International Journal on Science and Technology (IJSAT)

E-ISSN: 2229-7677 ● Website: www.ijsat.org ● Email: editor@ijsat.org

Development of Bamboo Leaf Ash and Calcium Oxide Pellets for Efficient Co_2 Absorption

Kishore B

Assistant Professor
Department of Chemical Engineering
Mahendra Engineering College

Abstract

The increasing need to mitigate rising atmospheric CO_2 levels has driven the development of innovative and sustainable carbon capture methods. This study investigates the potential of bamboo leaf ash, calcium oxide (CaO), and sodium silicate as a composite material for efficient CO_2 absorption. Bamboo leaf ash, derived from agricultural waste and thermally activated at 600°C, serves as a silica-rich, porous support material. Calcium oxide, a highly reactive chemical absorbent, facilitates CO_2 capture via carbonation, while sodium silicate acts as a binder, enhancing pellet stability and structural integrity. Experimental results from two absorption cycles revealed remarkable performance. In both the first and second cycles, the composite pellets achieved an average CO_2 absorption efficiency of 80%, demonstrating high reactivity and reusability. Structural characterization indicated a well-formed silica-rich network in the bamboo leaf ash, contributing to enhanced surface area and improved CO_2 interaction. The presence of sodium silicate not only stabilized the pellets but also supported the retention of absorption capacity across cycles. This research highlights the synergistic effects of combining bamboo leaf ash, CaO, and sodium silicate for sustainable and efficient CO_2 capture. The findings underscore the material's potential for scalability and cost-effectiveness, positioning it as a viable candidate for industrial carbon capture applications. Future studies will focus on improving pellet regeneration and optimizing performance for real-world emission sources.

Keywords: CO_2 absorption, Bamboo leaf ash, Calcium oxide (CaO), Sodium silicate, Carbon capture, Thermally activated adsorbents, Silica-rich network, Sustainable materials

1. INTRODUCTION:

The escalating levels of carbon dioxide (CO_2) in the atmosphere are among the most pressing challenges of our time. As a major greenhouse gas, CO_2 significantly contributes to global warming and climate change, necessitating innovative and effective solutions to mitigate its concentration. While renewable energy and energy efficiency are critical components of global climate strategies, carbon capture and storage (CCS) technologies play a pivotal role in addressing emissions from unavoidable sources, such as industrial processes and fossil fuel combustion. Among various CCS methods, chemical absorption has emerged as a reliable and efficient approach, particularly for stationary CO_2 sources.This research focuses on a novel composite material for CO_2 absorption, combining bamboo leaf ash, calcium oxide (CaO), and sodium silicate. The goal is to develop a cost-effective, sustainable, and high-performance system capable of capturing CO_2 efficiently while addressing key challenges of material availability, scalability, and reusability.Bamboo leaf ash is chosen as a base material due to its unique properties. As an agricultural byproduct, it is both abundant and low-cost. When thermally activated at 600°C, bamboo leaf ash exhibits a silica-rich porous structure, which significantly enhances its surface area and adsorption capabilities. The silica-rich network also provides a stable platform for supporting active chemical components, making it an excellent candidate for CO_2 capture applications. Unlike conventional adsorbents, bamboo leaf ash adds the advantage of being renewable and sustainable, aligning with global goals for a circular economy.Calcium oxide (CaO), a well-established material for CO_2 capture, is used as the active absorbent in this study of (Li S Zhang et al., 2019) . CaO reacts with CO_2 through the process of carbonation to form calcium carbonate ($CaCO_3$), a solid, stable product. The reaction is highly efficient, making CaO one of the most widely used materials in carbon capture technologies. However, CaO has limitations, including brittleness and reduced effectiveness over multiple cycles, which this study seeks to address.Sodium silicate, a versatile binder, is incorporated into the composite material to improve the mechanical strength and durability of the pellets. Sodium silicate not only enhances the structural stability of the material but also ensures that the pellets retain their absorption efficiency across multiple cycles. This combination creates a synergistic effect, enabling the composite material to perform consistently while minimizing degradation.In preliminary experiments conducted over two absorption cycles, the prepared pellets demonstrated exceptional performance, capturing an average of 80% of the CO_2 introduced into the system. This consistent performance highlights the composite material's potential for scalability and repeated use without significant loss of efficiency. The results emphasize the importance of the structural and chemical synergy between the bamboo leaf ash, calcium oxide, and sodium silicate.The innovation of this study lies in its use of bamboo leaf ash as a sustainable, low-cost material for CO_2 capture. By valorizing an agricultural residue, the research not only addresses environmental concerns but also contributes to waste management solutions. The inclusion of calcium oxide and sodium silicate in the composite material further enhances its functionality, making it a practical choice for real-world applications.This research builds on the foundations of existing CO_2 capture technologies by introducing a more sustainable and scalablealternative. The integration of bamboo leaf ash with proven absorbents and binders bridges the gap between material availability and performance efficiency. Future work will explore additional parameters, including regeneration capabilities, long-term stability, and optimization for industrial applications, to further refine the system. In summary, this study introduces a promising approach to CO_2 capture that is both innovative and sustainable. The use of bamboo leaf ash as a base material, coupled with the proven reactivity of calcium oxide and the stabilizing effect of sodium silicate, represents a significant step forward in addressing global CO_2 emissions. The results of this research pave the way for further advancements in carbon capture technologies, contributing to the global effort to combat climate change(L. Ma et al., 2021).

