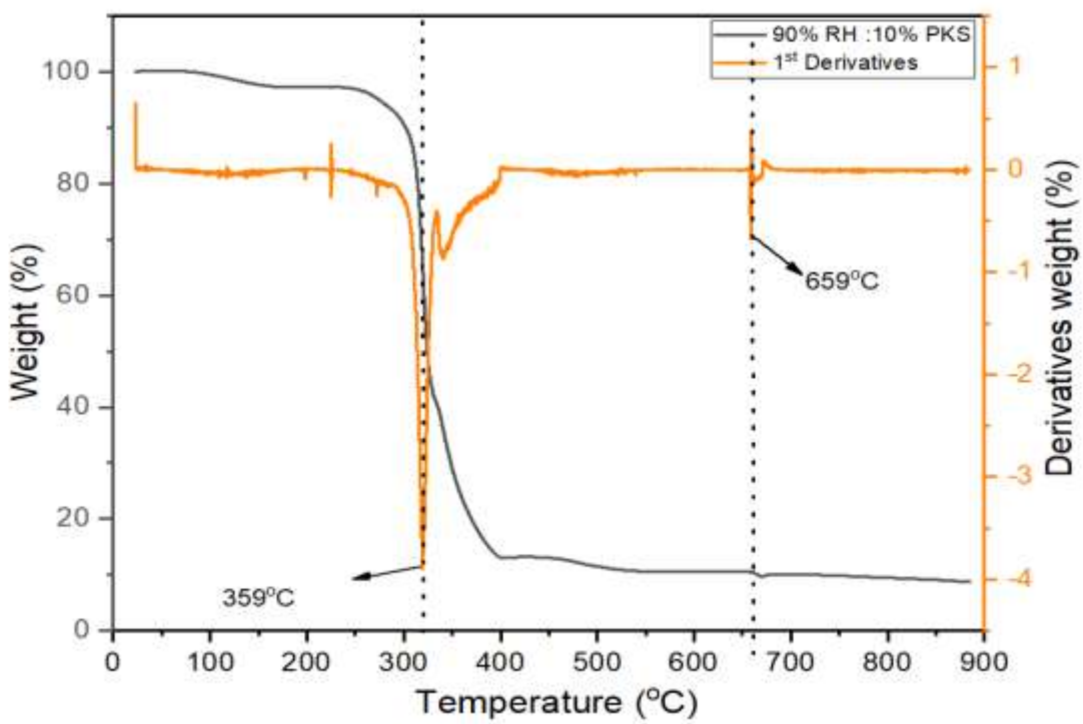
Figure 3: SEM images along with EDX graphs for the series Rice Husk EMI shielding material

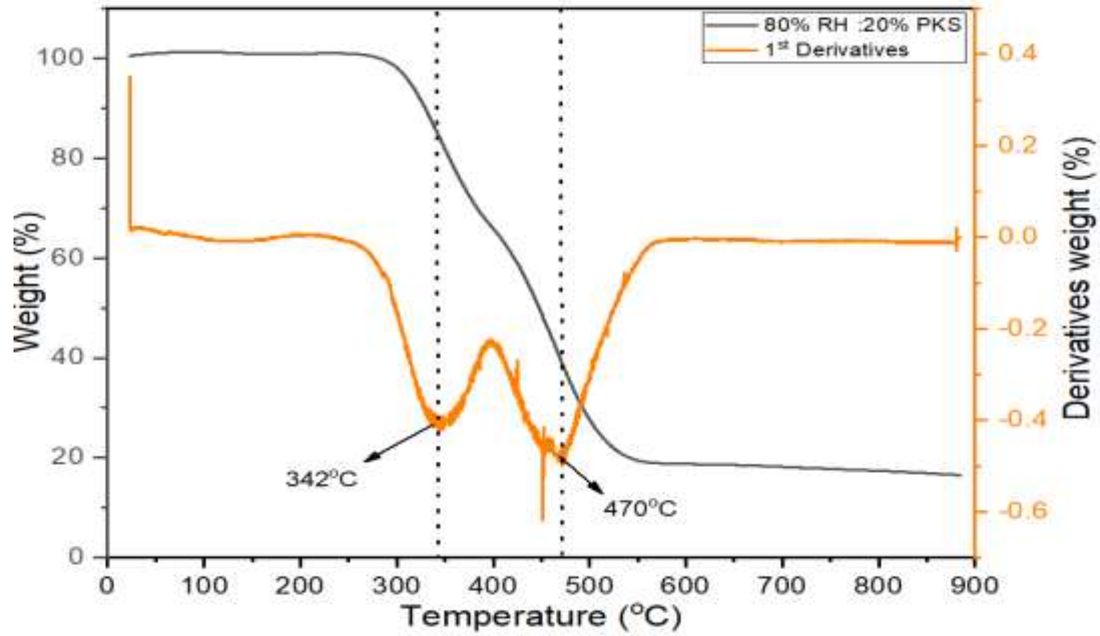
3.4 Thermogravimetric analysis (TGA)

