SYNTHESIS OF CERIUM OXIDE-MAGNESIUM OXIDE ADSORBENT USING EGG-SHELL MEMBRANE BIO-TEMPLATING FOR CARBON DIOXIDE CAPTURE

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DEDICATION

This thesis is dedicated to my parents, who taught me the real meaning of life. The always be my number one for the rest of my life. Also dedicated to my postgraduate colleague, who always helpful for any inquiries. Finally, to my supervisor, who guided me throughout the journey as a postgraduate student in UTM.

"Learning Never Ends"

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ABSTRACT

Increased CO_2 atmospheric concentration is majorly contributed by the uncontrolled greenhouse gasses emission from rapid industrialisation. This phenomenon could lead to irreversible environmental problems such as climate change, global warming, ocean acidification and other environmental related issues. Thus, to keep this under control, several approaches have been proposed and conducted. Currently, carbon capture via metal oxide solid adsorbent adsorption is one of the approaches that is progressively studied. However, commercialised metal oxide adsorbents such as magnesium oxide (MgO) and cerium oxide (CeO_2) have several drawbacks such as poor structural and textural properties and low surface basicity, leading to low CO_2 adsorption. Therefore, the purpose of this study was to prepare mesoporous composite CeO_2-MgO (CM-BT) adsorbent via the utilisation of egg-shell membrane (ESM) as a template. The prepared adsorbents were characterised using field emission scanning electron microscopy-energy dispersion X-ray spectroscopy, transmission electron microscopy-energy dispersion X-ray spectroscopy, X-ray diffraction, nitrogen (N_2) physisorption, Fourier-transform infrared spectroscopy, thermogravimetric analysis and CO_2-temperature-programmed desorption (CO_2-TPD). The CO_2 uptake performance was evaluated at 1 atm and 300 K. It was found that mesoporous CM-BT adsorbent exhibited an enhancement in structural properties, with higher surface area (42 m^2/g) and pore volume (0.185 cm^3/g) compared to composite CeO_2-MgO prepared via thermal decomposition (CM-TD). CM-BT exhibited a high CO_2 uptake capacity of 5.7 mmol/g, which was 2.5-times higher than CM-TD. This was due to the increased surface basicity of CM-BT, which was associated with abundant adsorption sites of weak, medium and strong base-site. This study revealed that ESM bio-templating is a promising approach in synthesising mesoporous material adsorbent with enhanced adsorbent's physicochemical properties, resulting in increased CO_2 uptake capacity.

ABSTRAK

Perindustrian yang pesat telah menjadi penyumbang terbesar kepada pelepasan gas rumah hijau yang tidak terkawal ke atmosfera dan telah menjurus kepada peningkatan tahap kepekatan karbon dioksida di atmosfera. Fenomena ini menyebabkan berlakunya masalah kepada alam sekitar termasuklah perubahan iklim, pemanasan global, pengasidan lautan dan masalah berkaitan alam sekitar yang lain. Oleh itu, bagi memastikan perkara tersebut berapa dibawah kawalan, beberapa pendekatan telah dicadangkan dan diambil. Pada ketika ini, penjerapan karbon dioksida dengan menggunakan penjerap logam oksida adalah salah satu pendekatan yang mana sedang dikaji dengan secara progresif sekali. Walau bagaimanapun, penjerap logam oksida yang dikomersialkan seperti magnesium oksida (MgO) dan serium oksida (CeO_2) memiliki beberapa kelemahan seperti sifat struktur dan tekstur yang lemah dan kelemahan pada bes permukaan yang mana telah menjurus kepada penjerapan CO_2 yang rendah. Oleh itu, kajian ini adalah bertujuan untuk menyediakan penjerap mesopori komposit CeO_2-MgO (CM-BT) dengan menggunakan membran kulit telur (ESM) sebagai pencontoh. Penjerap yang telah disediakan dicirikan dengan menggunakan mikroskop medan imbasan elektron penyebaran tenaga sinar-X, mikroskop penghantar elektron penyebaran tenaga sinar-X, pembelaun sinar-X, kaedah penjerapan nitrogen, spektroskopi inframerah transformasi Fourier, analisa termogravimetrik dan penyahjerapan CO_2 dengan suhu yang diprogramkan (CO_2-TPD). Prestasi penjerapan CO_2 dinilai pada 1 atm dan 300 K. Didapati bahawa penjerap komposit CM-BT mesopori menunjukkan peningkatan sifat strukturnya dengan luas permukaan (42 m^2/g) dan isipadu pori (0,185 cm^3/g) yang lebih tinggi berbanding komposit CeO_2-MgO yang disediakan melalui penguraian terma (CM-TD). CM-BT telah menunjukkan peningkatan kapasiti penjerapan CO_2 yang tinggi sebanyak 5.7 mmol/g, iaitu 2.5-kali lebih tinggi berbanding CM-TD. Hal ini didorong oleh kebesan permukaan penjerap CM-BT yang tinggi, yang mana berkaitan dengan bilangan tapak penjerap alkali lemah, sederhana dan kuat yang banyak. Kajian ini telah mendedahkan bahawa bio-pencontoh ESM adalah pendekatan yang meyakinkan dalam penyediaan penjerap mesopori yang memiliki sifat fizikokimia yang dipertingkatkan, yang mana menyumbang kepada peningkatan kapasiti penjerapan CO_2.

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Cu Kα - Copper Potassium Alpha X radiation

dV/dlogD - Pore volume

P/P_0 - Relative pressure

wt% - Percentage by weight

c - BET Constant

n - Order of Reflection

λ - Wavelength on Incident Ray

d - Interplanar Spacing of the Crystal

θ - Incident Angle

LIST OF ABBREVIATIONS

BET	-	Brunauer-Emmett-Teller
BJH	-	Barrett-Joyner-Halenda
CCS	-	Carbon Capture & Storage
CCU	-	Carbon Capture & Utilisation
ESM	-	Egg-Shell Membrane
CeO_2-BT	-	Cerium Oxide-Biotemplated
MgO-BT	-	Magnesium Oxide-Biotemplated
CM-BT	-	CeO_2-MgO-Biotemplated
CM-x	-	CeO_2-MgO-Biotemplated with investigated parameter of varies pH condition
CM-y	-	CeO_2-MgO-Biotemplated with investigated parameter of different solvent type
CM-z	-	CeO_2-MgO-Biotemplated with investiagted parameter of different calcination temperature
CO_2	-	Carbon Dioxide
FTIR	-	Fourier-Transform Infrared Spectroscopy
IPCC	-	Intergovernmental Panel on Climate Change
TEM	-	Transmission Electron Miscroscope
STEM	-	Scanning Transmission Electron Microscopy
HRTEM	-	High-Resolution Transmission Electron Microscopy
FESEM	-	Field Emission Scanning Electron Microscope
EDX	-	Element Dispersion X-ray Spectroscopy
SAED	-	Selected Area Electron Diffraction
TGA	-	Thermogravimetric Analysis
XRD	-	X-ray Diffraction
TPD	-	Temperature Programmed Desorption