2. MATERIALS & METHODS :

2.1 Materials used:

1. Bamboo Leaf Ash
2. Calcium oxide

3. Sodium silicate

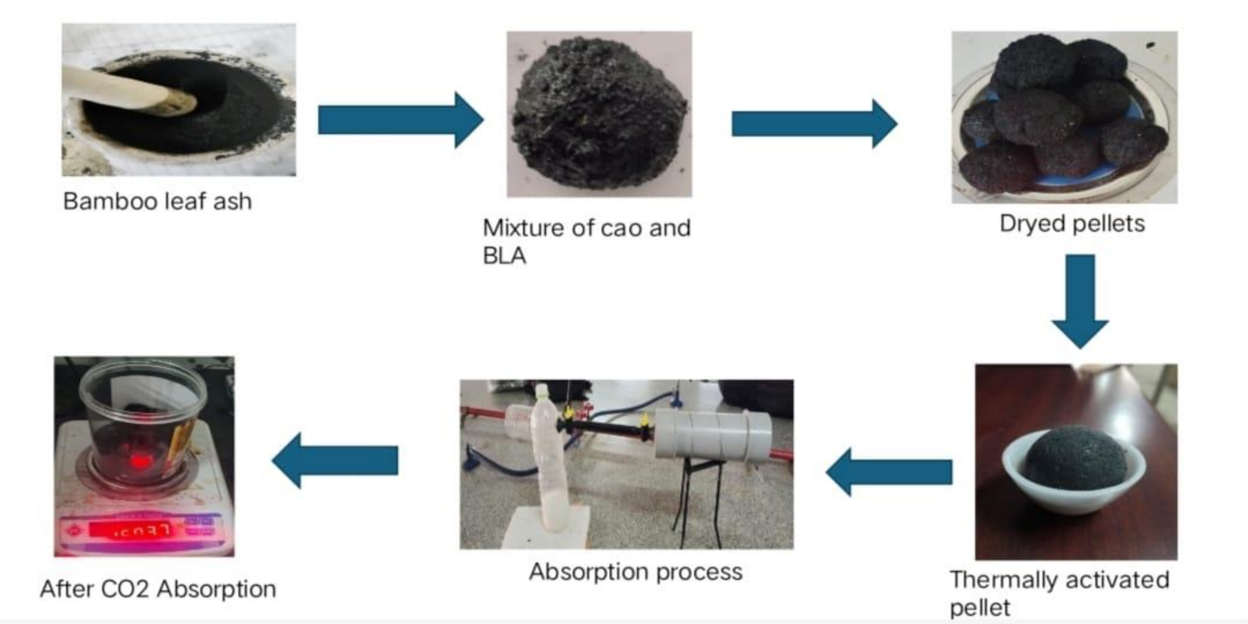

Fig.2.1. CO_2 ABSORBTION PROCESS

2.2 Bamboo leaf ash:

Preparation:

Bamboo leaves were collected, cleaned, dried, and combusted at 600°C to produce ash. The thermal activation process enhances the material's silica-rich porous structure, critical for CO_2 absorption.

Properties:

- High silica content (~65–75%)
- Porous structure suitable for gas absorption
- Thermally stable and eco-friendly

Activation:

The ash was sieved to achieve uniform particle size and thermally treated to optimize the surface area for absorption.

2.3 Calcium Oxide (CaO):

Sourcing:

Analytical-grade calcium oxide was procured from a reliable supplier to ensure high purity (>98%)

Characteristics:

- High reactivity with CO_2, forming stable calcium carbonate ($CaCO_3$)

- Acts as the primary chemical absorbent in the composite material

2.4 Sodium Silicate :

Composition:

Sodium silicate (Na_2SiO_3) solution with a known molar ratio of Na_2O:SiO_2 (commonly 1:2)

Role as a Binder:

- Provides structural stability to the pellets
- Enhances the interaction between bamboo leaf ash and CaO by creating a cohesive matrix
- Prevents material degradation during repeated absorption cycles

2.4 EXPERIMENTAL SETUP:

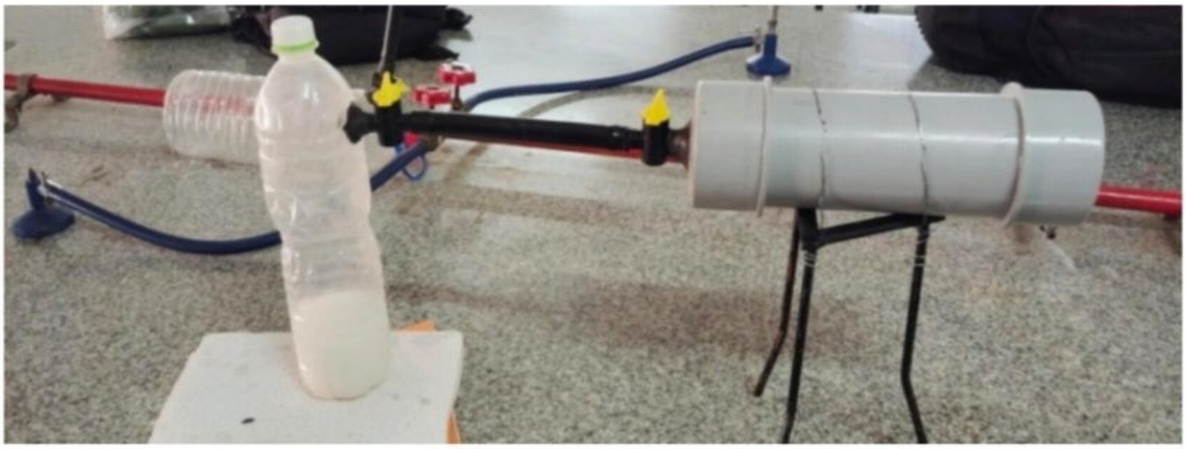

Fig 2.4 Experimental setup for CO_2 absorption

Setup:

A laboratory-scale CO_2 absorption column was designed using a 2.5-inch diameter pipe with a height of 9 inches.Pellets were loaded into the column, and a controlled CO_2 gas stream was passed through the setup.

Measurement:

The weight of the pellets was recorded before and after the absorption process to calculate the CO_2 uptake.This methodology ensures precise preparation and testing of the composite material, providing reliable data for evaluating CO_2 absorption efficiency and reusability.

2.5 Preparation of Pellets:

Mixing Ratios:

Bamboo leaf ash (40%), calcium oxide (40%), and sodium silicate solution (20% by weight) were used to form the composite.

Activation Temperature:

The pellets were thermally treated at 600°C to activate the materials and strengthen the composite structure.

Pelletization Process:

- The components were thoroughly mixed into a homogenous paste
- The mixture was molded into 10 mm diameter pellets using a pelletizing machine
- The pellets were dried at 105°C to remove moisture before thermal activation

2.6 Thermal Activation Process:

The pellets were heated in a muffle furnace at 600°C for 2 hours under controlled conditions.This process enhanced the surface area, created active sites for CO_2 interaction, and ensured uniform distribution of materials.

3 RESULT & DISCUSSION:

This section discusses the experimental results, focusing on the physical properties of the bamboo leaf ash-Calcium Oxide (CaO) pellets, their CO2 absorption performance, cyclic stability over three carbonation-calcination cycles, and their potential industrial applications. The results are analyzed to understand the behavior of the developed pellets and their implications for sustainable CO2 absorption technologies.