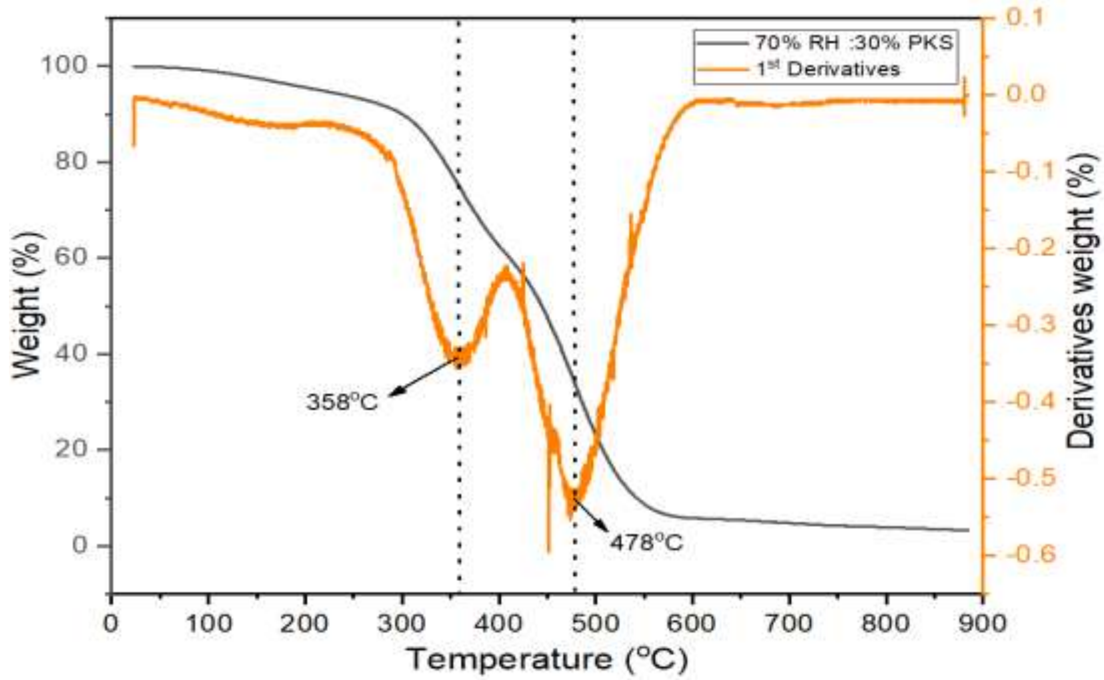
Thermogravimetric analysis (TGA) is a technique used to characterize the thermal properties of materials by measuring their weight changes as a function of temperature. In the context of fuel applications, TGA can provide crucial information about the thermal decomposition behavior, combustion characteristics, and energy content of biomass feedstocks such as rice husk. The thermal decomposition profile can reveal the temperature at which rice husk starts to decompose, as well as the rate and extent of decomposition over a range of temperatures. This information is essential for optimizing the pyrolysis or combustion process in fuel production. Also, TGA can elucidate the thermal decomposition behavior of palm kernel, including the onset temperature of decomposition, rate of mass loss, and char formation. This information guides the design and optimization of pyrolysis or combustion processes for palm kernel-based biofuels **[10].** By conducting TGA analysis on rice husk used in the series EMI shielding material intended for fuel applications, researchers can better understand their thermal behavior, combustion kinetics, and suitability for various bioenergy conversion processes. This aids in the development of efficient and sustainable fuel production technologies using agricultural residues **[10].** The RH and polymer ratio percentages, they shown only two decomposition curve which revealed the maximum stability temperature of the briquette stating materials i.e., rice husk , shell respectively as summarized in the Table 2 below. It was equally observed that the 50% RH: 50% polymer is the best ratio that withstand high temperature with the higher percentage of 41% at 359 ºC.

