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STRUCTURAL AND OPTICAL CHARACTERIZATION OF HEAT-TREATED SIC PARTICLES DERIVED FROM RICE HUSK ASH FOR PHOTOVOLTAIC

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ABSTRAK

Penelitian ini mengeksplorasi potensi partikel silikon karbida (SiC) berskala nano yang disintesis dari abu sekam padi untuk meningkatkan karakteristik penyerapan cahaya dalam aplikasi panel surya. Partikel SiC diproduksi melalui pembakaran sekam padi, diikuti dengan pemurnian dan pembagian menjadi dua kelompok: satu kelompok mengalami perlakuan panas dengan temperature 400 ºC dan kelompok lainnya dipertahankan dalam kondisi tidak terolah untuk analisis komparatif. Penggilingan Energi Tinggi (High Energy Milling/HEM) selama 60 jam digunakan untuk reduksi ukuran partikel pada sampel terpilih. Karakterisasi komprehensif dilakukan menggunakan Mikroskop Elektron Pemindai (SEM), Difraksi Sinar-X (XRD), Spektroskopi Inframerah Transformasi Fourier (FTIR), dan spektroskopi UV-Vis pada rentang panjang gelombang 200–1100 nm. Hasil penelitian menunjukkan bahwa SiC yang mengalami perlakuan panas menunjukkan aglomerasi yang berkurang secara signifikan dan dispersi partikel yang lebih baik dibandingkan sampel tidak terolah. Analisis FTIR mengonfirmasi keberadaan gugus fungsi tambahan (C=C dan O–H) pada SiC terolah, yang berkontribusi pada modifikasi kimia permukaan. Yang paling penting, spektrum UV-Vis menunjukkan bahwa SiC terolah mempertahankan nilai absorbansi yang konsisten lebih tinggi (0,5–0,6) pada wilayah tampak hingga inframerah dekat (400–1100 nm), sedangkan SiC tidak terolah menunjukkan tren penurunan (0,4–0,2). Temuan ini mengindikasikan bahwa proses termal dapat meningkatkan kinerja optik nanopartikel SiC melalui perbaikan dispersi dan pengenalan gugus fungsi yang memperkuat interaksi cahaya-materi. Karakteristik absorbansi unggul dari SiC terolah menunjukkan potensi menjanjikan sebagai aditif atau lapisan berstruktur nano untuk meningkatkan penangkapan foton dan efisiensi keseluruhan pada perangkat fotovoltaik.
Kata kunci: Silikon karbida, nanopartikel, perlakuan panas, spektroskopi UV-Vis, panel surya, absorbansi cahaya

ABSTRACT

This study explores the potential of nanoscale silicon carbide (SiC) particles synthesized from rice husk ash to enhance light absorption characteristics in solar panel applications. The SiC particles were produced by burning rice husks, followed by purification and division into two groups: one group underwent heat treatment at 400 °C, *while the other was kept untreated for comparative analysis. High-Energy Milling (HEM) for 60 hours was used to reduce the particle size of selected samples. Comprehensive characterization was performed using Scanning Electron Microscopy (SEM), X-ray Diffraction (XRD), Fourier Transform Infrared Spectroscopy (FTIR), and UV-Vis spectroscopy in the wavelength range of 200–1100 nm. The results of the study indicate that heat-treated SiC exhibits significantly reduced agglomeration and better particle dispersion compared to untreated samples. FTIR analysis confirmed the presence of additional functional groups (C=C and O–H) in the treated SiC, which contribute to surface chemical modification. Most importantly, the UV-Vis spectra show that the treated SiC maintains consistently higher absorbance values (0.5–0.6) in the visible to near-infrared region (400–1100 nm), whereas the untreated SiC exhibits a decreasing trend (0.4–0.2). These findings suggest that thermal processing can enhance the optical performance of SiC nanoparticles by improving dispersion and introducing functional groups that strengthen light-matter interactions. The superior absorption characteristics of the processed SiC demonstrate promising potential as an additive or nanostructured layer to improve photon capture and overall efficiency in photovoltaic devices*

Keywords: *Silicon carbide, nanoparticles, heat treatment, UV-Vis spectroscopy, solar panel, light absorbance*

1. INTRODUCTION

The progression of materials science, especially regarding nanoparticles, is crucial for fostering technological innovation. Advances in nanomaterials have produced innovations in a variety of sectors, including construction, energy storage, and data storage. When compared to their bulk counterparts, these materials, which are frequently made up of hybrid inorganic-organic or organic-inorganic structures, have special and improved qualities. Nanomaterials have improved electrochemical performance, adjustable optical properties, exceptional mechanical strength, and excellent electrical conductivity. They are also essential in advanced applications due to their structural versatility and catalytic effectiveness. By utilizing these unique qualities, scientists and engineers are able to push the limits of technology and provide more effective, long-lasting, and high-performing solutions for contemporary problems. Nanomaterials' revolutionary potential is shown by this synergy between technical advancement and nanomaterials, opening the door for breakthroughs that raise industrial standards and enhance daily living [1].