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Rapid urbanisation and industrialisation are significant contributors to the increasing CO_2 emissions into the atmosphere (Chen et al., 2019). According to the statistical data (Richie, 2017), Asia countries are the highest contributor amounting to 19 billion tons of CO_2, led by China with 53 % of global CO_2 emission. The Intergovernmental Panel on Climate Change (IPCC) has reported that the atmospheric CO_2 concentration will reach up to 570 ppm in the year 2100. This increasing CO_2 concentration will be causing an irreversible environmental issue such as global warming due to the elevation of global average temperature (Rahimi et al., 2019) and ocean acidification (Guo et al., 2019). Ocean acidification is result from the gas exchange between air and ocean surface. Hence, the high dissolved inorganic carbon will decrease the pH of the surface ocean (Aghaie et al., 2018). Therefore, many studies have been conducted to minimise CO_2 emissions into the atmosphere such as through the carbon capture approach then further proceed with utilisation and storage process operated under CCU and CCS application, respectively.

Carbon capture can be achieved through several techniques such as absorption, cryogenic, membrane and adsorption (Azmi & Aziz, 2019). Nowadays, the most industrial implemented method in capturing CO_2 is the absorption technique. However, the currently used absorption technique faced several significant drawbacks: high equipment corrosion rate, high energy consumption during the regeneration stage, and loss of solvent in the presence of SO_2, NO_2 and O_2 and also through evaporation (Aghaie et al., 2018; Jiang et al., 2019; Wang et al., 2014; Yu et al., 2012). These disadvantages are linked with the inherent properties of amine, which have high vapour pressure, corrosive nature, and high energy input for regeneration (Aghaie et al., 2018). Therefore, due to these limitations, the adsorption method seems to be much promising method due to the advantage adsorption process such as easy handling and recovery process, low CO_2 separation cost, low regeneration energy requirement and economical solid adsorbent (Jiang et al., 2019).

Metal oxide-based adsorbent such as magnesium oxide (MgO) possesses a promising adsorbent characteristic which beneficial in capturing CO_2, such as its high theoretical uptake capacity (24.8 mmol/g), low toxicity, tuneability porous structure, having appropriate surface basicity strength, and wide range of adsorption temperature up-to 673 K (Azmi & Aziz, 2019; Hu et al., 2019). However, conventional MgO tends to suffer an issue such as limited adsorption capacity and low adsorption rate (Li et al., 2020). This issue could be related to poor physicochemical properties (low basicity strength, surface area and pore volume), limiting the binding of the CO_2 to the adsorbent active binding site. Therefore, it is desirable to fabricate an adsorbent with excellent physicochemical properties. This tuning approach could be achieved by composite MgO with other metal oxide/non-metal and choosing a suitable synthesis method.

In addition, composite MgO adsorbent has also attracted much attention, which composite MgO adsorbent offers better physicochemical properties and surface basicity strength, leading to high CO_2 uptake capacity (Chen et al., 2019; Yu et al., 2018). According to (Liu et al., 2015), this reactivity is correlated with the synergetic effect between compositing metal (e.g. CeO_2) and other doped metal (M) such as MgO. This effect facilitates the ion exchange between M^{n+} / M^{n+1} and Ce^{3+} and $Ce^{4+,}$ which act as an active site for trapping CO_2. In addition, as reported by (Yu et al., 2018), the MgO-based adsorbent was successfully prepared via urea co-precipitation. It is found that composite Al_2O_3-MgO and CeO_2-MgO have exhibited better surface strength basicity with the evidence of CO_2-TPD than pure MgO. Although, every composite MgO-based adsorbent also possessing a varies surface basicity strength. In addition, decent adsorbent’s physicochemical properties also reported influenced by the type of synthesis method used. Each synthesis method will result in different adsorbent’s textural and structural properties that affecting its adsorption performance (Guo et al., 2020). These structural enhancements were usually found related to surfactant templates utilisation, such as Cetyltrimethylammonium Bromide (CTAB). However, this surfactant template possesses several drawbacks, such as the formation of aggregated adsorbent nanocrystals with a disordered mesoporosity due to the relatively weak interaction between surfactant and the adsorbent-based species (Yang et al., 2017), costly (Wang et al., 2009) and complicated procedure (Abarna et al., 2016; Li et al., 2015).

Consider minimising the issue faced by the current surfactant-used synthesis method, the bio-templating method is one of the alternative approaches. The Bio-templating method uses a natural-based material (biomaterial) as a template (Ma et al., 2019). Biomaterial used will act as a pore generator for adsorbent where metal ions will be loaded to and then removed via the calcination process. The remaining metal-oxide residue will be formed as the parental bio-template structure used (He et al., 2019). For instances, (Witoon et al., 2014) has reported on the chitosan bio-templated Ca-based adsorbent toward CO_2 capture application. It is found that the chitosan bio-templated Ca-based adsorbent's morphological feature was influenced by the ratio of the chitosan used and has resulted to higher CO_2 capture than pure CaO and surfactant-used CaO. Considering the high fibrous structure material that could be induced to the increase of adsorbent's surface area, eggshell membrane (ESM) is a potential candidate to be utilised as a bio-templating material. ESM possess a 3D interwoven natural protein fibrous network structure (Chen et al., 2019; Preda et al., 2020), leading to the generation of mesoporous structured adsorbent (Fan et al., 2016; He & Yang, 2018).

In this study, mesoporous composite CeO_2-MgO was synthesised using the bio-templating method with ESM as a template. As a comparison, composite CeO_2-MgO adsorbent was also synthesised via the thermal decomposition method. The prepared adsorbents were all subjected to characterisation by using X-ray diffraction (XRD), Fourier-transform infrared (FTIR) spectroscopy, Nitrogen (N_2) adsorption-desorption, High-resolution transmission electron microscopy (HRTEM), Field emission scanning electron microscopes (FESEM), Energy-dispersive X-ray (EDX) spectroscopy, Thermogravimetric analysis (TGA) and Temperature-programmed desorption of carbon dioxide (CO_2-TPD). The adsorbent's CO_2 uptake capacity was tested under CO_2 gas conditions at atmospheric pressure and temperature.