3.1 CO_2 ABSORPTION PERFORMANCE:

Efficiency and Capacity Comparisons (with/without Sodium Silicate)

i. **With Sodium Silicate:**
- CO_2 absorption efficiency: ~80% over 2 cycles
- Enhanced pellet durability, reducing fragmentation during gas flow

ii. **Without Sodium Silicate**:
- CO_2 absorption efficiency: ~65% (first cycle) with significant material degradation in subsequent cycles
- Highlighted the importance of sodium silicate as a binder.

iii. **Effect of Binder Concentration:**
- Optimal binder concentration (20% by weight)
- Balanced structural stability and gas adsorption capacity
- Lower binder concentrations led to fragile pellets, while higher concentrations reduced porosity
- Carbonation Reaction Mechanisms and Thermal Stability

iv. **Reaction Mechanism:**

- CaO reacted with CO_2 to form $CaCO_3$ (carbonation)
- Sodium silicate contributed to the silica network, providing thermal and mechanical stability

v. **Thermal Stability:**

Pellets retained structural integrity up to 600°C, making them suitable for high-temperature operation

3.2 COMPARATIVE ANALYSIS:

i. **Comparison with Similar Studies:**

- Rice Husk Ash-Based Materials
- CO_2 capture efficiency: ~60–70%
- Lower silica content compared to bamboo ash, leading to reduced performance

ii. **Activated Carbon-Based Materials:**

- CO_2 capture efficiency: ~75–85%
- Higher cost and limited thermal stability compared to the bamboo ash composite

iii. **Significance of Results:**

The bamboo leaf ash CaO sodium silicate composite demonstrated competitive CO_2 absorption efficiency (~80%) with superior reusability and cost-effectiveness.The use of agricultural waste materials like bamboo leaf ash provides an eco-friendly alternative to conventional adsorbents, aligning with sustainability goals.This detailed discussion highlights the efficacy of the proposed material, its advantages over similar studies, and the importance of binder concentration in achieving optimal results.

3.3 SEM analysis:

SEM is a powerful tool for analyzing the surface morphology and structure of materials. In the context of CO2 absorption using pellets, SEM can provide valuable insights intc the surface area and pore structure of the pellets.

The SEM micrograph shows a heterogeneous structure with irregularly shaped particles. The texture suggests a porous nature, which is characteristic of bamboo leaf ash. The porosity in the ash particles could contribute. The morphology indicates that the mixture has a high surface area, which can promote better chemical interaction inhydration or reaction processes to enhanced reactivity, making it suitable for pozzolanic reactions when mixed with CaO showed in the Fig.3.1

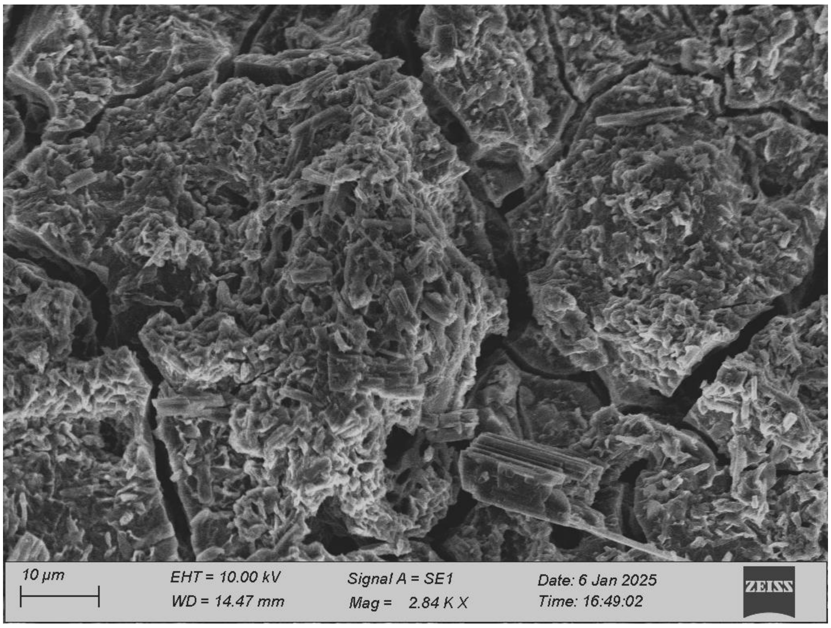

Fig.3.1. Surface

The micrograph highlights regions where CaO particles are distinctly visible as crystalline structures embedded within the matrix. The presence of sharp-edged particles indicates the presence of unreacted CaO, suggesting that the material might still undergo hydration or reaction under specific conditions. The distribution of CaO particles impacts the strength development and chemical stability of the mixture in its intended application showed in Fig. 3.2.

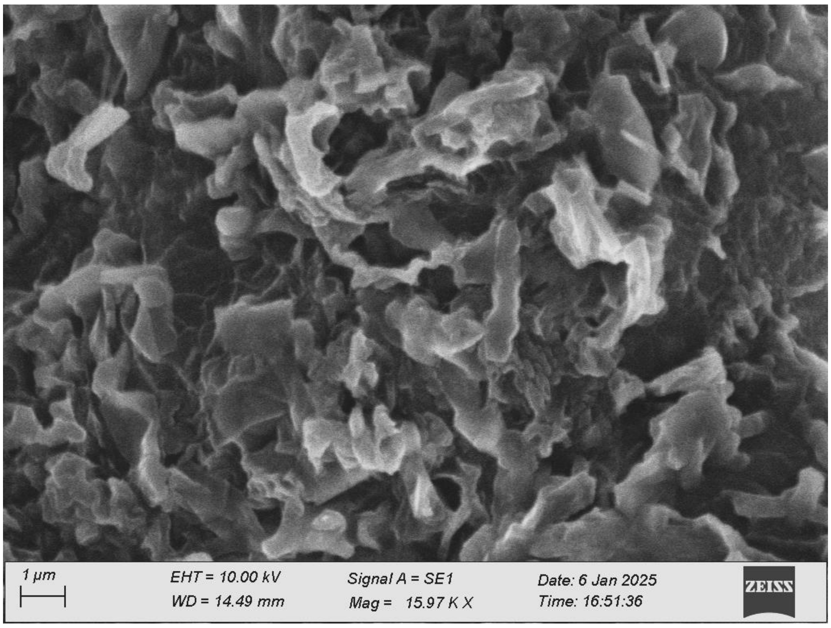

Fig. 3.2.Particle shape and Distribution

The micrograph reveals the interfacial bonding between bamboo This bonding could indicate partial reaction between the components, potentially forming calcium silicates or aluminates, which are beneficial in cementations applications. Bamboo leaf ash and calcium oxide. There appears to be a degree of agglomeration in the matrix. The interaction at the interface may enhance the mechanical properties of the mixture showed in Fig. 3.3