UV-Vis spectroscopy is a useful tool for characterizing the light interaction behavior of nanomaterials and for analyzing their optical absorption features. Material attributes including color, transparency, mechanical strength, electrical conductivity, and magnetism are all greatly influenced by these absorption properties [2]. Nanomaterials are very beneficial in industries like optoelectronics, photovoltaics, and biomedical imaging because of their capacity to be engineered with specific qualities. Since nanoparticles have special qualities that may be altered for certain uses, they have drawn a lot of attention from researchers in a variety of scientific domains, including materials science, chemistry, and biology. This study employs Density Functional Theory (DFT) and machine learning to optimize donor-π-acceptor silicon carbide quantum dots (SQs), identifying Topological Polar Surface Area (TPSA) as the primary factor influencing maximum light absorption. By demonstrating strong correlations between absorption wavelength and photovoltaic performance metrics like Short-Circuit Current Density and Light Harvesting Efficiency, the findings offer valuable guidelines for designing high-efficiency SQ-based solar materials[3]. The creation and characterisation of nanoparticles to improve material characteristics including thermal conductivity, optical qualities, and photocatalytic performance is one well-known field of study. For instance, the investigation of carbon-based nanofluids in the S45C carbon steel quenching process. They discovered that incorporating carbon nanoparticles into the cooling medium may speed up cooling and have a big impact on the steel's hardness and microstructure [4].

Furthermore, research has been done on the production of silicon carbide (SiC) nanoparticles using high-energy ball milling. The results indicated that after 50 hours of grinding, the size of SiC crystallites decreased from 120 nm to 26 nm, and the percentage of crystallinity decreased from 74% to 49% [5]. This work shows that high-energy ball milling is a useful technique for creating nanoparticles with regulated size and shape that may be used in advanced material applications like catalysts and composites.Ionic liquid-containing MXene-based nanofluids have been employed in the energy sector for solar thermal collector applications [6].

The manufacture of nanohydroxyapatite from cuttlefish bone using a high-energy milling technique to create particles as small as 65 nm is another pertinent work. Tests on cell viability demonstrated that this substance is non-toxic and possesses compressive strength appropriate for use in cancellous bone. These results pave the way for the application of nanohydroxyapatite in medicine, namely in the area of bone restoration [7].

WO3-ZnO composites have improved photocatalytic activity when exposed to UV-Vis light in the context of photocatalysis. They discovered that these composites have the ability to store energy in addition to being efficient in breaking down methyl orange, which makes them desirable materials for energy and environmental applications. [8]. Investigation of the optical properties of C60 fullerene in various organic solvents. They found that the photoluminescence (PL) spectrum of C60 is significantly influenced by the polarity of the solvent, indicating that interactions between nanoparticles and their surrounding medium can be exploited to control the optical properties of materials. These results have important implications for applications in optoelectronics and sensors [9]. In the field of health, carbon quantum dots (CQDs) have attracted attention as fluorescent sensor materials for food analysis. CQDs have unique optical properties, such as photoluminescence and tolerance to photobleaching, which make them suitable for detecting food additives, heavy metals, and pesticide residues. Additionally, CQDs can be modified to enhance light absorption within the UV-Vis spectrum, enabling their use as an additional layer on solar cells to improve energy conversion efficiency [10].

In the energy sector, nanoparticles can be used as materials for the manufacturing process of solar panels. The ability of nanoparticles to absorb light when used as solar panels was observed through UV-Vis testing. UV-Vis is an analytical method used to measure light absorption in the ultraviolet (UV) and visible (visible) ranges by a sample, allowing the level of light absorption in the tested sample to be observed and analyzed.

Ultraviolet-Visible Spectroscopy (UV-Vis) is one of the most important analytical techniques in the fields of chemistry, physics, and materials science. This technique utilizes the interaction between light and matter within the ultraviolet (190-400 nm) and visible (400-800 nm) wavelength ranges to identify and measure the concentration of a compound or material. UV-Vis spectroscopy is widely used due to its ability to provide information about the electronic structure, concentration, and stability of a compound or material [11].

One of the main applications of UV-Vis spectroscopy is in the characterization of nanomaterials, such as metal nanoparticles, fullerenes, and composite materials. UV-Vis spectroscopy is used to study the optical properties of C60 fullerene in various organic solvents. Research findings indicate that UV-Vis spectroscopy can distinguish interactions between C60 and solvents based on the solvents' polarity [9]. Additionally, UV-Vis spectroscopy is used to monitor the growth of metal nanoparticles in polymer networks to study the plasmonic properties and catalytic applications of noble metal nanoparticles integrated into responsive microgels [12].

UV-Vis spectroscopy also plays an important role in water quality analysis to detect water quality parameters such as Chemical Oxygen Demand (COD), heavy metal ions, and nitrate nitrogen. The ability of UV-Vis spectroscopy to perform qualitative and quantitative analysis makes it a very useful tool in environmental monitoring [13].

UV-Vis spectroscopy is also used in the development of photocatalytic materials based on bismuth, niobium, and iron ($Bi_2F\_xNbO_7$) by using UV-Vis spectroscopy to determine the band gap of these materials. Research results indicate that the addition of iron can reduce the band gap of the material, thereby enhancing the efficiency of visible light absorption [14].