1.2 Problem Statement

Commercial MgO adsorbent seems to suffer several drawbacks, such as low specific surface area and low surface basicity. This issue has caused low CO_2 uptake capacity since the accessibility of the CO_2 molecule to the adsorbent's active site and number of basic attachment site are very limited. Thus, enhancement approaches are needed. MgO's physicochemical properties can be tuned by compositing with other metal oxide and fabricating a high surface area MgO adsorbent. Metal oxide composite (e.g. with CeO_2) can enhance the adsorbent's physicochemical properties by tuning the adsorbent's surface basicity strength. Then, influencing adsorbent CO_2 uptake capacity. Utilising a proper synthesis method, such as a surfactant-template-based method, could also improve MgO's physicochemical properties. However, a common surfactant used, such as CTAB utilised is costly. Hence, using biomass as a template is an alternative to minimising this issue since the bio-material template is abundantly available. Therefore, it is expected that using ESM as a template in the preparation phase will result in the generation of high surface area adsorbent, which further contributes to the enhancement of the adsorbent's CO_2 uptake capacity.

1.3 Objectives of the Study

The objectives of this study are;

1. To synthesise mesoporous composite CeO_2-MgO by using the thermal decomposition method and ESM bio-templating method.

2. To characterise the prepared adsorbent using X-ray diffraction (XRD), Fourier-transform infrared (FTIR) spectroscopy, Thermogravimetric analysis (TGA), N_2 adsorption-desorption isotherm, Temperature-programmed desorption (TPD), Field emission scanning electron microscope (FESEM), High-resolution transmission electron microscopy (HRTEM) and Energy-dispersive x-ray (EDX) spectroscopy.

3. To test the prepared adsorbent on the CO_2 adsorption uptake capacity.

1.4 Scope of the Study

a) The composite CeO_2-MgO adsorbent was synthesised via the thermal decomposition and eggshell membrane (ESM) templating methods. Initially, the adsorbent was prepared by using thermal decomposition method with different adsorbent CeO_2-MgO molar ratio of (0:1), (0.25:0.75), (0.5:0.5), (0.75:0.25) and (1:0). This to determine the optimum CeO_2-MgO molar ratio that yields high CO_2 uptake capacity. Then, single metal and composite adsorbents with high CO_2 uptake capacity were further investigated on the ESM bio-templating method's effect. Moreover, to further understand the ESM bio-templating method, several synthesis parameters such as the solution’s pH condition, type of solvent used, and different calcination temperature was investigated on the composite CeO_2-MgO adsorbent.

b) The physicochemical properties of the prepared adsorbents were investigated by using several characterisation analyses, as listed in Section 1.3 (Objective). The morphological features of the prepared adsorbent were examined and observed using FESEM and HRTEM analysis with EDX elemental mapping. Moreover, the X-ray diffraction analysis was executed to investigate the crystallinity properties of all prepared samples. For the analysis using FTIR spectroscopy, the adsorbents surface functional group was examined. The structural properties such as surface area and pore volume were investigated via N_2 adsorption-desorption isotherm. The TGA was conducted to study the thermal decomposition behaviour of the prepared adsorbent. Lastly, the adsorbent surface basicity strength was evaluated using TPD with CO_2 gas as a probe.

c) The CO_2 adsorption process was conducted for all prepared adsorbents using a fixed bed U-shaped adsorption column equipped with a CO_2 analyser instrument with 100 % CO_2 flow condition under ambient conditions with 5 adsorption-desorption cycles.

1.5 Significant of Study

In this study, the mesoporous composite CeO_2-MgO adsorbent was synthesised using the bio-templating method with the ESM utilisation as a template and expected to exhibit a high CO_2 uptake capacity. This high CO_2 uptake capacity was induced by the enhanced adsorbent's surface area and surface basicity strength/defect site generated by ESM bio-templating and composite CeO_2-MgO, respectively. An abundance of porous surfaces provides much efficient gas diffusion into the adsorbent's interior structure, and further increases active binding site exposure. In addition, this bio-template is a promising template to be used since it possesses a 3-dimensional structure contributing to the generation of mesoporous structure adsorbent. Moreover, it appears to be more economical due to abundantly available bio-material sources. These improvements and approaches were beneficial to the adsorption process in a wide range of applications such as post-combustion, gas purification, bio-gas purification, etc.

REFERENCES

Abarna, B., Preethi, T., Karunanithi, A., & Rajarajeswari, G. (2016). Influence of jute template on the surface, optical and photocatalytic properties of sol-gel derived mesoporous zinc oxide. *Materials Science in Semiconductor Processing, 56*, 243-250.

Abdolmohammad-Zadeh, H., & Talleb, Z. (2014). Magnetite-doped eggshell membrane as a magnetic sorbent for extraction of aluminum(III) ions prior to their fluorometric determination. *Microchimica Acta, 181*(15), 1797-1805. doi: 10.1007/s00604-014-1225-6

Abdullah, N., Osman, N., Hasan, S., & Hassan, O. (2012). Chelating agents role on thermal characteristics and phase formation of modified cerate-zirconate via sol-gel synthesis route. *Int. J. Electrochem. Sci*, *7*, 9401-9409.

Aghaie, M., Rezaei, N., & Zendehboudi, S. (2018). A systematic review on CO_2 capture with ionic liquids: Current status and future prospects. *Renewable and Sustainable Energy Reviews, 96*, 502-525. doi: 10.1016/j.rser.2018.07.004

Alavi, M. A., & Morsali, A. (2010). Syntheses and characterization of $Mg(OH)_2$ and MgO nanostructures by ultrasonic method. *Ultrasonics sonochemistry, 17*(2), 441-446. doi: 10.1016/j.ultsonch.2009.08.013

Alkadhem, A. M., Elgzoly, M. A. A., & Onaizi, S. A. (2020). Novel Amine-Functionalized Magnesium Oxide Adsorbents for CO_2 Capture at Ambient Conditions. *Journal of Environmental Chemical Engineering, 8*(4), 103968. doi: 10.1016/j.jece.2020.103968

Alonso-Vicario, A., Ochoa-Gómez, J. R., Gil-Río, S., Gómez-Jiménez-Aberasturi, O., Ramírez-López, C. A., Torrecilla-Soria, J., & Domínguez, A. (2010). Purification and upgrading of biogas by pressure swing adsorption on synthetic and natural zeolites. *Microporous and mesoporous materials, 134*(1), 100-107. doi: 10.1016/j.micromeso.2010.05.014

Alsawalha, M. (2005). *Characterization of acidic and basic properties of heterogeneous catalysts by test reactions.* Universität Oldenburg.

Arefi Pour, A., Sharifnia, S., Neishabori Salehi, R., & Ghodrati, M. (2016). Adsorption separation of CO_2/CH_4 on the synthesized NaA zeolite shaped with montmorillonite clay in natural gas purification process. *Journal of Natural Gas Science and Engineering, 36,* 630-643. doi: 10.1016/j.jngse.2016.11.006

Azmi, A., & Aziz, M. (2019). Mesoporous adsorbent for CO_2 capture application under mild condition: A review. *Journal of Environmental Chemical Engineering*, 103022.