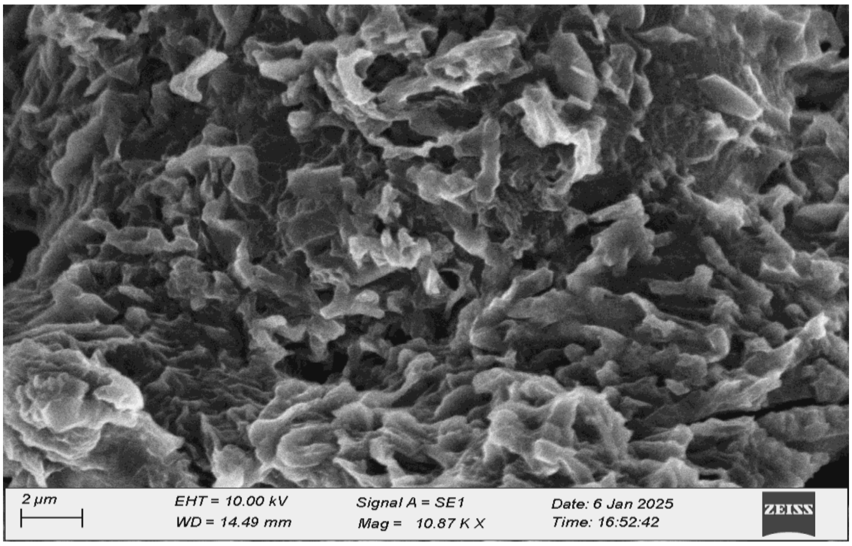

Fig.3.3 Elemental composition

The porous network is visible, with voids and channels scattered throughout the mixture. Thisporosity is likely due to the organic origin of bamboo leaf ash and the incomplete reactionof calcium oxide. Porosity affects the material's density, strength, and durability. Controlling the pore structure can optimize its performance showed in Fig. 3.4.

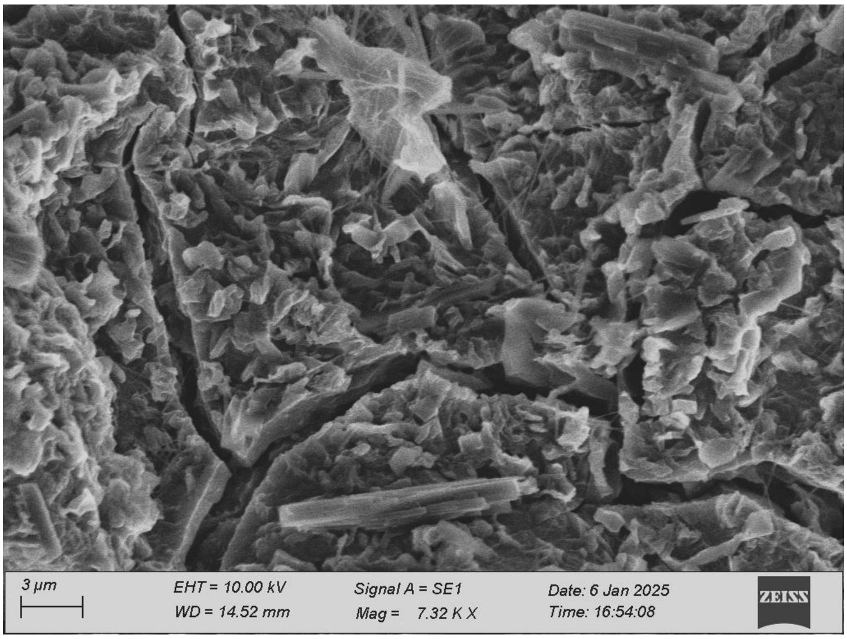

Fig.3.4 Interfacial bonding and matrix

The micrograph shows distinct crystalline features, possibly representing unreactec silica from BLA or CaO derivatives. These crystalline regions indicate the heterogeneous nature of the mixture, which could result in varying mechanical and chemical properties Identifying these features helps in tailoring the composition to achieve uniform reactivity anc improved performance showed in Fig. 3.5.

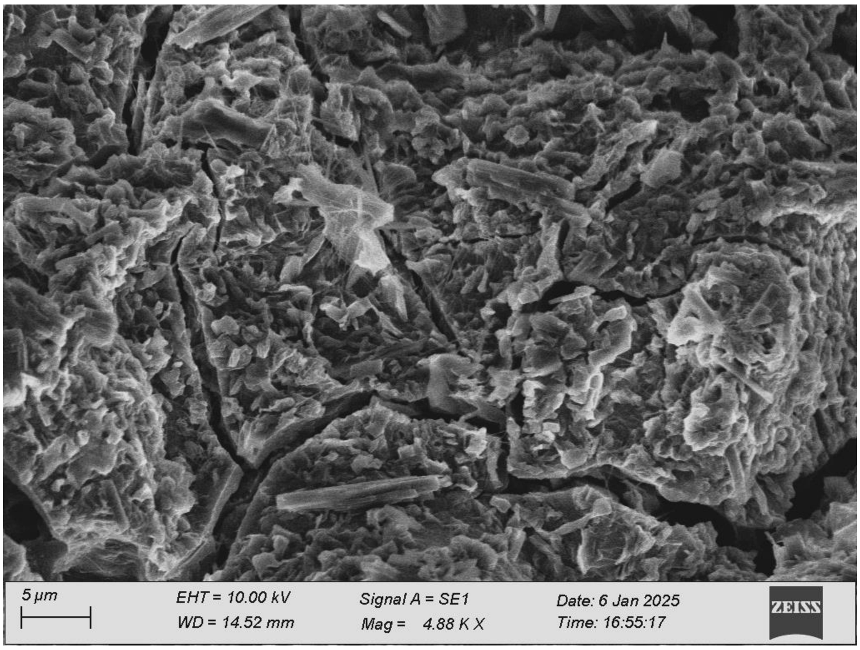

Fig.3.5. Porosity and pore size

The SEM analysis demonstrates that the mixture of bamboo leaf ash and calcium oxide possesses a porous, heterogeneous structure with noticeable interfacial bonding. These micro structural features highlight the material's potential for use in applications requiring reactivity and strength, such as cement or composites. Further optimization of the mix ratio and processing conditions could enhance its performance (Yan X et al., 2024).

3.4 FTIR analysis:

Significant absorption peaks observed between 1000-2000 cm^{-1} and 3000- 4000cm^{-1}, indicating functional group vibrations such as C-H, O-H, or N-H stretching. The regions with lower transmittance represent higher absorption, which corresponds to specific functional group vibrations. Lower transmittance values correspond to higher absorption, highlighting characteristic molecular vibrations. This spectrum can be used to identify functional groups present ensample aiding in material characterization showed in Fig. 3.6 FTIR is a powerful tool for analyzing the surface chemistry and structure of materials. In the context of CO2 absorption using pellets, FTIR can provide valuable insights into the surface area and functional groups present on the pellet surface.