In this study, UV-Vis spectroscopy will be used to analyze the optical properties and stability of the developed nanomaterials. This technique was chosen due to its ability to provide accurate and rapid information about the interaction of light with materials, as well as its ease of operation. Thus, UV-Vis spectroscopy is expected to make a significant contribution to the development of nano materials with broad applications in various fields, including energy, the environment, and health.

Spectroscopy is the science of studying matter and its attributes based on the light, sound, or particles emitted, absorbed, or reflected by that matter. Spectroscopy can also be defined as the science of studying the interaction between light and matter.

Near-ultraviolet and visible electromagnetic radiation sources are used on 16 spectrophotometer equipment in a UV-Vis spectrophotometer, an analytical technique. A device that combines a spectrometer with a photometer is called a spectrophotometer. Energy may be measured approximately when it is transmitted, reflected, or emitted as a function of wavelength using a spectrophotometer. Wavelengths in the visible spectrum range from

380 nm (violet) to 740 nm (red). The wavelengths that the UV-Vis spectrophotometer measures fall between 200 and 900 nm. A UV-Vis spectrophotometer may be used to ascertain the properties of nanoparticles. The spectrophotometer quickly and automatically examines every wavelength component in a given area [15].

The measurement of light absorption and scattering through a material is done by UV-Visible Spectroscopy (UV-Vis). UV-Vis is a useful technique for detecting, characterizing, and researching nanomaterials because of the special optical characteristics of nanoparticles, which are sensitive to size, shape, concentration, aggregation state, and refractive index close to the nanoparticle surface [16]. It is possible to synthesize nanomaterials into nanofluids and test them with UV-Vis testing. UV-Vis spectroscopy was used to thoroughly examine the optical potential of Diethylene Glycol/MXene nanofluids in combination with 1-ethyl-3-methyl imidazolium octyl sulfate ionic liquid with respect to MXene content (0.1 to 0.4% by weight) and time (first day and seventh day). The suggested ionanofluids were synthesized in two steps, with nanoparticle concentrations varying from 0.1 to 0.4% by weight. Enhancing the absorbance capacity of the formulated MXene-based ionanofluid at wavelengths between 240 and 790 nm is largely dependent on the effects of the ionic liquid, MXene concentration, and dispersion stability. High light absorption is made possible by higher absorbance peaks produced by increasing the quantity of MXene nanoparticles. Lastly, because MXene renders ionanofluids intriguing for solar cell applications, their electrical conductivity was also examined. At a concentration of 0.4% by weight, the formed fluid's maximum electrical conductivity of 571 S/cm (micro-siemens per centimeter) was attained [14].

Since WO3 greatly aids in extending ZnO's optical absorption edge from the ultraviolet to the visible light area and prevents photo-induced carrier recombination, the WO3–ZnO composite shows better photocatalytic activity under UV-Vis light than pure ZnO and P25 substances. The WO_3–ZnO composite also shows catalytic function in the absence of light following UV-Vis irradiation because WO_3 stores the reductive energy produced by UV-irradiated ZnO (at the excited electron level) and keeps it for a while after the light is switched off [12].

In this investigation, SEM and XRD tests were used to analyze the crystal morphology. An electron microscope intended for direct surface observation of solid objects is called a scanning electron microscope (SEM). SEMs have a resolution of 1–10 nm, a depth of field of 4–0.4 mm, and a magnification of 10–3,000,000 times. SEM is often used in research and industry because of its high magnification, wide depth of field, excellent resolution, and capacity to ascertain composition and crystallographic information [17]. The chemical makeup of material alloys and the structure of nanomaterials are ascertained using SEM examination [18]. The superior electrical and thermal characteristics of silicon carbide (SiC) materials, as demonstrated in power electronics applications, highlight the material's exceptional stability and performance under extreme conditions, suggesting similar benefits could be leveraged in photovoltaic systems. Understanding how structural modifications and material treatments enhance SiC performance in MOSFET devices provides valuable insights for optimizing SiC nanoparticles as light-absorbing coatings, where improved thermal stability and structural integrity could similarly enhance solar panel efficiency and durability.[19]

UV-Vis may be used to monitor wave absorption for energy absorption purposes, as well as to identify the presence of pollutants for the evaluation of water cleanliness [20]. Analyzing the light absorption capability of SiO_2 nanoparticles using comparable techniques is an outstanding chance to use nanotechnology to enhance solar panel performance. The incorporation of specifically created nanoparticles to improve solar cell energy transformation and sunlight absorption efficiency is what makes this strategy unique. According to certain study findings, the TiO_2/graphene/TiO_2 sandwich structure can boost dye-sensitized solar cells' (DSSCs') energy conversion efficiency by as much as 60% when compared to conventional architectures. This method can be used to create new materials that are more effective at absorbing and converting solar energy by employing developed nanoparticle synthesis techniques, such as high-energy ball milling to create nano-sized elements and photographic analysis through UV-Vis to guarantee ideal absorption of light properties [21].