Azmi, A. A., Ngadi, N., Kamaruddin, M. J., Yamani, Z., Zakaria, L. P. T., Annuar, N. H. R., Jalil A.A., & Aziz, M. A. A. (2019). Rapid one pot synthesis of mesoporous ceria nanoparticles by sol-gel method for enhanced CO_2 capture. *Chemical Engineering Transactions, 72, 403-408.*

Azmi, A. A., Ruhaimi, A. H., & Aziz, M. A. A. (2020). Efficient 3-aminopropyltrimethoxysilane functionalised mesoporous ceria nanoparticles for CO_2 capture. *Materials Today Chemistry, 16*, 100273. doi: 10.1016/j.mtchem.2020.100273

Balsamo, M., Erto, A., Lancia, A., Totarella, G., Montagnaro, F., & Turco, R. (2018). Post-combustion CO_2 capture: On the potentiality of amino acid ionic liquid as modifying agent of mesoporous solids. *Fuel, 218*, 155-161. doi: 10.1016/j.fuel.2018.01.038

Benedetti, V., Cordioli, E., Patuzzi, F., & Baratieri, M. (2019). CO_2 Adsorption study on pure and chemically activated chars derived from commercial biomass gasifiers. *Journal of CO_2 Utilization, 33*, 46-54. doi: 10.1016/j.jcou.2019.05.008

Benvenuti, J., Fisch, A., dos Santos, J. H. Z., & Gutterres, M. (2019). Silica-based adsorbent material with grape bagasse encapsulated by the sol-gel method for the adsorption of Basic Blue 41 dye. *Journal of Environmental Chemical Engineering, 7*(5), 103342. doi: 10.1016/j.jece.2019.103342

Bhagiyalakshmi, M., Hemalatha, P., Ganesh, M., Mei, P. M., & Jang, H. T. (2011). A direct synthesis of mesoporous carbon supported MgO sorbent for CO_2 capture. *Fuel, 90*(4), 1662-1667.

Bhagiyalakshmi, M., Lee, J. Y., & Jang, H. T. (2010). Synthesis of mesoporous magnesium oxide: its application to CO_2 chemisorption. *International Journal of Greenhouse Gas Control, 4*(1), 51-56.

Bhatta, L. K. G., Subramanyam, S., Chengala, M. D., Olivera, S., & Venkatesh, K. (2015). Progress in hydrotalcite like compounds and metal-based oxides for CO_2 capture: a review. *Journal of Cleaner Production, 103*, 171-196. doi: 10.1016/j.jclepro.2014.12.059

Boningari, T., Inturi, S. N. R., Manousiouthakis, V. I., & Smirniotis, P. G. (2018). Facile synthesis of flame spray pyrolysis-derived magnesium oxide nanoparticles for CO_2 sorption: effect of precursors, morphology, and structural properties. *Industrial & Engineering Chemistry Research, 57*(28), 9054-9061.

Brigham, K. (Producer). (2019). CNBC : Bill Gates and Big Oil back this company that's trying to solve climate change by sucking CO_2 out of the air. Retrieved from https://www.cnbc.com/2019/06/21/carbon-engineering-co2-capture-backed-by-bill-gates-oil-companies.html

Campbell, C. T., & Peden, C. H. F. (2005). Oxygen Vacancies and Catalysis on Ceria Surfaces. *Science, 309*(5735), 713. doi: 10.1126/science.1113955

Cazetta, A. L., Pezoti, O., Bedin, K. C., Silva, T. L., Paesano Junior, A., Asefa, T., & Almeida, V. C. (2016). Magnetic Activated Carbon Derived from Biomass Waste by Concurrent Synthesis: Efficient Adsorbent for Toxic Dyes. *ACS Sustainable Chemistry & Engineering, 4*(3), 1058-1068. doi: 10.1021/acssuschemeng.5b01141

Chen, G., Yang, X., Miao, K., Long, M., & Deng, W. (2017). Root hairs as biotemplates for fabricating hollow double-layer CuO microtubes. *Materials Letters, 194*, 193-196.

Chen, H., Liu, H., Guo, Y., Wang, B., Wei, Y., Zhang, Y., & Wu, H. (2018). Hierarchically ordered mesoporous TiO_2 nanofiber bundles derived from natural collagen fibers for lithium and sodium storage. *Journal of Alloys and Compounds*, *731*, 844-852.

Chen, J. L., Dong, X. Y. M., Shi, C. L., Li, S. H., Wang, Y., & Zhu, J. H. (2019). Fabrication of Strong Solid Base FeO–MgO for Warm CO_2 Capture. *CLEAN – Soil, Air, Water, 47*(8), 1800447. doi:10.1002/clen.201800447

Chen, Q., Hui, T., Sun, H., Peng, T., & Ding, W. (2020). Synthesis of magnesium carbonate hydrate from natural talc. *Open Chemistry, 18*(1), 951-961. doi: 10.1515/chem-2020-0154

Chen, S., Jin, H., & Lu, Y. (2019). Impact of urbanization on CO_2 emissions and energy consumption structure: A panel data analysis for Chinese prefecture-level cities. *Structural Change and Economic Dynamics, 49,* 107-119. doi: 10.1016/j.strueco.2018.08.009

Chen, X., Zhu, L., Wen, W., Lu, L., Luo, B., & Zhou, C. (2019). Biomimetic mineralisation of eggshell membrane featuring natural nanofiber network structure for improving its osteogenic activity. *Colloids and Surfaces B: Biointerfaces, 179,* 299-308.

Chen, Y., Ji, X., Yang, Z., & Lu, X. (2019). Novel Solvent for CO_2 Capture. *Energy Procedia, 158,* 5124-5129. doi: 10.1016/j.egypro.2019.01.687

Chen, Y., Zhou, T., Fang, H., Li, S., Yao, Y., & He, Y. (2015). A Novel Preparation of Nano-sized Hexagonal $Mg(OH)_2$. *Procedia Engineering, 102,* 388-394. doi: 10.1016/j.proeng.2015.01.169

Chen, Z., Hu, Z., Wang, J., Wang, X., Niu, X., Wang, Y., Shen, Y., Teng, W., Fan, J., & Zhang, W. X. (2019). Synthesis of mesoporous silica-carbon microspheres via self-assembly and in-situ carbonization for efficient adsorption of Di-n-butyl phthalate. *Chemical Engineering Journal, 369,* 854-862. doi: 10.1016/j.cej.2019.03.128

Chowdhury, I. H., Chowdhury, A. H., Bose, P., Mandal, S., & Naskar, M. K. (2016). Effect of anion type on the synthesis of mesoporous nanostructured MgO, and its excellent adsorption capacity for the removal of toxic heavy metal ions from water. *RSC Advances, 6*(8), 6038-6047.