Table 2: TGA results for the series Rice Husk EMI shielding material

	1st curve		**2nd curve**	
Sample Ratio	**Weight (%)**	**Stability Temperature (ºC)**	**Weight (%)**	**Stability Temperature (ºC)**
90% RH: 10% P**olymer**	10	359	75	659
80% RH: 20% P**olymer**	30	342	20	470
70% RH: 30% P**olymer**	40	358	10	478
60% RH: 40% P**olymer**	25	335	11	496
50% RH: 50% P**olymer**	41	359	10	478




80% RH :20% PKS
1st Derivatives
342°C
470°C
Weight (%)
Derivatives weight (%)
Temperature (°C)


70% RH :30% PKS
1st Derivatives
358°C
478°C
Weight (%)
Derivatives weight (%)
Temperature (°C)

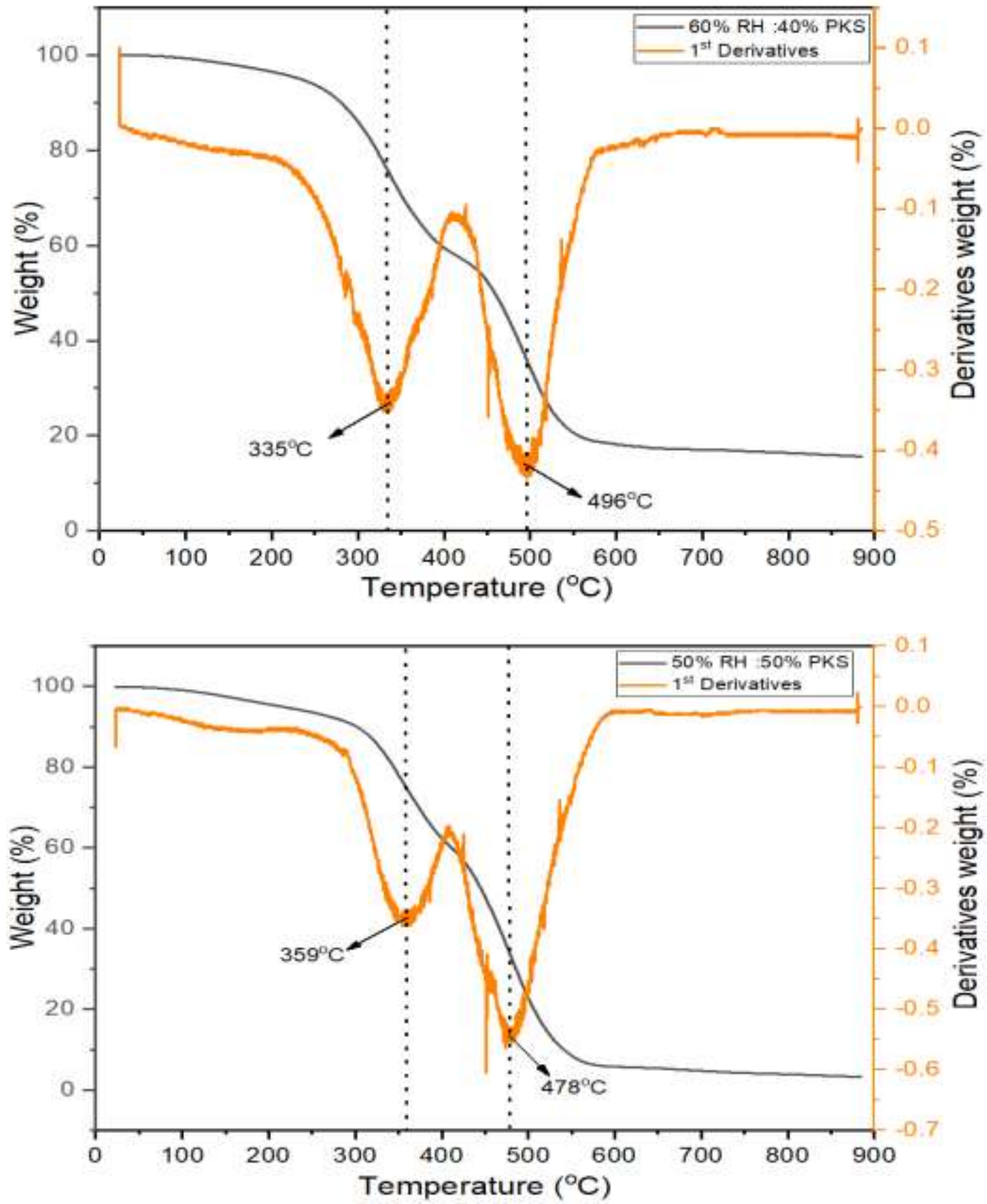


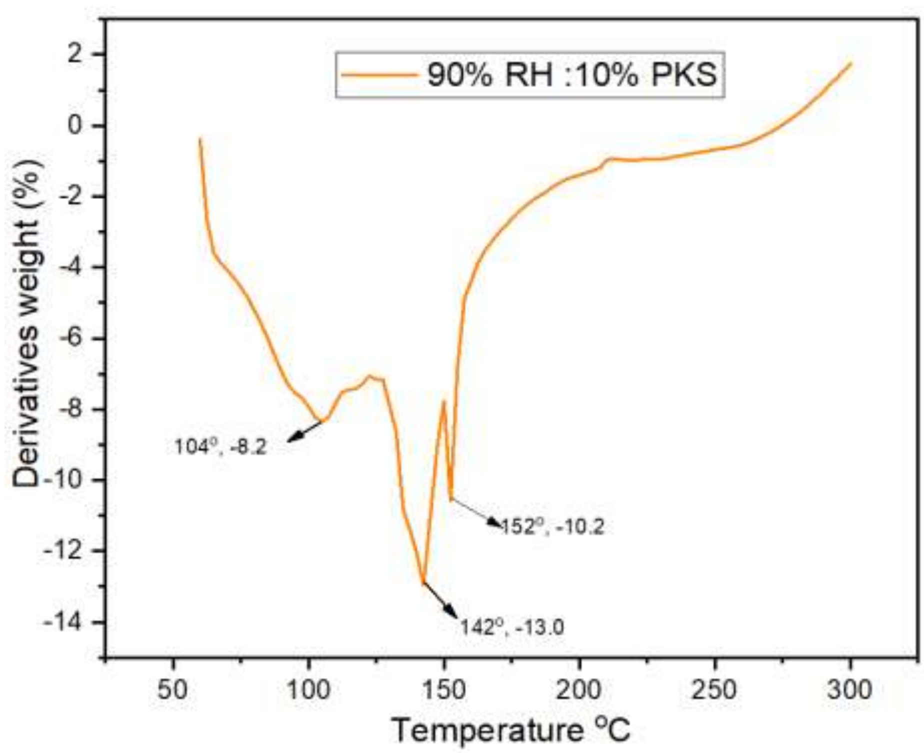
Figure 5: TGA Analysis the series Rice Husk EMI shielding material

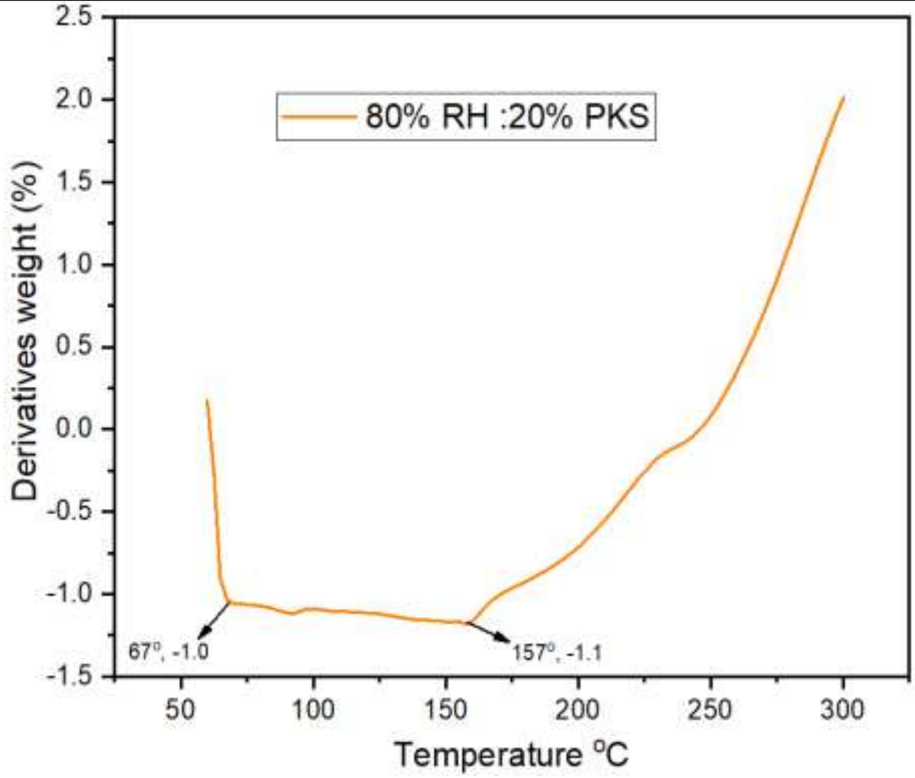
3.5 Differential Scanning Calorimetry (DSC)