Ionic liquid-based MXene-based nanofluids have demonstrated notable enhancements in electrical conductivity and absorption of solar light. For example, it examines how well amorphous photovoltaic (PV) systems function inside using two distinct cooling techniques: passive cooling with a circular heatsink and active cooling with PVC water flow. Water was circulated into plastic tubes in the research arrangement to keep the PV modules warm, and the finned design of the heatsink allowed for natural convection. The findings demonstrated that, especially in situations with high light intensity, the PVC water cooling system was superior at maintaining thermal stability and improving the PV modules' electrical performance. This suggests that in regulated indoor situations, active cooling significantly increases the efficiency of amorphous photovoltaic systems [22].

This opens up opportunities to integrate nanofluids into solar panel cooling systems, which not only improve thermal efficiency but also maintain the operational stability of solar panels in extreme environmental conditions [6]. By combining proven effective nanoparticle synthesis methods with optical analysis using UV-Vis, this approach offers an innovative solution to address key challenges in solar panel technology, such as low energy conversion efficiency and material degradation due to environmental exposure. Further research could focus on developing nano-materials with improved optical and thermal properties, as well as conducting direct application tests on solar panels to validate significant performance improvements. Thus, the integration of nano-technology in solar panels not only enhances energy efficiency but also paves the way for the development of more sustainable and economical renewable energy through analysis of the impact of nano-particles on light absorption capabilities

2. RESEARCH METHODS

Silicon carbide (SiC) was synthesized via the controlled combustion of rice husks in a furnace at 400 °C for 1 hours. The resulting ash was washed with distilled water and use magnetic stirrer to remove impurities and minimize residual blackish coloration. The washed material was dried under sunlight for 8 hours to eliminate moisture content. The dried SiC was divided into two groups: one retained in its unprocessed form, and the other subjected to particle size reduction using High Energy Milling (HEM). The milling process was conducted at 1500 rpm for 60 hours. The optical properties of the samples were analyzed using UV–Vis spectroscopy in the wavelength range of 200–1100 nm, conducted at the Chemistry Laboratory, Universitas Muhammadiyah Surakarta (UMS). The crystalline structure and surface morphology were examined using X-ray Diffraction (XRD) and Scanning Electron Microscopy (SEM), respectively, at the Central Laboratory of Universitas Negeri Malang. In addition, quantum dot behavior was investigated using a violet laser excitation source within the wavelength range of 100–400 nm.

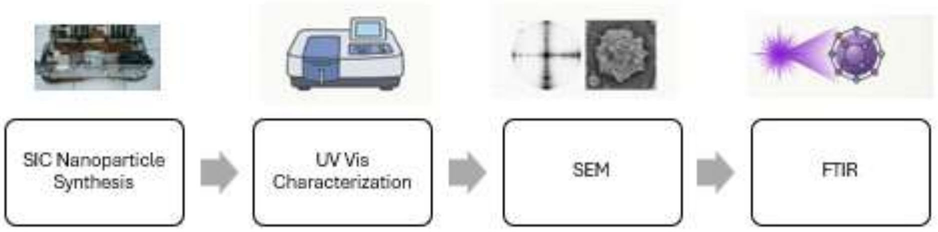

Figure 1. Schematic Characterization Process

3. RESULT AND DISCUSSION

Figure 2 presents the surface morphology by using SEM and gray scale distribution of silicon carbide (SiC) prior to the heat treatment process. The SEM micrograph in Figure 1A reveals that the SiC particles exhibit significant agglomeration, forming dense clusters with irregular shapes. It is showed the the particle SiC particle size larger than 15 µm Fine particles are observed adhering to larger grains which indicates the presence of interparticle attractive forces. This agglomerated morphology is commonly associated with the presence of functional groups on the particle surface that promote van der Waals and electrostatic interactions, thereby reducing particle dispersion.

The corresponding gray scale intensity profile along the scan line (Figure 1B) further confirms this observation. The profile exhibits fluctuating gray values ranging from approximately 0 to 200, with an average intensity of 128.5. The periodic peaks and troughs in the curve reflect variations in particle size distribution and packing density across the scanned region. High intensity regions correspond to densely packed particle areas, whereas low intensity regions represent less compact zones or voids. This heterogeneity in the gray scale distribution suggests that the SiC particles have not yet achieved uniform dispersion or sintering.

The relatively high average gray scale value indicates that the overall material density is substantial, even in the untreated condition. However, the uneven distribution underscores the dominant effect of agglomeration. Without heat treatment, the SiC particles remain in a loosely bound configuration where surface energy minimization drives clustering rather than uniform packing. Subsequent thermal processing is therefore expected to enhance particle bonding, reduce porosity, and improve homogeneity by promoting neck formation between adjacent particles.