Chowdhury, S., Parshetti, G. K., & Balasubramanian, R. (2015). Post-combustion CO_2 capture using mesoporous TiO_2/graphene oxide nanocomposites. *Chemical Engineering Journal, 263,* 374-384. doi: 10.1016/j.cej.2014.11.037

Cui, H., Zhang, Q., Hu, Y., Peng, C., Fang, X., Cheng, Z., Galvita, V.V., & Zhou, Z. (2018). Ultrafast and Stable CO_2 Capture Using Alkali Metal Salt-Promoted MgO–$CaCO_3$ Sorbents. *ACS applied materials & interfaces, 10*(24), 20611-20620.

Das, S. K., Wang, X., & Lai, Z. (2018). Facile synthesis of triazine-triphenylamine-based microporous covalent polymer adsorbent for flue gas CO_2 capture. *Microporous and mesoporous materials, 255,* 76-83. doi: 10.1016/j.micromeso.2017.07.038

Delkash, M., Ebrazi Bakhshayesh, B., & Kazemian, H. (2015). Using zeolitic adsorbents to cleanup special wastewater streams: A review. *Microporous and mesoporous materials, 214,* 224-241. doi: 10.1016/j.micromeso.2015.04.039

Della Mea, G. B., Matte, L. P., Thill, A. S., Lobato, F. O., Benvenutti, E. V., Arenas, L. T., Jürgensen, A., Hergenröder, R., Poletto, F., & Bernardi, F. (2017). Tuning the oxygen vacancy population of cerium oxide (CeO_{2-x}, $0<x<0.5$) nanoparticles. *Applied Surface Science, 422*, 1102-1112. doi: 10.1016/j.apsusc.2017.06.101

Demiral, H., & Güngör, C. (2016). Adsorption of copper(II) from aqueous solutions on activated carbon prepared from grape bagasse. *Journal of Cleaner Production, 124*, 103-113. doi: 10.1016/j.jclepro.2016.02.084

Deshpande, S., Patil, S., Kuchibhatla, S. V., & Seal, S. (2005). Size dependency variation in lattice parameter and valency states in nanocrystalline cerium oxide. *Applied Physics Letters, 87*(13), 133113. doi: 10.1063/1.2061873

Diagboya, P. N. E., & Dikio, E. D. (2018). Silica-based mesoporous materials; emerging designer adsorbents for aqueous pollutants removal and water treatment. *Microporous and mesoporous materials, 266*, 252-267. doi: 10.1016/j.micromeso.2018.03.008

Ding, J., Yu, C., Lu, J., Wei, X., Wang, W., & Pan, G. (2020). Enhanced CO_2 adsorption of MgO with alkali metal nitrates and carbonates. *Applied energy, 263*, 114681.

Djilani, C., Zaghdoudi, R., Djazi, F., Bouchekima, B., Lallam, A., Modarressi, A., & Rogalski, M. (2015). Adsorption of dyes on activated carbon prepared from apricot stones and commercial activated carbon. *Journal of the Taiwan Institute of Chemical Engineers, 53*, 112-121. doi: 10.1016/j.jtice.2015.02.025

Du, J., Sabatini, D. A., & Butler, E. C. (2014). Synthesis, characterization, and evaluation of simple aluminum-based adsorbents for fluoride removal from drinking water. *Chemosphere, 101*, 21-27. doi: 10.1016/j.chemosphere.2013.12.027

Eckhardt, B., Ortel, E., Polte, J., Bernsmeier, D., Görke, O., Strasser, P., & Kraehnert, R. (2012). Micelle-Templated Mesoporous Films of Magnesium Carbonate and Magnesium Oxide. *Advanced Materials, 24*(23), 3115-3119. doi: 10.1002/adma.201104984

Egerton, R. F. (2005). *Physical principles of electron microscopy* (Vol. 56): Springer.

Elvira, G. B., Francisco, G. C., Víctor, S. M., & Alberto, M. L. R. (2017). MgO-based adsorbents for CO_2 adsorption: Influence of structural and textural properties on the CO_2 adsorption performance. *Journal of Environmental Sciences, 57*, 418-428.

Fan, S., Zhao, M., Ding, L., Liang, J., Chen, J., Li, Y., & Chen, S. (2016). Synthesis of 3D hierarchical porous Co_3O_4 film by eggshell membrane for non-enzymatic glucose detection. *Journal of Electroanalytical Chemistry, 775*, 52-57.

Feng, Z., Ren, Q., Peng, R., Mo, S., Zhang, M., Fu, M., Chen, L., & Ye, D. (2019). Effect of CeO_2 morphologies on toluene catalytic combustion. *Catalysis Today, 332,* 177-182. doi: 10.1016/j.cattod.2018.06.039

Fleury, E., Kittel, J., Vuillemin, B., Oltra, R., & Ropital, F. (2008). *Corrosion in amine solvents used for the removal of acid gases.* Paper presented at the Eurocorr 2008.

Gao, A., Guo, N., Yan, M., Li, M., Wang, F., & Yang, R. (2018). Hierarchical porous carbon activated by $CaCO_3$ from pigskin collagen for CO_2 and H_2 adsorption. *Microporous and mesoporous materials, 260*, 172-179.

Gao, P., Yang, C., Liang, Z., Wang, W., Zhao, Z., Hu, B., & Cui, F. (2019). N-propyl functionalized spherical mesoporous silica as a rapid and efficient adsorbent for steroid estrogen removal: Adsorption behaviour and effects of water chemistry. *Chemosphere, 214*, 361-370.
doi: 10.1016/j.chemosphere.2018.09.115

Gao, W., Zhou, T., Gao, Y., Louis, B., O'Hare, D., & Wang, Q. (2017). Molten salts-modified MgO-based adsorbents for intermediate-temperature CO_2 capture: A review. *Journal of energy chemistry, 26*(5), 830-838.

Gao, W., Zhou, T., Gao, Y., Wang, Q., & Lin, W. (2018). Study on MNO_3/NO_2 (M= Li, Na, and K)/MgO Composites for Intermediate-Temperature CO_2 Capture. *Energy & fuels*.

Gao, W., Zhou, T., Louis, B., & Wang, Q. (2017). Hydrothermal fabrication of high specific surface area mesoporous MgO with excellent CO_2 adsorption potential at intermediate temperatures. *Catalysts, 7*(4), 116.

Gao, W., Zhou, T., & Wang, Q. (2018). Controlled synthesis of MgO with diverse basic sites and its CO_2 capture mechanism under different adsorption conditions. *Chemical Engineering Journal, 336*, 710-720.