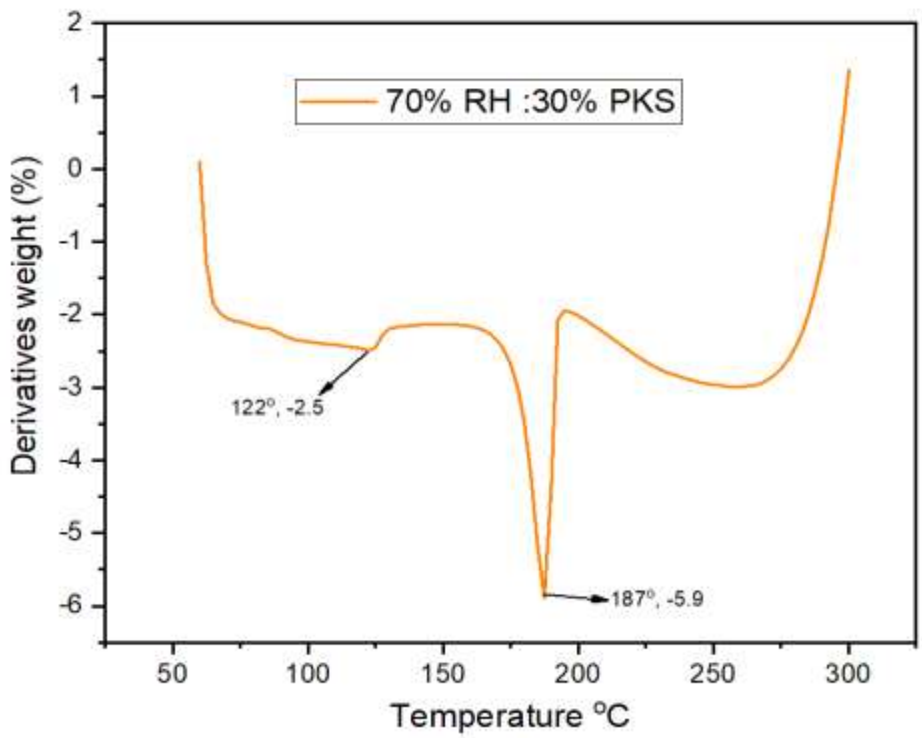
The Differential Scanning Calorimetry (DSC) is a thermal analysis technique used to measure the heat flow associated with physical and chemical changes in materials as a function of temperature. In the context of fuel applications, DSC can provide valuable insights into the thermal properties and behavior of biomass feedstocks like rice husk [11,12]. DSC can reveal the thermal stability of rice husk and crystallization behavior of palm kernel shell by detecting the onset of decomposition and the heat flow associated with various degradation reactions. This information helps in determining the temperature range for safe handling and processing of rice husk in fuel production [13]. In this research, the stability temperature and maximum temperature of heat flow was detected using DSC spectroscopy as tabulated in Table 3. The thermal heat flow of the series EMI shielding material found to be in difference stages due to the amorphous nature of the sample as shown in Figure 5. It was equally observed that the 50% RH: 50% **polymer** is the best ratio that withstand high thermal heat flow with the higher temperature at 127 º C.

Table 3: a summary of DSC Derivative Thermal Heat Flow the EMI Shielding Material

	1st curve		**2nd curve**		**3nd curve**	
Sample Ratio	Derivatives Weight (%)	Maximum thermal heat flow Temperature (ºC)	Derivatives Weight (%)	Maximum thermal heat flow Temperature (ºC)	Derivatives Weight (%)	Maximum thermal heat flow Temperature (ºC)
90% RH: 10% P**olymer**	-8.2	104	-13.0	142	-10.2	152
80% RH: 20% P**olymer**	-1.0	67	-1.1	157		
70% RH: 30% P**olymer**	-2.5	122	-5.9	187		
60% RH: 40% P**olymer**	-3.6	79.8	-4.0	99.8		
50% RH: 50% P**olymer**	-3.2	127				




80% RH :20% PKS
Derivatives weight (%)
Temperature °C
67°, -1.0
157°, -1.1
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
50
100
150
200
250
300


70% RH :30% PKS
Derivatives weight (%)
Temperature °C
122°, -2.5
187°, -5.9
2
1
0
-1
-2
-3
-4
-5
-6
50
100
150
200
250
300