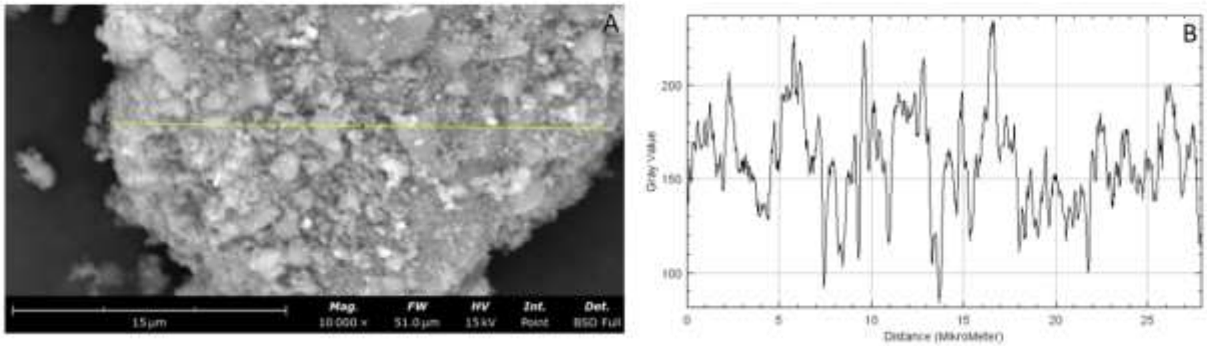

Figure 2. SEM and Gray Value distribution SEM for untreated SiC (a) SEM (b) Gray Value

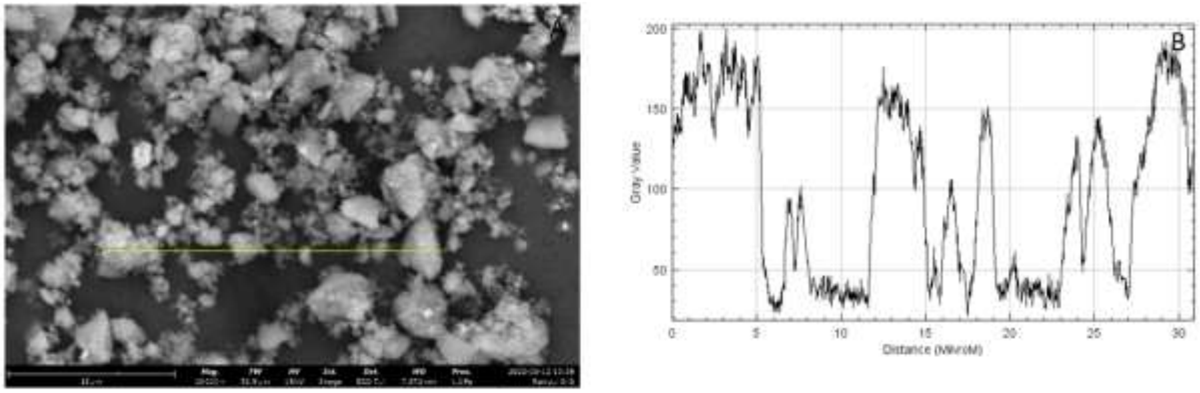

Figure 3. SEM and Gray Value distribution for treated SiC SEM (a) SEM (b) Gray Value

Figure 3 illustrates the morphological changes in SiC particles after undergoing heat treatment. As shown in the SEM micrograph (Figure 2A), the particle distribution becomes more dispersed compared to the untreated condition in Figure 1A. The particle size becomes approximately 5µm. The previously agglomerated clusters are partially broken down, leading to improved particle separation. This transformation indicates that thermal energy facilitates particle rearrangement and reduces the dominance of interparticle attractive forces, such as van der Waals and electrostatic interactions, which were responsible for the initial aggregation.

The corresponding gray scale intensity profile in Figure 2B further supports this observation. The gray scale values fluctuate over the scanned distance of 0–30 µm, with an average intensity of approximately 121. Compared to the untreated sample (average ~128.5 in Figure 1B), a slight reduction in mean gray value suggests changes in packing density and surface compactness. The more defined and sharper transitions in intensity indicate improved particle boundaries and reduced overlap among clusters, consistent with the enhanced particle dispersion observed in the SEM image.

This behavior highlights the role of heat treatment in modifying the microstructural characteristics of SiC. Thermal exposure promotes limited sintering and surface diffusion, which reduces agglomeration and enhances homogeneity in particle distribution. Consequently, the treated material exhibits a more uniform microstructure with better-defined particle morphology, which can positively influence subsequent densification, mechanical stability, and thermal conductivity in engineering applications.

Figure 4 and Table 1 presents the FTIR spectra of the SiC samples, where spectrum A corresponds to sample SiC A and spectrum B to sample SiC B. A clear difference can be observed in the number of absorption peaks between the two samples. Sample SiC A exhibits fewer peaks, with only five significant absorption bands, whereas sample SiC B shows a richer spectrum with nine well-defined peaks. This indicates that sample SiC B contains a greater variety of functional groups or structural vibrations compared to sample SiC A.

In the spectrum of sample SiC B, a distinct absorption band is observed at the wavenumber range of 1610–1680 cm⁻¹, which corresponds to the stretching vibration of the C=C functional group. This peak is absent in sample SiC A, suggesting the presence of unsaturated carbon structures exclusively in sample SiC B. Furthermore, a broad peak in the range of 3200–3600 cm⁻¹ is detected in sample SiC B, attributed to O–H stretching vibrations. The presence of this band indicates hydroxyl groups, which may originate from surface-adsorbed water or alcohol groups attached to the SiC structure.