Ghosh, S., Ranjan, P., Ramaprabhu, S., & Sarathi, R. (2018). Carbon Dioxide Adsorption of Zinc Oxide Nanoparticles Synthesized by Wire Explosion Technique. *INAE Letters, 3*(4), 197-202. doi:10.1007/s41403-018-0049-9

Gnanam, S., & Rajendran, V. (2013). Influence of Various Surfactants on Size, Morphology, and Optical Properties of CeO_2 Nanostructures via Facile Hydrothermal Route. *Journal of Nanoparticles, 2013*, 839391. doi: 10.1155/2013/839391

Goharshadi, E. K., Samiee, S., & Nancarrow, P. (2011). Fabrication of cerium oxide nanoparticles: Characterization and optical properties. *Journal of Colloid and Interface Science, 356*(2), 473-480. doi: 10.1016/j.jcis.2011.01.063

Gondolini, A., Mercadelli, E., Sanson, A., Albonetti, S., Doubova, L., & Boldrini, S. (2013). Effects of the microwave heating on the properties of gadolinium-doped cerium oxide prepared by polyol method. *Journal of the European Ceramic Society, 33*(1), 67-77. doi: 10.1016/j.jeurceramsoc.2012.08.008

Gunathilake, C. A., Ranathunge, G. G. T. A., Dassanayake, R. S., Illesinghe, S. D., Manchanda, A. S., Kalpage, C. S., Rajapakse, R.M.G., & Karunaratne, D. G. G. P. (2020). Emerging investigator series: synthesis of magnesium oxide nanoparticles fabricated on a graphene oxide nanocomposite for CO_2 sequestration at elevated temperatures. *Environmental Science: Nano*. doi: 10.1039/C9EN01442J

Guo, Y., Tan, C., Wang, P., Sun, J., Li, W., Zhao, C., & Lu, P. (2019). Magnesium-based basic mixtures derived from earth-abundant natural minerals for CO_2 capture in simulated flue gas. *Fuel, 243*, 298-305.

Guo, Y., Tan, C., Wang, P., Sun, J., Li, W., Zhao, C., & Lu, P. (2020). Structure-performance relationships of magnesium-based CO_2 adsorbents prepared with different methods. *Chemical Engineering Journal, 379*, 122277.

Han, K. K., Zhou, Y., Lin, W. G., & Zhu, J. H. (2013). One-pot synthesis of foam-like magnesia and its performance in CO_2 adsorption. *Microporous and mesoporous materials, 169*, 112-119.

Han, Q., Wang, Z., Chen, X., Jiao, C., Li, H., & Yu, R. (2019). Facile Synthesis of Fe-based MOFs(Fe-BTC) as Efficient Adsorbent for Water Purifications. *Chemical Research in Chinese Universities, 35*(4), 564-569. doi: 10.1007/s40242-019-8415-z

Hanif, A., Dasgupta, S., & Nanoti, A. (2016). Facile Synthesis of High-Surface-Area Mesoporous MgO with Excellent High-Temperature CO_2 Adsorption Potential. *Industrial & Engineering Chemistry Research, 55*(29), 8070-8078. doi: 10.1021/acs.iecr.6b00647

Harada, T., Simeon, F., Hamad, E. Z., & Hatton, T. A. (2015). Alkali metal nitrate-promoted high-capacity MgO adsorbents for regenerable CO_2 capture at moderate temperatures. *Chemistry of Materials, 27*(6), 1943-1949.

Harvey C, G. N. (2019). CO_2 Emissions Will Break Another Record in 2019. *Scientific American : E&E News*.

Hauchhum, S., & Mahanta, P. (2014). Carbon dioxide adsorption on zeolites and activated carbon by pressure swing adsorption in a fixed bed. *International Journal of Energy and Environmental Engineering, 5*, 349-356. doi: 10.1007/s40095-014-0131-3

He, H., & Yang, P. (2018). CeO_2/NiO Nanostructures Created Using Eggshell Membrane Towards Enhanced Catalytic Activity. *Journal of nanoscience and nanotechnology, 18*(1), 340-346.

He, X., Tang, K., Li, X., Wang, F., Liu, J., Zou, F., Yang, M., & Li, M. (2019). A porous collagen-carboxymethyl cellulose/hydroxyapatite composite for bone tissue engineering by bi-molecular template method. *International journal of biological macromolecules, 137*, 45-53.

He, X., Yang, D. P., Zhang, X., Liu, M., Kang, Z., Lin, C., Jia, N., & Luque, R. (2019). Waste eggshell membrane-templated CuO-ZnO nanocomposites with enhanced adsorption, catalysis and antibacterial properties for water purification. *Chemical Engineering Journal, 369*, 621-633.

Hernández-Castillo, Y., García-Hernández, M., López-Marure, A., Luna-Domínguez, J. H., López-Camacho, P. Y., & Morales-Ramírez, Á. d. J. (2019). Antioxidant activity of cerium oxide as a function of europium doped content. *Ceramics International, 45*(2, Part A), 2303-2308. doi: 10.1016/j.ceramint.2018.10.145

Hiremath, V., Shavi, R., & Seo, J. G. (2017). Controlled oxidation state of Ti in MgO-TiO_2 composite for CO_2 capture. *Chemical Engineering Journal, 308*, 177-183.

Hiremath, V., Trivino, M. L. T., & Seo, J. G. (2019). Eutectic mixture promoted CO_2 sorption on MgO-TiO_2 composite at elevated temperature. *Journal of Environmental Sciences, 76*, 80-88.

Ho, K., Jin, S., Zhong, M., Vu, A.-T., & Lee, C.-H. (2017). Sorption capacity and stability of mesoporous magnesium oxide in post-combustion CO_2 capture. *Materials Chemistry and Physics, 198*, 154-161.

Hu, Y., Guo, Y., Sun, J., Li, H., & Liu, W. (2019). Progress in MgO sorbents for cyclic CO_2 capture: a comprehensive review. *Journal of Materials Chemistry A, 7*(35), 20103-20120.

Hu, Y., Liu, X., Zhou, Z., Liu, W., & Xu, M. (2017). Pelletization of MgO-based sorbents for intermediate temperature CO_2 capture. *Fuel, 187,* 328-337. doi: 10.1016/j.fuel.2016.09.066

Jackson, R., Le Quéré, C., Andrew, R., Canadell, J., Peters, G., Roy, J., & Wu, L. (2017). Warning signs for stabilizing global CO_2 emissions. *Environmental Research Letters, 12*(11), 110202.