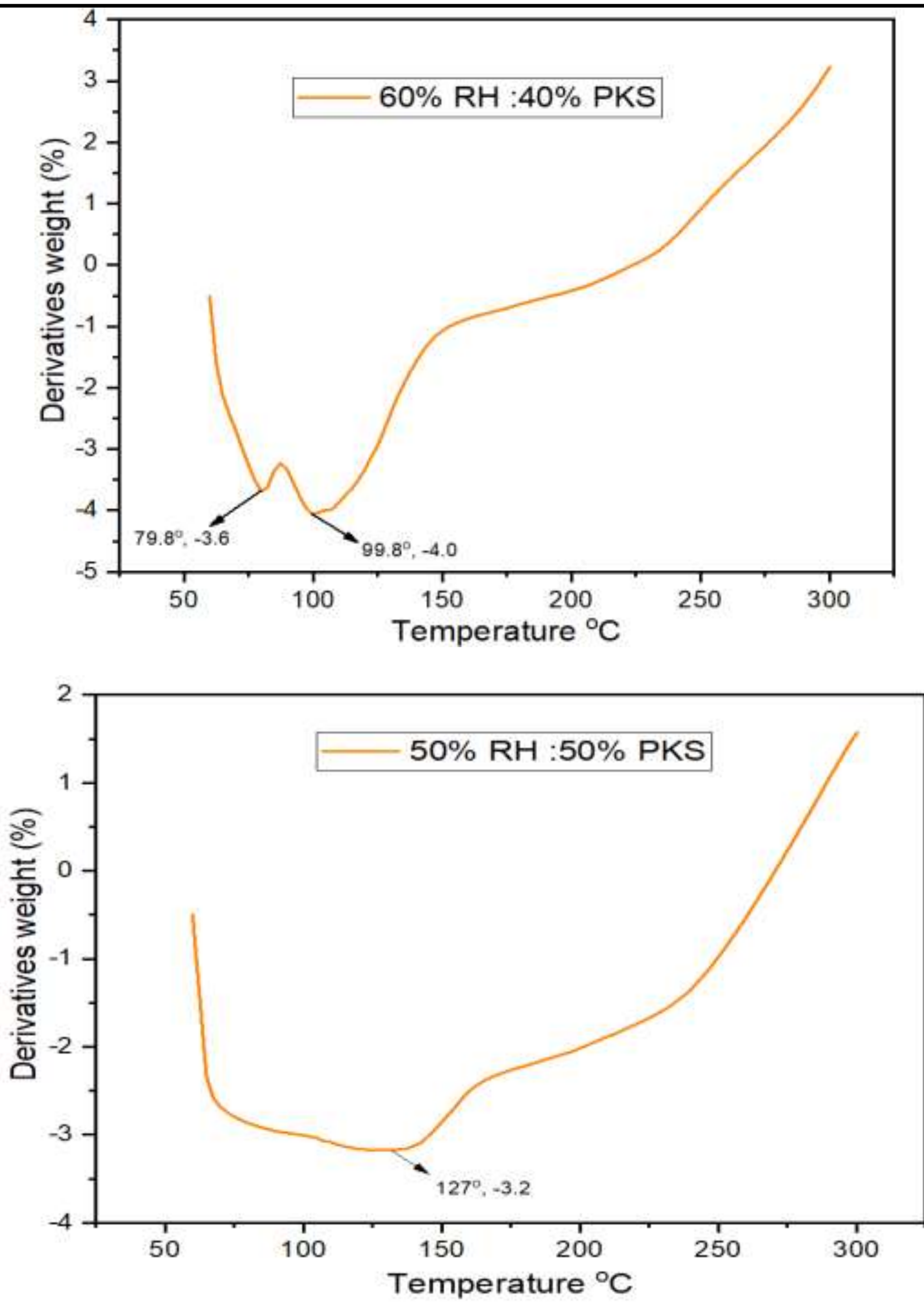


Figure 6: DSC Analysis for the for the series Rice Husk EMI shielding material

3.6 The shielding effectiveness (SE)

Figure 7 shows the **shielding effectiveness** results due to absorption (SE_A) of the sample. For the rice husk (RH)-Polymer ratio of 90:10, 80:20,70:30, 60:40 and 50:50, out of the 50:50 ratio was found to have highest shielding effectiveness of 37.7 (dB) due to the stability of the composite. This value is equivalent to almost the EM energy being shielded from absorption. The SEA value was observed to increase as the concentration of conducting polymer was increased. At 90:10 ratio, the lowest SEA was observed due to the lowest concentration of conducting polymer filler.