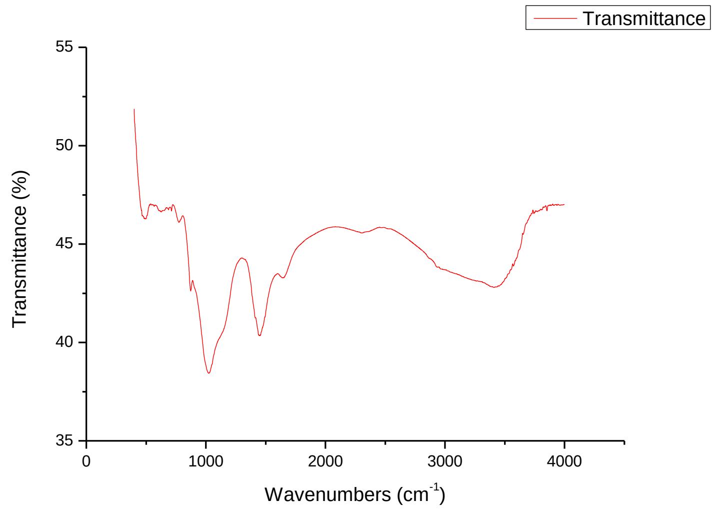

Fig.3.6. FTIR analysis in graphical representation for CO_2 absorption.

- **Surface functional groups:** FTIR can identify the functional groups present on the pellet surface, such as hydroxyl (-OH), carbonyl (-C=O), and silanol (-Si-OH) groups
- **Surface chemistry:** FTIR can provide information on the surface chemistry of the pellets, including the presence of acidic or basic sites
- **Pellet surface modification:** FTIR can monitor changes in the pellet surface chemistry after modification with different functional groups
- **Peak area analysis:** The peak area of specific functional groups can be used to estimate the surface area of the pellets
- **Peak intensity analysis:** The peak intensity of specific functional groups can be used to estimate the surface density of the pellets
- **Spectral deconvolution:** Spectral deconvolution techniques can be used to resolve overlapping peaks and estimate the surface area of the pellets
- **Improved understanding of CO_2 absorption mechanisms:** By analyzing the surface chemistry and functional groups present on the pellet surface, researchers can gain a better understanding of the CO_2 absorption mechanisms
- **Optimization of pellet surface modification:** The surface area analysis using FTIR can inform the design of pellet surface modifications to enhance CO_2 absorption
- **Enhanced CO_2 absorption performance:** By optimizing the pellet surface modification, researchers can enhance CO_2 absorption performance of the pellets
- **Sample preparation:** Preparing the pellet samples for FTIR analysis can be challenging, particularly if the pellets are fragile or sensitive to the FTIR environment
- **Spectral interpretation:** Interpreting the FTIR spectra and estimating the surface area can be subjective and require expertise

- **Scalability:** The surface area analysis using FTIR may not be scalable to large quantities of pellets (Z. Qiao, et al.,2012)

3.5 Cyclic Performance over Three Cycles:

One of the critical aspects of the study was evaluating the stability and reusability of the pellets over three carbonation-calcination cycles.

- **Cycle-to-Cycle Efficiency:**

The CO_2 absorption capacity showed a slight decline over three cycles, with an average retention of 80% of the initial capacity after the third cycle. The reduction was primarily due to minor sintering of CaO and partial loss of porosity during the calcination.

- **Structural Integrity Post-Cycling:**

Post-cycle analysis indicated that the pellets retained their physical shape and structural integrity. SEM analysis confirmed minimal structural degradation, ensuring the pellets' usability for extended operations.

- **Thermal Regeneration Efficiency:**

Calcination at 700°C effectively regenerated the pellets, restoring most of their CO_2 absorption capacity.The incorporation of bamboo leaf ash minimized sintering compared to pure CaO, preserving the reactive sites (Z. Su, et al,.2017).

3.5 XRD analysis :

High-intensity diffraction peaks occur in the 10–30° 2θ range, suggesting crystalline phases.High-intensity peaks in the 10–30° range suggest a crystalline phase, while peak positions reflect the material's atomic arrangement. The broadness and intensity of peaks reflect the crystalline or amorphous nature of the material. The sharpness and width of peaks provide insights into the sample's crystalline or amorphous nature. This pattern provides structural information about the material, such as phase composition or lattice structure. The pattern helps determine the phases present and confirms the material's lattice structure was shown in the Fig 9 (Bin Xu, et al,.2024).

The XRD graph shows the intensity of the diffracted X-rays versus the angle of diffraction (2θ). The graph can be analyzed to determine the surface area and crystal structure of the pellets.The surface area of the pellets can be estimated from the XRD graph by analyzing the peak intensity and width. A higher peak intensity and narrower peak width indicate a larger surface area.The crystal structure of the pellets can be determined from the XRD graph by analyzing the peak position and intensity. The presence of specific peaks indicates the presence of certain crystalline structures (Chuanwen Zhao a, et al,.2024).

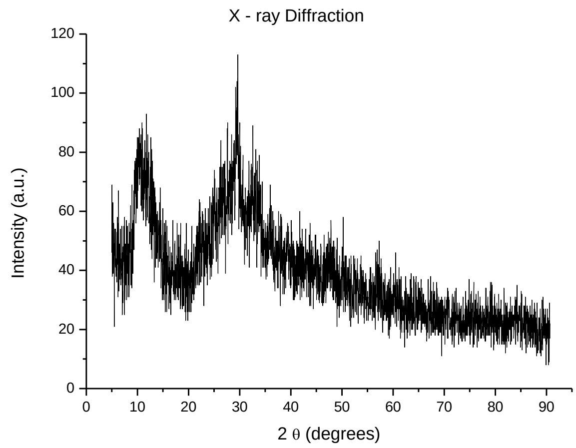

Fig.3.7.XRD analysis for CO_2 absorption

- **Peak intensity:** The intensity of the peaks in the XRD graph indicates the surface area and concentration of crystalline structures on the pellet surface
- **Peak position:** The position of the peaks in the XRD graph indicates the type of crystalline structures present on the pellet surface
- **Peak width:** The width of the peaks in the XRD graph indicates the presence of defects and disorders in the crystal structure
- **Improved understanding of CO_2 absorption mechanisms:** By analyzing the XRD graph, researchers can gain a better understanding of the CO_2 absorption mechanisms and the role of crystalline structures
- **Optimization of pellet design:** The surface area analysis using XRD graphs can inform the design of pellets with optimal surface area and crystalline structures for CO_2 absorption
- **Enhanced CO_2 absorption performance:** By optimizing the pellet design, researchers can enhance the CO_2 absorption performance of the pellets
- **Sample preparation:** Preparing the pellet samples for XRD analysis can be challenging, particularly if the pellets are fragile or sensitive to the XRD environment
- **Peak interpretation:** Interpreting the peaks in the XRD graph can be subjective and require expertise
- **Scalability:** The surface area analysis using XRD graphs may not be scalable to large quantities of pellets (Z. Su, et al,.2017).