The absence of these functional groups in sample SiC A suggests a comparatively simpler chemical composition, with fewer surface modifications or impurities. In contrast, the additional functional groups in sample SiC B may influence its physicochemical behavior, including hydrophilicity and potential reactivity in further applications. Overall, the FTIR results demonstrate that sample SiC B has a more complex surface chemistry compared to sample SiC A.

Table 1. FTIR Peak Assigments

FTIR PEAK ASSIGNMENTS AND CORRESPONDING FUNCTIONAL GROUPS FOR SIC SAMPLES				
WAVENUMBER (CM^{-1})	**Assignment**	**Functional Group/Bond**	**Sample SiC A**	**Sample SiC B**
3200–3600	Stretching vibration	O–H (hydroxyl, adsorbed water)	Absent	Present (broad)
2850–3000	Stretching vibration	C–H (alkane)	Weak/Absent	Present
1610–1680	Stretching vibration	C=C (unsaturated carbon)	Absent	Present (distinct)
1400–1450	Bending vibration	C–H / O–H	Weak	Present
1000–1100	Stretching vibration	Si–O / C–O	Present	Present
780–840	Stretching vibration (TO mode)	Si–C (fundamental)	Present (strong)	Present (strong)
900–1000	Stretching vibration (LO mode)	Si–C	Present	Present
450–500	Bending vibration	Si–O–Si / SiC lattice	Weak	Present

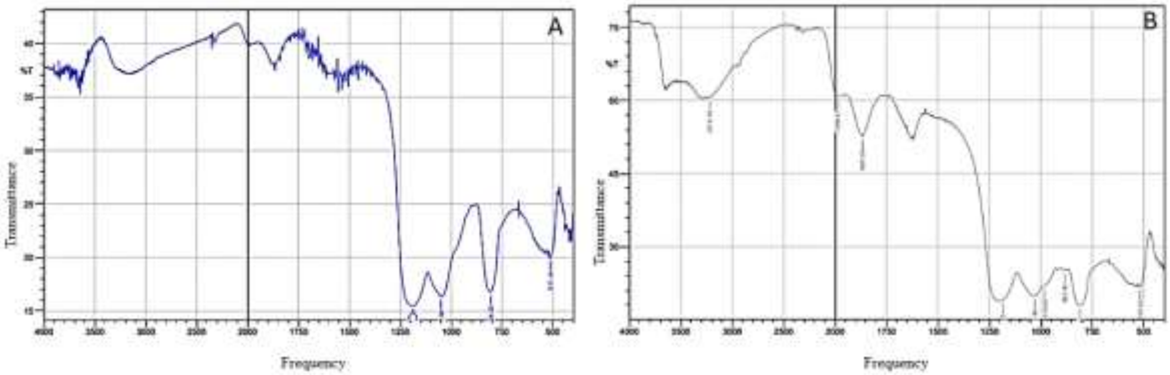

Figure 4. SiC FTIR Value distribution (a) Treated (b) Untreated

Figure 4 presents the UV-Vis absorption spectra of SiC samples A and B in the wavelength range of 200–1100 nm. Both spectra display distinct absorption features at lower wavelengths, which gradually stabilize toward longer wavelengths. A clear difference is observed between the two samples: SiC B exhibits consistently higher absorbance compared to SiC A across the measured spectrum. In the visible to near-infrared region (400–1100 nm), the absorbance values of SiC B remain relatively stable in the range of 0.5–0.6, while SiC A shows a progressive decrease from approximately 0.4 down to 0.2. Furthermore, the maximum absorbance peak of SiC B surpasses 0.6, which is notably higher than the corresponding peak of SiC A. This sustained absorption in the visible region suggests a narrowing of the optical band gap for SiC B compared to the wider band gap typical of untreated SiC. This reduction allows for the absorption of lower-energy photons, a phenomenon often attributed to the introduction of surface defect states or intermediate energy levels caused by the treatment process.

These findings are consistent with similar studies on surface-modified SiC, where functionalization has been reported to reduce the band gap and extend light harvesting capabilities into the visible spectrum, thereby enhancing photocatalytic efficiency. The higher absorbance of SiC B may be further attributed to modifications in the microstructure resulting from processing conditions, which enhance particle dispersion and reduce agglomeration, as evidenced by SEM and grey scale analyses (Figure 1-2). Improved particle dispersion increases the effective surface area available for photon interaction, while surface functional groups can act as active sites that strengthen photon absorption. In contrast, the lower absorbance and declining trend in SiC A suggest that agglomeration reduces optical activity by limiting the available surface for photon interaction and causing light scattering losses.

These findings demonstrate that structural and morphological differences between the two SiC samples directly influence their optical properties. The enhanced absorbance of SiC B, driven by both band gap modification and improved morphology, highlights its potential for applications where efficient light absorption is crucial, such as in optoelectronic devices, photocatalysis, and solar energy conversion.