Jackson, R. B., Le Quéré, C., Andrew, R. M., Canadell, J. G., Korsbakken, J. I., Liu, Z., Peters, G.P., & Zheng, B. (2018). Global energy growth is outpacing decarbonization. *Environmental Research Letters, 13*(12), 120401. doi:10.1088/1748-9326/aaf303

Jackson RB, L. Q. C., Andrew RM , Canadell JG, Korsbakken JI , Liu Z, Peters GP , Zheng B, Friedlingstein P. (2019). *Global Energy Growth Is Outpacing Decarbonization.* Retrieved from Canberra Australia: https://www.globalcarbonproject.org/global/pdf/GCP_2019_Global%20energy%20growth%20outpace%20decarbonization_UN%20Climate%20Summit_HR.pdf

Jahagirdar, A., Ahmed, M. Z., Donappa, N., Nagabhushana, H., & Nagabhushana, B. (2012). Cod Removal Of An Industrial Effluent Using Nan crystalline Ceria Synthesized By Solution Combustion Method. *J. Appl. Chem., 1*, 14-17.

Jaidka, S., Khan, S., & Singh, K. (2018). Na_2O doped CeO_2 and their structural, optical, conducting and dielectric properties. *Physica B: Condensed Matter, 550*, 189-198. doi: 10.1016/j.physb.2018.08.036

Janoš, P., Hladík, T., Kormunda, M., Ederer, J., & Šťastný, M. (2014). Thermal Treatment of Cerium Oxide and Its Properties: Adsorption Ability versus Degradation Efficiency. *Advances in Materials Science and Engineering, 2014*, 706041. doi: 10.1155/2014/706041

Janssens, W., Makshina, E. V., Vanelderen, P., De Clippel, F., Houthoofd, K., Kerkhofs, S., Martens, J.A., Jacobs, P.A., & Sels, B. F. (2015). Ternary Ag/MgO-SiO_2 Catalysts for the Conversion of Ethanol into Butadiene. *ChemSusChem, 8*(6), 994-1008. doi: 10.1002/cssc.201402894

Jeevanandam, J., Chan, Y. S., & Danquah, M. K. (2020). Effect of pH variations on morphological transformation of biosynthesized MgO nanoparticles. *Particulate Science and Technology, 38*(5), 573-586. doi: 10.1080/02726351.2019.1566938

Jeon, H., Min, Y. J., Ahn, S. H., Hong, S. M., Shin, J. S., Kim, J. H., & Lee, K. B. (2012). Graft copolymer templated synthesis of mesoporous MgO/TiO_2 mixed oxide nanoparticles and their CO_2 adsorption capacities. *Colloids and Surfaces A: Physicochemical and Engineering Aspects, 414*, 75-81. doi: 10.1016/j.colsurfa.2012.08.009

Jiang, D., Chen, M., Wang, H., Zeng, G., Huang, D., Cheng, M., Liu, Y., Xue, W., & Wang, Z. (2019). The application of different typological and structural MOFs-based materials for the dyes adsorption. *Coordination Chemistry Reviews, 380*, 471-483. doi: 10.1016/j.ccr.2018.11.002

Jiang, L., Gonzalez-Diaz, A., Ling-Chin, J., Roskilly, A., & Smallbone, A. (2019). Post-combustion CO_2 capture from a natural gas combined cycle power plant using activated carbon adsorption. *Applied energy, 245*, 1-15.

Jin, S., Bang, G., & Lee, C. H. (2020). Unusual morphology transformation and basicity of magnesium oxide controlled by ageing conditions and its carbon dioxide adsorption. *Journal of CO_2 Utilization, 41*, 101273. doi: 10.1016/j.jcou.2020.101273

Jin, S., Bang, G., Liu, L., & Lee, C. H. (2019). Synthesis of mesoporous MgO–CeO_2 composites with enhanced CO_2 capture rate via controlled combustion. *Microporous and mesoporous materials, 288*, 109587.

Jin, S., Ho, K., & Lee, C. H. (2018). Facile synthesis of hierarchically porous MgO sorbent doped with $CaCO_3$ for fast CO_2 capture in rapid intermediate temperature swing sorption. *Chemical Engineering Journal, 334*, 1605-1613.

Jin, S., Ko, K. J., & Lee, C. H. (2019). Direct formation of hierarchically porous MgO-based sorbent bead for enhanced CO_2 capture at intermediate temperatures. *Chemical Engineering Journal, 371*, 64-77. doi: 10.1016/j.cej.2019.04.020

Jin, S., Ko, K. J., Song, Y. G., Lee, K., & Lee, C. H. (2019). Fabrication and kinetic study of spherical MgO agglomerates via water-in-oil method for pre-combustion CO_2 capture. *Chemical Engineering Journal, 359*, 285-297.

Juhari, S. K., Omar, D. B., Leh, O. L. H., Kamarudin, S. M., & Marzukhi, M. A. (2019). *The Readiness Of The Stakeholders In The Implementation Of Low Carbon Cities Framework (Lccf) In An Urban Area: Methodology Of Research.* Paper presented at the IOP Conference Series: Earth and Environmental Science.

Kanahara, K., & Matsushima, Y. (2019). Adsorption and Desorption Properties of CO_2 on CeO_2 Nanoparticles Prepared via Different Synthetic Routes. *Journal of The Electrochemical Society, 166*(12), B978.

Kang, Y. S., Kim, D. Y., Yoon, J., Park, J., Kim, G., Ham, Y., Park, I., Koh, M., & Park, K. (2019). Shape control of hierarchical lithium cobalt oxide using biotemplates for connected nanoparticles. *Journal of Power Sources, 436,* 226836.

Kapica-Kozar, J., Kusiak-Nejman, E., Wanag, A., Kowalczyk, Ł., Wrobel, R. J., Mozia, S., & Morawski, A. W. (2015). Alkali-treated titanium dioxide as adsorbent for CO_2 capture from air. *Microporous and mesoporous materials, 202*, 241-249. doi: 10.1016/j.micromeso.2014.10.013

Kasikamphaiboon, P., & Khunjan, U. (2018). CO_2 Adsorption from Biogas Using Amine-Functionalized MgO. *International Journal of Chemical Engineering, 2018*.

Kaur, B., & Bhattacharya, S. N. (2011). 7 - Automotive dyes and pigments. In M. Clark (Ed.), *Handbook of Textile and Industrial Dyeing* (Vol. 2, pp. 231-251): Woodhead Publishing.