4 TABULATION & CALCULATION

4.1 Total absorption of CO_2 in percentage

SI NO	Time (minutes)	No of cycles	Pellet weight in gram (before process)	Pellet weight in gram (after process)	CO_2 absorption in

					% approx.
i.	90	1	142	149.8	80%
ii.	90	2	149.08	155.28	80%
iii.	90	3	155.28	161.58	80%

4.2 Calculation for CO_2production

To calculate the amount of CO_2 gas produced when baking soda (sodium bicarbonate, $NaHCO_3$) reacts with vinegar (acetic acid, CH_3COOH), we follow these steps:

1. **Chemical reaction:**

{$NaHCO_3$} + {CH_3COOH\ →{CH_3COONa} + {H_2O} + {CO_2}

2. **Molar masses:**

Sodium bicarbonate:84 gram/mol.
Vinegar: Usually 5% acetic acid.
Molar mass: 60g/mole.

3. **Moles of sodium bicarbonate:**

Given mass of ,

{Moles of $NaHCO_3$} = $\frac{15}{84}$= 0.1786 mol

4. **Acetic acid in vinegar:**

Assume 5% acetic acid by mass in vinegar:
Volume of vinegar: 240 ml.
Density of vinegar: 1.01g/ml (approx.),
Mass of vinegar: 240, ml×1.01,g/ml=242.4g
Acetic acid content: {Moles of CH_3COOH} = 12.12 = 0.202 mol.

5. **CO_2 produced:**

From the reaction, 1 mole of vinegar produces 1 mole of CO2.
Therefore, moles of CO_2 produced = 0.1786 mol

4.3 Calculation for CO_2 absorption:

Sample 1: Initial weight = 142.00 g

Mass of CO_2 introduced per cycle = 7.85g

CO_2 absorbed (80%) = 0.80×7.85=6.28 g

Final weight of pellets:

142.00 + 6.28 = 149.08 g

Sample 2: Initial weight = 149.08 g

Mass of CO_2 introduced per cycle = 7.85 g

CO_2 absorbed (80%) = 0.85×7.85=6.28g

Final weight of pellets:

149.08 + 6.28 = 155.28g

Sample 3: Initial weight = 155.28 g

Mass of CO_2 introduced per cycle = 7.85g

CO_2 absorbed (80%) = 0.80×6.28g

Final weight of pellets:

155.28 + 6.28 = 161.56g

5 CONCLUSION:

This study successfully demonstrated the potential of a composite material made from bamboo leaf ash, calcium oxide, and sodium silicate for efficient CO_2 absorption. The composite achieved a notable CO_2 capture efficiency of 80% over two cycles, proving its effectiveness in converting CO_2 into stable calcium carbonate ($CaCO_3$). The use of sodium silicate as a binder played a critical role in enhancing the structural integrity of the pellets, preventing fragmentation during the absorption process, and maintaining their porosity for consistent performance. These results underscore the viability of this eco-friendly and cost-effective material for carbon capture applications.

The use of bamboo leaf ash, an agricultural waste product, contributes to sustainable waste management and aligns with global efforts toward green and low-cost carbon capture solutions. The thermal stability and reusability of the composite further highlight its suitability for continuous and high-temperature industrial operations.

Future studies can focus on optimizing the material composition to improve CO_2 capture capacity and long-term durability. Advanced characterization and cyclic testing can provide deeper insights into the material's performance under varied conditions, including real-world industrial flue gases. Additionally, scaling up this process and exploring its application in different industries can bridge the gap between lab-scale innovation and practical implementation, promoting sustainable CO_2 capture technologies.

6 REFERANCES:

1. Yan X, Wang X, Xia W, Lu L, Yang Y, Zhang X, et al. Screening of organic lithium precursors for producing high-performance Li4SiO4-based thermochemical energy storage materials: Experimental and kinetic investigations. J Energy Storage 2024; 85:111098. https://doi.org/10.1016/J.EST.2024.111098

2. Rossi D, Anguillesi I, Desideri U, Seggiani M. Easy fabrication method of Li4SiO4- K2CO3 based pellets for CO2 capture at high temperature. Chem Eng J 2024;481: 148615. https://doi.org/10.1016/J.CEJ.2024.148615
3. Luming Qi a, Linlin Zhang a,Ming Xia a, Mifen Cui a,Qing Liu a, Xu Qiao a b ,Xihua Xu a, Zhenyang Rong a ,Zhaoyang Fei a, Mild preparation of structured solid amine adsorbent pellets with the assistance of alginate for efficient and stable CO2 adsorption,Journal of Solid State ChemistryVolume 336, August 2024, 124747,https://doi.org/10.1016/j.jssc.2024.124747
4. Damiano Rossi, Irene Anguillesi, Maurizia Seggiani, Umberto Desideri,Easy fabrication method of Li4SiO4-K2CO3 based pellets for CO2 capture at high temperature,Chemical Engineering Journal Volume 481, 1 February 2024, 148615, https://doi.org/10.1016/j.cej.2024.14615
5. Hongyu Liu a b, Jiehong Tang a b, Jingmin Deng a b, Weilong Chen a b,Xiaoqian Ma a b ,Yuting Tang a b,Ziwei Sun a b,Preparation of nano-Al2O3 support CaO-based sorbent pellets by novel methods for high-temperature CO2 capture,Journal of EnvironmentalChemical EngineeringVolume 12, Issue 6, December 2024, 114157,https://doi.org/10.1016/j.jece.2024.114157
6. Chuanwen Zhao a , Jian Sun a, Kaiwen Ma a, Keke Li a, Pengjie Kong a, Rongyue Sun b, Zijian Zhou c, Core-shell structured CaO-based pellets with enhanced cyclic CO2 capture performance, Journal of Environmental Chemical Engineering Volume 12, Issue 3, June 2024, 113033, https://doi.org/10.1016/j.jece.2024.113033
7. Bin Xu, Ruicheng Fu, Yujie Liu, Yingchao Hu,Fabrication of CaO pellets via polyvinyl alcohol (PVA) method for efficient CO2 capture and solar energy storage, Separation and Purification Technology Volume 335, 5 May 2024, 126135, https://doi.org/10.1016/j.seppur.2023.126135
8. Yang Y, Dai P, Chen Z, Sun X, Ren X. Kinetic and thermodynamic investigations on the cyclic CO2 adsorption-desorption processes of lithium orthosilicate. Chem Eng J 2023;468:143679. https://doi.org/10.1016/j.cej.2023.143679
9. Mu Y, Wang T, Zhang M, Guo M. CO2 high-temperature sorbent (Al, Fe, Ti) COdoped Li4SiO4 from fly ash-derived SiO2 aerogel: In-situ synthesis, enhanced capture ability and long cycle stability. Fuel Process Technol2023;239:107533. https://doi.org/10.1016/J.FUPROC.2022.107533.
10. R. Fu, G. Yu, J. Cheng, Y. Hu, S. Yan, One-Step Synthesis of Porous Li4SiO4 Pellets by Polyvinyl Alcohol (PVA) Method for CO2 Capture, Fuel 331 (2023) 1–8, https://doi.org/10.1016/j.fuel.2022.125873.
11. Hern´ andez-Tapia V, Vera E, Ramírez-Zamora RM, Alc´ antar-Vazquez ´ B. Cyclic CO2 capture behavior of slag-derived Li4SiO4: A kinetic analysis of CO2 desorption. Fuel 2023;340:127518. https://doi.org/10.1016/J.FUEL.2023.127518.
12. V. Kulkarni, D. Panda, S.K. Singh, Evaluation of Amine-Based Solid Adsorbents for Direct Air Capture: A Critical Review, React. Chem. Eng. 8 (2022) 10-40, https://Coi.org/10.1039/d2re00211f
13. S.Bhattacharyya, S.Castro-Pardo, A.P. de Carvalho Teixeira, M. A. Campos Mata, M.A. Kabbani, M.G. Kibria,T. Prasankumar, S. Roy,T. Xu,R.M. Yadav ; A Comprehensive Overview of Carbon Dioxide Capture: From Materials, Methods to Industrial Status, Mater. Today 60 (2022) 227-270, https://doi.org/10.1016/j. rmettod. 2022.08.018.