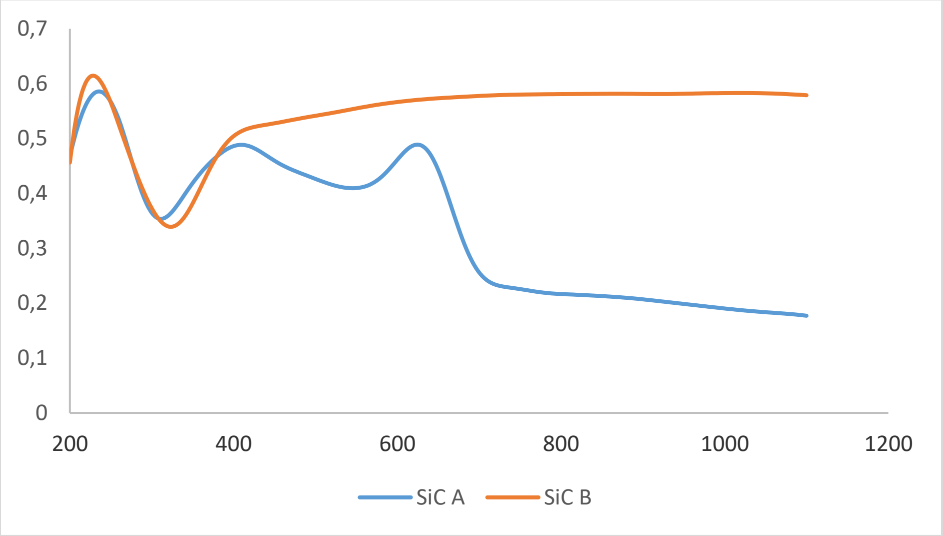

Figure 5. UV-Vis Spectra

4. CONCLUSION

This study successfully demonstrated the significant influence of heat treatment and High Energy Milling (HEM) on the structural, chemical, and optical characteristics of Silicon Carbide (SiC) particles synthesized from rice husk ash. Comparative analysis between untreated samples and those subjected to heat treatment at 400 °C followed by 60 hours of milling revealed distinct improvements in the processed material.

SEM and gray scale analyses indicated that thermal processing effectively reduced particle agglomeration, resulting in a more homogeneous microstructure with reduced particle sizes (approximately 5 µm) compared to the untreated condition (>15 µm). FTIR spectroscopy confirmed that the treated SiC exhibited a richer surface chemistry, characterized by the presence of additional functional groups, specifically C=C and O–H vibrations, which were absent in the untreated samples. These modifications suggest enhanced surface reactivity and potential for improved light–matter interactions.

UV-Vis spectroscopy further highlighted the superior optical performance of the treated SiC. The processed samples maintained consistently higher absorbance values (0.5–0.6) across the visible to near-infrared region (400–1100 nm), whereas untreated samples exhibited a declining trend (0.4–0.2). This enhanced absorbance is attributed to the combined effects of improved particle dispersion, reduced agglomeration, and surface functionalization, which collectively facilitate stronger photon absorption and minimize scattering losses.

While these findings confirm the strong potential of thermally treated SiC as an additive material or nanostructured coating for photovoltaic applications, this study was limited to optical characterization. Future research should focus on the direct integration of treated SiC into solar cell architectures to quantitatively assess its impact on power conversion efficiency and thermal stability under operational conditions.

REFERENCES

[1] P. M. Ajayan, L. S. Schadler, and P. V Braun, “Nanocomposite Science and Technology,” *Materials Today*, vol. 6, no. 11, p. 52, 2003, doi: 10.1016/s1369-7021(03)01139-8.

[2] M. A. Morsi, A. Rajeh, and A. A. Al-Muntaser, “Reinforcement of the optical, thermal and electrical properties of PEO based on MWCNTs/Au hybrid fillers: Nanodielectric materials for organoelectronic

devices," *Compos. B Eng.*, vol. 173, p. 106957, 2019, doi: https://doi.org/10.1016/j.compositesb.2019.106957.

[3] S. Noreen *et al.*, "A DFT and Molecular Correlational Analysis on Newly Designed Silicon-Carbide Quantum Dots with Extended Acceptors for their Photovoltaic Performance," *Silicon*, vol. 17, no. 10, pp. 2249–2261, 2025, doi: 10.1007/s12633-025-03313-8.

[4] R. I. Riza, W. N. Putra, and S. Harjanto, "Cooling rate observation in quenching process using carbon nanofluids for S45C carbon steel," *Key Eng. Mater.*, vol. 833 KEM, pp. 13–17, 2020, doi: 10.4028/www.scientific.net/KEM.833.13.

[5] J. Rao, G. Catherin, I. Murthy, D. Rao, and B. Raju, "Production of nano structured silicon carbide by high energy ball milling," *International Journal of Engineering, Science and Technology*, vol. 3, no. 4, pp. 82–88, 2011, doi: 10.4314/ijest.v3i4.68544.

[6] B. Bakthavatchalam, K. Habib, R. Saidur, N. Aslfattahi, and A. Rashedi, "Investigation of electrical conductivity, optical property, and stability of 2D MXene nanofluid containing ionic liquids," *Applied Sciences (Switzerland)*, vol. 10, no. 24, pp. 1–20, 2020, doi: 10.3390/app10248943.