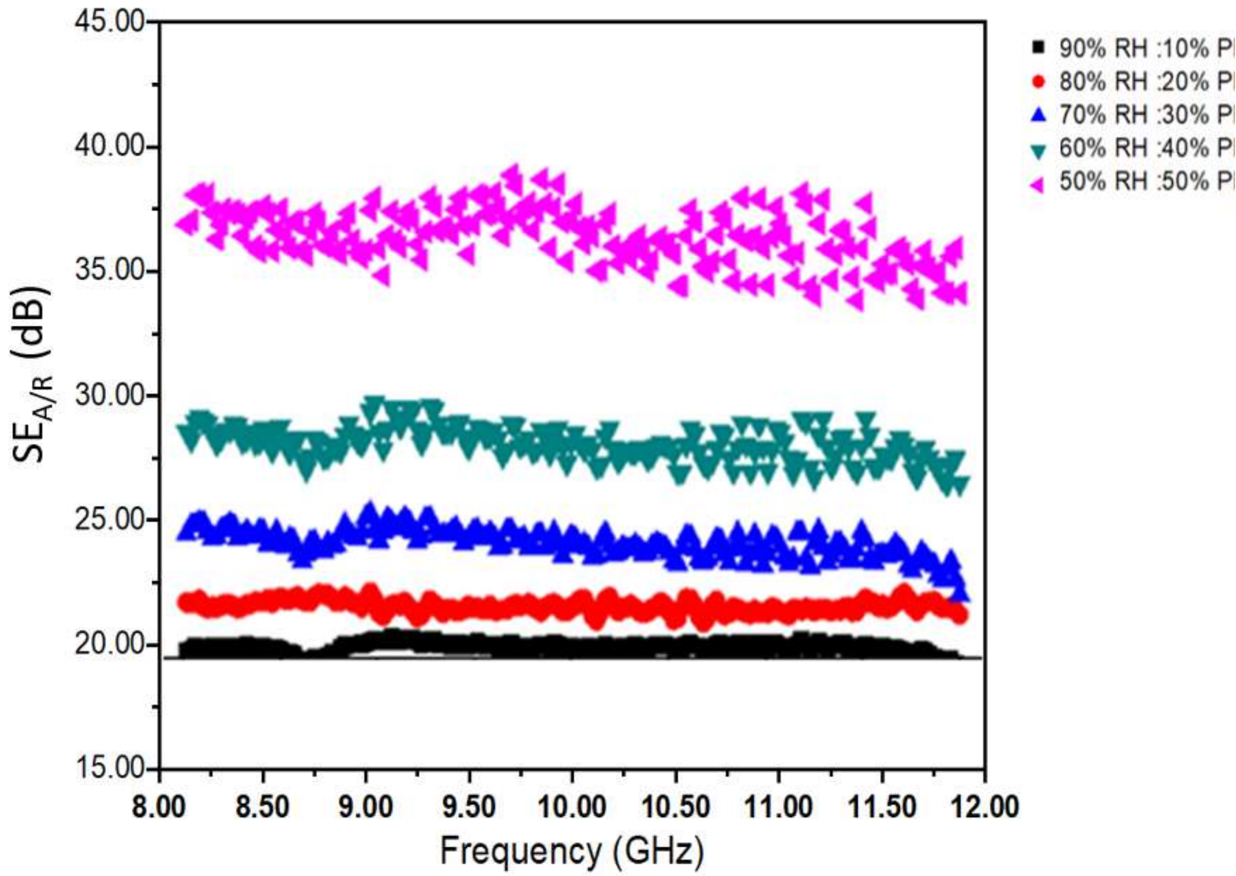


Figure 7: Shielding Efficiency due to absorption of rice husk f series Rice Husk EMI shielding material

CONCLUSION

The development of an electromagnetic interference (EMI) shielding material using local rice straw represents a significant advancement in the search for sustainable and effective solutions to mitigate EMI in various industrial applications. This study has demonstrated that rice straw, a readily available agricultural byproduct, can be transformed into a high-performance EMI shielding material through a series of processing techniques, including chemical treatment and carbonization. The resulting composites exhibit impressive shielding effectiveness due to their unique structural properties and the inherent conductivity achieved through carbonization.

The research findings indicate that the incorporation of rice straw not only enhances the electrical conductivity of the composites but also contributes to their lightweight and biodegradable nature, making them an environmentally friendly alternative to conventional EMI shielding materials.