14. S. Chen,J. Chen, X. Huang,C. Qin, Y. Tong,CO2 Capture by 145104 Sorbents. From Fundamentals to Applications, Sep. Purif. Technol. 301 (2022) 121977, https://doi.org/10.1016/j.seppar. 2022.121977.
15. A.A. Abd, J. Kim, M.R. Othrian, A Review on Application of Activated Carbons for Carbon Dioxide Capture: Present Performance, Preparation, and Surface Modification for Further Improvement (2021) 43329-43364, https://doi.org/10.1016/j.cej.2019.122385.
16. Gödde.J, Merko.M, Muhler.M, Xia.W, 2021. Nickel nanoparticles supported on nitrogen-doped carbon nanotubes are a highly active, selective and stable CO, metha nation catalyst. J. Energy Chem. 54, 323-331,https://doi:10.1016/j jechem 2020.06.007
17. L. Ma, S. Chen, C. Qin, S. Chen, W. Yuan, X. Zhou, J. Ran, Understanding the Effect of H2S on the Capture of CO2 Using K-Doped Li4SiO4 Sorbent, Fuel 283 (2021) 119364, https://doi.org/10.1016/j.fuel.2020.119364.
18. E. Stefanelli, M. Puccini, S. Vitolo, M. Seggiani, CO2 Sorption Kinetic Study and Modeling on Doped-Li4SiO4 under Different Temperatures and CO2 Partial Pressures, Chem. Eng. J. 379 (2020) 122307, https://doi.org/10.1016/j. cej.2019.122307.
19. H. Cui, L. Ma,S. Pi, C. Qin, Fabrication of Efficient and Stable Li4SiO4-Based Sorbent Pellets via Extrusion-Spheronization for Cyclic CO2 Capture, Chem. Eng. J. 379 (2020) 122385, https://doi.org/10.1016/j.cej.2019.122385.
20. S. Kumar, J. Koh, R. Srivastava, Utilization of Zeolites as CO2capturing Agents: Advances and Future Perspectives, J. CO2 Util. 41 (2020) 101251, https://doi.org/10.1016/j.jcou 2020 101251.IEA2023
21. Vallace A, Brooks S, Coe C, Smith MA. Kinetic model for CO2 capture by lithium silicates. J Phys Chem C 2020124:20506–15. https://doi.org/10.1021/acs. jpcc.0c04230.
22. Vallace A, Brooks S, Coe C, Smith MA. Kinetic model for CO2 capture by lithium silicates. J Phys Chem C 2020;124:20506–15. https://doi.org/10.1021/acs. jpcc.0c04230.
23. Y. Hu, H. Li W. Liu, M. Qu,Y. Yang, CO2 Capture by Li4SiO4 Sorbents and Their Applications: Current Developments and New Trends, Chem. Eng. J. 359 (2019) 604-625, https://doi.org/10.1016/j.cuj.2018.11.126
24. M. Puccini, M. Seggiani, E. Stefanelli, S. Vitolo, CO2 Sorption/Desorption Performance Study on K2CO3-Doped LI4SIO4-Based Pellets, Chem. Eng. J. 339 (2018) 51-60, https://doi.org/10.1016/j.cej.2018.01.117.
25. Q. Chen, Y. Hu,W. Liu, Q. Li, J. Sun, X. Tong, Y. Yang, One-Step Synthesis of Porous Li4SiO4-Based Adsorbent Pellets via Graphite Moulding Method for Cyclic CO2 Caixia Liu, Lifei Wei, Mingke Peng, Qingling Liu,Rui Han ,Yang Wang, Zhiyong Li -Integrated CO2 capture and conversion by Cu/CaO dual function materials: Effect of in-situ conversion on the sintering of CaO and its CO2 capture performance , Carbon Capture Science & Technology September 2024, 100220, Capture, Chem. Eng. J. 353 (2018) 92-99, https://doi.org/10.1016/j. cej.2018.07.044.
26. Zhao M, Fan H, Yan F, Song Y, He X, Memon MZ, et al. Kinetic analysis for cyclic CO2 capture using lithium orthosilicate sorbents derived from different silicon precursors. Dalt Trans 2018;47:9038–50. https://doi.org/10.1039/C8DT01617H.