[7] Aminatun, A. Supardi, Z. I. Nisa, D. Hikmawati, and Siswanto, "Synthesis of Nanohydroxyapatite from Cuttlefish Bone (*Sepia* sp.) Using Milling Method," *Int. J. Biomater.*, vol. 2019, p. 1831208, 2019, doi: 10.1155/2019/1831208.

[8] J. Xie *et al.*, "Simple preparation of WO3-ZnO composites with UV-Vis photocatalytic activity and energy storage ability," *Ceram. Int.*, vol. 40, no. 8 PART A, pp. 12519–12524, 2014, doi: 10.1016/j.ceramint.2014.04.106.

[9] T. E. Saraswati, U. H. Setiawan, M. R. Ihsan, I. Isnaeni, and Y. Herbani, "The Study of the Optical Properties of C60 Fullerene in Different Organic Solvents," *Open Chem.*, vol. 17, no. 1, pp. 1198–1212, 2019, doi: 10.1515/chem-2019-0117.

[10] N. NGAFWAN *et al.*, "Study on novel fluorescent carbon nanomaterials in food analysis," *Food Science and Technology*, vol. 42, pp. 1–6, 2022, doi: 10.1590/fst.37821.

[11] C. S. S. R. Kumar, *UV-VIS and photoluminescence spectroscopy for nanomaterials characterization*. 2013. doi: 10.1007/978-3-642-27594-4.

[12] R. Begum *et al.*, "Applications of UV/Vis Spectroscopy in Characterization and Catalytic Activity of Noble Metal Nanoparticles Fabricated in Responsive Polymer Microgels: A Review," *Crit. Rev. Anal. Chem.*, vol. 48, no. 6, pp. 503–516, 2018, doi: 10.1080/10408347.2018.1451299.

[13] Y. Guo, C. Liu, R. Ye, and Q. Duan, "Advances on water quality detection by uv-vis spectroscopy," *Applied Sciences (Switzerland)*, vol. 10, no. 19, pp. 1–18, 2020, doi: 10.3390/app10196874.

[14] A. R. A. Scharnberg, A. C. de Loreto, and A. K. Alves, "Optical and structural characterization of Bi2fexNbO7 nanoparticles for environmental applications," *Emerging Science Journal*, vol. 4, no. 1, pp. 11–17, 2020, doi: 10.28991/esj-2020-01205.

[15] A. Ray, K. Santhosh, and S. Bhattacharya, "Absorption spectrophotometric, fluorescence, transient absorption and quantum chemical investigations on fullerene/phthalocyanine supramolecular complexes," *Spectrochim. Acta A Mol. Biomol. Spectrosc.*, vol. 78, no. 5, pp. 1364–1375, 2011, doi: 10.1016/j.saa.2011.01.011.

[16] M. H. Binsabt, H. M. Al-Matar, A. L. Balch, and M. A. Shalaby, "Synthesis and Electrochemistry of Novel Dumbbell-Shaped Bis-pyrazolino[60]fullerene Derivatives Formed Using Microwave Radiation," *ACS Omega*, vol. 6, no. 31, pp. 20321–20330, 2021, doi: 10.1021/acsomega.1c02245.

[17] P. Bermejo-barrera, M. Aboal-somoza, and M. Fondo, "Semiconductor Quantum Dots as Target Analytes : Properties , Surface Chemistry and Detection," pp. 1–35, 2022.

[18] S. Prof and P. Rauwel, "Institute of Technology ABSORPTION SPECTROSCOPY STUDIES OF SILICON DIOXIDE NANOPARTICLES AND THEIR APPLICATIONS IN SOLAR NENDE RAKENDUS PÄIKESEPANEELIDES Bakalaureusetöö Tehnika ja tehnoloogia õppekava Tartu 2021," 2021.

[19] D.-X. Chen, Y. Wang, Y.-X. Song, and W. Zhang, "TCAD Analysis of Single-Event Burnout Hardness for an Improved CoolSiC Trench MOSFET," *IEEE Trans. Electron Devices*, vol. 71, no. 8, pp. 4596–4603, Aug. 2024, doi: 10.1109/TED.2024.3418727.

[20] M. Alim-Al-Razy, G. M. A. Bayazid, R. U. Rahman, R. Bosu, and S. S. Shamma, "Silver nanoparticle synthesis, UV-Vis spectroscopy to find particle size and measure resistance of colloidal solution," *J. Phys. Conf. Ser.*, vol. 1706, no. 1, 2020, doi: 10.1088/1742-6596/1706/1/012020.

[21] L. C. Chen, C. H. Hsu, P. S. Chan, X. Zhang, and C. J. Huang, "Improving the performance of dye-sensitized solar cells with TiO2/graphene/TiO2 sandwich structure," *Nanoscale Res. Lett.*, vol. 9, no. 1, pp. 1–7, 2014, doi: 10.1186/1556-276X-9-380.

[22] D. A. Pratiwi *et al.*, "Experimental Study of Amorphous Photovoltaic Systems in Indoor Performance with Different Coolants," *Engineering Proceedings*, vol. 84, no. 1, 2025, doi: 10.3390/engproc2025084024.