Furthermore, the development of EMI shielding materials from local rice straw not only showcases the potential of agricultural waste in advanced material science but also paves the way for future research aimed at optimizing composite formulations and processing methods. Continued exploration in this field could lead to even greater advancements in EMI shielding technologies, promoting sustainability and innovation within the industry.

AKNOWLEDGMENT
The Authors wishes to acknowledge the effort of Tertiary Education Trust Fund (TETFUND) through Institution Based Research (IBR) for funding the research.

REFERENCES

[1] Singh, B., & Kaur, M. (2020). "Agricultural Waste Utilization for Sustainable Material Development: A Review." Journal of Cleaner Production, 258, 120850.
[2] Liu, Y., et al. (2018). "Dielectric and Electromagnetic Interference Shielding Properties of Polymer Composites." Composites Science and Technology, 160, 21-30.
[3] Zhao, X., & Cui, W. (2019). "Biomass-Based Composites for Electromagnetic Interference Shielding." ACS Sustainable Chemistry & Engineering, 7(9), 8537-8546.
[4] Ismail, S., (2021). "Utilization of Agricultural Residues for Eco-Friendly EMI Shielding Materials." Materials Today: Proceedings, 47, 1125-1130.
[5] Li, M., Zhao, Y., Zhang, M., Jiang, S., Farooq, A., Liu, L., ... & Liu, L. (2022). Recent progress in the application of cellulose in electromagnetic interference shielding materials. Macromolecular Materials and Engineering, 307(7), 2100899.
[6] Zecchi, S., Cristoforo, G., Bartoli, M., Tagliaferro, A., Torsello, D., Rosso, C., ... & Acerra, F. (2024). A Comprehensive Review of Electromagnetic Interference Shielding Composite Materials. Micromachines, 15(2), 187.
[7] Krishnasamy, P., Muralidharan, B., Govindasamy, R., Subramanian, J., & Perumal, R. (2022). Investigation of Natural Fiber Composite in EMI Shielding under the Influence of Hematite and Rice Husk Ash Filler (No. 2022-28-0588). SAE Technical Paper.
[8] Wang, X. Y., Liao, S. Y., Wan, Y. J., Zhu, P. L., Hu, Y. G., Zhao, T., ... & Wong, C. P. (2022). Electromagnetic interference shielding materials: recent progress, structure design, and future perspective. Journal of Materials Chemistry C, 10(1), 44-72.
[9] Ma, X., Shen, B., Zhang, L., Chen, Z., Liu, Y., Zhai, W., & Zheng, W. (2019). Novel straw-derived carbon materials for electromagnetic interference shielding: a waste-to-wealth and sustainable initiative. ACS Sustainable Chemistry & Engineering, 7(10), 9663-9670.
[10] Liu, D., Yang, L., Wu, J., & Li, B. (2022). Molten salt shielded preparation of rice straw biochars doped by copper sulfide for elemental mercury capture. Journal of the Energy Institute, 102, 176-183.
[11] Zhao, Y. Y., Chen, S. K., Wu, J. M., Dong, X., Liang, Z. H., Song, F., & Wang, Y. Z. (2023). Cellulose microfibers from rice straw: Low-temperature alkali-mediated extraction and functionalization for thermal insulation and electromagnetic shielding. Industrial Crops and Products, 204, 117306.
[12] Kaniapan, S., Suhaimi, H., Hamdan, Y., & Pasupuleti, J. (2021). Experiment analysis on the characteristic of empty fruit bunch, palm kernel shell, coconut shell, and **rice husk** for biomass boiler fuel. *Journal of Mechanical Engineering and Sciences*, *15*(3), 8300-8309.
[13] Alchalil, Setiawan, A., Juwaini, & Nur, T. B. (2021). Effect of Densification Pressure on Physical and Combustion Properties of Binderless Briquettes Made from **Rice-Husk** and Coffee-Pulp. In *Proceedings of the 2nd International Conference on Experimental and Computational Mechanics in Engineering: ICECME 2020, Banda Aceh, October 13–14* (pp. 1-8). Springer Singapore.
[14] Yiga, V. A., Katamba, M., Lubwama, M., Adolfsson, K. H., Hakkarainen, M., & Kamalha, E. (2023). Combustion, kinetics and thermodynamic characteristics of **rice husks and rice husk-bio-composites** using thermogravimetric analysis. *Journal of Thermal Analysis and Calorimetry*, *148*(21), 11435-11454.