27. Zhao M, Fan H, Yan F, Song Y, He X, Memon MZ, et al. Kinetic analysis for cyclic CO2 capture using lithium orthosilicate sorbents derived from different silicon precursors. DaltTrans2018;47:9038–50. https://doi.org/10.1039/C8DT01617H.
28. J.Sun, K.Wang, Z. Yin, P. Zhao, Z. Su, Z.Zhou Molten K2CO3-Promoted High- Performance Li4SiO4 Sorbents at Low CO2 Concentrations, Thermochim. Acta 655 (2017) 284-291, https://doi.org/10.1016/j.tca.2017.07.014.
29. Y. Ma, J. Xu, X. Zeng, H. Jiang, J. Li, Preparation and Performance Evaluation of MPAO8 Using Olefin from Coal as Raw Material, Ind. Lubr. Tribol. 69 (2017) 678–682, https://doi.org/10.1108/ILT-03-2016-0049.
30. Z. Su, J. Sun, K. Wang, Z. Yin, Z. Zhou, P. Zhao, Molten Sodium-Fluoride Promoted High-Performance Li4SiO4 Based CO2 Sorbents at Low CO2 Concentrations, Appl. Energy 204 (2017) 403-41, https://doi.org/10.1016/j.apenergy.2017.07.072
31. Z. Zhou, K. Wang, Z. Yin, P. Zhao, Z. Su, J. Sun, Molten K2CO3-Promoted High- Performance Li4SiO4 Sorbents at Low CO2 Concentrations, Thermochim. Acta 655 (2017) 284-291, https://doi.org/10.1016/j.tca.2017.07.014.
32. Y. Ma, J. Xu, X. Zeng, H. Jiang, J. Li, Preparation and Performance Evaluation of MPAO8 Using Olefin from Coal as Raw Material, Ind. Lubr. Tribol. 69 (2017) 678–682, https://doi.org/10.1108/ILT-03-2016-0049.
33. H. Chen, Y. Hu, W. Liu, X. Li, J. Sun, W. Wang,M. Xu, X.Yang, Y. Zhang, Alkali- Doped Lithium Orthosilicate Sorbents for Carbon Dioxide Capture, Chu SusChem 9 (2016) 2480-2487, https://doi.org/10.1002/c 201600737.
34. Anqi Huang, Hedan Tang, Jian Chen.A, Weimin Xia,Changqiang Huang ,Yong Li ,Yuxin Jiang ,Zhicheng Wang ,Yiheng Gu ,Bin Qian ,Core-in-shell, glucose-templated, ZrO2-stabilized calcium/copper-based pellets with robust CO2 capture performance for Ca/Cu process,Separation and Purification Technology,1 January 2015, 128241,https://doi.org/10.1016/j.seppur.2024.128241
35. Eleonora Stefanelli, Flavio Francalanci, Sandra Vitolo, Monica Puccini,Insights into adsorption mechanism and kinetic modeling of K2CO3-doped Li4SiO4 pellets for CO2 capture at high temperature and low concentration Fuel Volume 380, 15 January 2015, 133161, https://doi.org/10.1016/j.fuel.2024.133161
36. Y. Ni, H. Wang, S. Zhang, Q. Zhang, Z. Zhu, Absorption Behaviors Study on Doped Li4SiO4 under a Humidified Atmosphere with Low CO2 Concentration, Int. J. Hydrogen Energy 39 (2014) 17913-17920, https://doi.org/10.1016/j jhydene. 2014.07.011.
37. Y. Ni, H. Wang, S. Zhang, Q. Zhang, Z. Zhu, Absorption Behaviors Study on Doped Li4SiO4 under a Humidified Atmosphere with Low CO2 Concentration, Int. J. Hydrogen Energy 39 (2014) 17913-17920, https://doi.org/10.1016/j. ijhydene.2014.07.011.
38. M. Puccini, M. Seggiani, S. Vitolo, Alkali Promoted Lithium Orthosilicate for CO2 Capture at High Temperature and Low Concentration, Int. J. Greenh. Gas Control 17 (2013) 25-31, https://doi.org/10.1016/jigg 2013.04.009.
39. T. Gundersen,R. Soundararajan, Coal Based Power Plants Using Oxy Combustion for CO2 Capture: Pressurized Coal Combustion to Reduce Capture Penalty, Appl. Therm. Eng. 61 (2013) 115-122, https://doi.org/10.1016/j. appithermaleng 2013.04.010.

40. T.L. Avalos Rendón, C. Gómez-Yáñez, J. Ortiz-Landeros, H. Pfeiffer,J. Therm Anal CalorimAnalysis and Perspectives Concerning CO2 Chemisorption on Lithium Ceramics Using Thermal Analysis 108 (2012) 647-655https://doi.org/10.1007/$10973011-2063-y
41. Z. Qiao, Z. Wang,J. WangS. Yuan, C. Zhang, Y. Zhn. Analysis of CO2 Sorption/ Desorption Kinetic Behaviors and Reaction Mechanisms on Li4SiO4, AICHE J. 59 (2012) 215-228, https://doi.org/10.1002/ajc.13861
42. M. Puccini, M. Seggiani, S. Vitolo, High-Temperature and Low Concentration CO2 Sorption on Li4SiO4 Based Sorbents: Study of the Used Silica and Doping Method Effects, Int. J. Greenh. Gas Control 5 (2011) 741-748, https://doi.org/10.1016/j. tigge 2011.03.003.
43. M.J. Venegas, E. Fregoso-Israel, R. Escamilla, H. Pfeiffer, Kinetic and Reaction Mechanism of CO2 Sorption on Li 4SiO4: Study of the Particle Size Effect, Ind. Eng. Chem. Res. 46 (2007) 2407–2412, https://doi.org/10.1021/ie061259e.
44. FactSageTM, FACT Salt Database, (2007). Available online: www.factsage.cn/fact/ documentation. [37] M.J. Venegas, E. Fregoso-Israel, R. Escamilla, H. Pfeiffer, Kinetic and Reaction Mechanism of CO2 Sorption on Li4SiO4: Study of the Particle Size Effect, Ind. Eng. Chem. Res. 46 (2007) 2407–2412, https://doi.org/10.1021/ie061259e.
45. D. Cruz, S. Bulbulian, E. Lima, H. Pfeiffer, Kinetic Analysis of the Thermal Stability of Lithium Silicates (Li4SiO4 and Li2SiO3), J. Solid State Chem. 179 (2006) 909–916, https://doi.org/10.1016/j.jssc.2005.12.020.
46. K.Essaki ,M. Kato, K. Nakagawa CO2 Removal at High Temperature Using Packed Bed of Lithium Silicate J. Ceram Soc Japan 114 (2006) 739-742, https://doi.org/10.2109/jcersj.114.739.
47. Liu G, Li B, Hu K, van Genuchten MT. Simulating the Gas Diffusion Coefficient in Macropore Network Images: Influence of Soil Pore Morphology. Soil Sci Soc Am J 2006;70:1252–61. https://doi.org/10.2136/sssaj2005.0199.
48. K. Essaki, M. Kato, H. Uemoto, Influence of Temperature and CO2 Concentrationon the CO2 Absorption Properties of Lithium Silicate Pellets, J. Mater. Sci. 40 (2005) 5017-5019, https://doi.org/10.1007/s10853-005-1812-3.
49. J.I. Ida, Y.S. Lin, Mechanism of High Temperature CO2 Sorption on Lithium Zirconate, Environ. Sci. Technol. 37 (2003)1999-2004,https://doi.org/10.1021/S0022-3115(98)00449-8EssakiY.K. Kato Masahiro N.K, Nakagawa, Y.T., Ohashi, K.S; Carbon Dioxide Gas Absorbent Containing Lithium Silicate 2002, US Patent M. Kato, K. Nakagawa, S. Yoshikawa, Carbon Dioxide Absorption by Lithium Orthosilicate in a Wide Range of Temperature and Carbon Dioxide Concentrations, J. Mater. Sci. Lett. 21 (2002) 485-487, https://doi.org/10.1023/A:10153388085:13
50. H. Pfeiffer, P. Bosch, S. Bulbulian, Synthesis of Lithium Silicates, J. Nucl. Mater. 257 (1998) 309–317https://doi.org/10.1016/S0022-3115(98)00449-8