Kaur, G., Mitra, A., & Yadav, K. L. (2015). Pulsed laser deposited Al-doped ZnO thin films for optical applications. *Progress in Natural Science: Materials International, 25*(1), 12-21. doi: 10.1016/j.pnsc.2015.01.012

Koronaki, I. P., Prentza, L., & Papaefthimiou, V. (2015). Modeling of CO_2 capture via chemical absorption processes − An extensive literature review. *Renewable and Sustainable Energy Reviews, 50*, 547-566. doi: 10.1016/j.rser.2015.04.124

Korotkova, A. M., Borisovna, P. O., Aleksandrovna, G. I., Bagdasarovna, K. D., Vladimirovich, B. D., Vladimirovich, K. D., Alexandrovich, F. A., Yurievna, K. M., Nikolaevna, B. E., Yurievich, C. M., & Aleksandrovich, K. D. (2019). " Green" Synthesis of Cerium Oxide Particles in Water Extracts Petroselinum crispum. *Current Nanomaterials, 4*(3), 176-190.

Kuhn, P., Antonietti, M., & Thomas, A. (2008). Porous, Covalent Triazine-Based Frameworks Prepared by Ionothermal Synthesis. *Angewandte Chemie International Edition, 47*(18), 3450-3453. doi: 10.1002/anie.200705710

Kulkarni, J., Ravishankar, R., Nagabhushana, H., Anantharaju, K. S., Basavaraj, R. B., Sangeeta, M., Nagaswarupa, H. P., & Renuka, L. (2017). Structural, Optical and Photocatalytic Properties of MgO/CuO Nanocomposite Prepared by a Solution Combustion Method. *Materials Today: Proceedings, 4*(11, Part 3), 11756-11763. doi: 10.1016/j.matpr.2017.09.092

Kwon, H. J., Kwon, S., Seo, J. G., Jung, I. S., Son, Y.H., Lee, C. H., Lee, K. B., & Lee, H. C. (2017). Predictive Guide for Collective CO_2 Adsorption Properties of Mg−Al Mixed Oxides. *ChemSusChem, 10*(8), 1701-1709. doi:10.1002/cssc.201601581

Kwon, S., Fan, M., DaCosta, H. F. M., Russell, A. G., Berchtold, K. A., & Dubey, M. K. (2011). Chapter 10 - CO_2 Sorption. In D. A. Bell, B. F. Towler, & M. Fan (Eds.), *Coal Gasification and Its Applications* (pp. 293-339). Boston: William Andrew Publishing.

Lachowicz, J. I., Delpiano, G. R., Zanda, D., Piludu, M., Sanjust, E., Monduzzi, M., & Salis, A. (2019). Adsorption of Cu^{2+} and Zn^{2+} on SBA-15 mesoporous silica functionalized with triethylenetetramine chelating agent. *Journal of Environmental Chemical Engineering, 7*(4), 103205. doi: 10.1016/j.jece.2019.103205

Lahuri, A. H., Khai, M. L. N., Rahim, A. A., & Nordin, N. (2020). Adsorption Kinetics for CO_2 Capture using Cerium Oxide Impregnated on Activated Carbon. *Acta Chim. Slov*, 67.

Lai, Q., Diao, Z., Kong, L., Adidharma, H., & Fan, M. (2018). Amine-impregnated silicic acid composite as an efficient adsorbent for CO_2 capture. *Applied energy, 223*, 293-301. doi: 10.1016/j.apenergy.2018.04.059

Li, B., Duan, Y., Luebke, D., & Morreale, B. (2013). Advances in CO_2 capture technology: A patent review. *Applied energy, 102,* 1439-1447. doi: 10.1016/j.apenergy.2012.09.009

Li, B., Zhao, J., Liu, J., Shen, X., Mo, S., & Tong, H. (2015). Bio-templated synthesis of hierarchically ordered macro-mesoporous anatase titanium dioxide flakes with high photocatalytic activity. *RSC Advances, 5*(20), 15572-15578.

Li, C., Liu, X., Lu, G., & Wang, Y. (2014). Redox properties and CO_2 capture ability of CeO_2 prepared by a glycol solvothermal method. *Chinese Journal of Catalysis, 35*(8), 1364-1375.

Li, G., Xiao, P., Webley, P., Zhang, J., Singh, R., & Marshall, M. (2008). Capture of CO_2 from high humidity flue gas by vacuum swing adsorption with zeolite 13X. *Adsorption, 14*(2), 415-422. doi: 10.1007/s10450-007-9100-y

Li, J., Ng, D. H., Ma, R., Zuo, M., & Song, P. (2017). Eggshell membrane-derived $MgFe_2O_4$ for pharmaceutical antibiotics removal and recovery from water. *Chemical Engineering Research and Design, 126,* 123-133.

Li, P., Chen, R., Lin, Y., & Li, W. (2021). General approach to facile synthesis of MgO-based porous ultrathin nanosheets enabling high-efficiency CO_2 capture. *Chemical Engineering Journal, 404,* 126459. doi: 10.1016/j.cej.2020.126459

Li, P., Lin, Y., Chen, R., & Li, W. (2020). Construction of a hierarchical-structured MgO-carbon nanocomposite from a metal–organic complex for efficient CO_2 capture and organic pollutant removal. *Dalton Transactions*. doi: 10.1039/D0DT00722F

Li, S., Jiang, T., Xu, Z., Zhao, Y., Ma, X., & Wang, S. (2019). The Mn-promoted double-shelled $CaCO_3$ hollow microspheres as high efficient CO_2 adsorbents. *Chemical Engineering Journal, 372,* 53-64.

Li, S., Wang, Z. J., & Chang, T. T. (2014). Temperature oscillation modulated self-assembly of periodic concentric layered magnesium carbonate microparticles. *PLoS One, 9*(2), e88648.

Li, X., Xiao, W., He, G., Zheng, W., Yu, N., & Tan, M. (2012). Pore size and surface area control of MgO nanostructures using a surfactant-templated hydrothermal process: High adsorption capability to azo dyes. *Colloids and Surfaces A: Physicochemical and Engineering Aspects, 408,* 79–86. doi: 10.1016/j.colsurfa.2012.05.034

Li, Y. Y., Wan, M. M., Sun, X. D., Zhou, J., Wang, Y., & Zhu, J. H. (2015). Novel fabrication of an efficient solid base: carbon-doped MgO–ZnO composite and its CO_2 capture at 473 K. *Journal of Materials Chemistry A, 3*(36), 18535-18545. doi: 10.1039/C5TA04309C

Lin, Y. F., Syu, C. R., Huang, K. W., & Lin, K. Y. A. (2019). Synthesis of silica aerogel membranes using low-cost silicate precursors for carbon dioxide capture. *Chemical Physics Letters, 726*, 13-17. doi: 10.1016/j.cplett.2019.04.017

Liu, J., Cao, J., Chen, H., & Zhou, D. (2015). Adsorptive removal of humic acid from aqueous solution by micro- and mesoporous covalent triazine-based framework. *Colloids and Surfaces A: Physicochemical and Engineering Aspects, 481*, 276-282. doi: 10.1016/j.colsurfa.2015.05.021

Liu, J., Zong, E., Fu, H., Zheng, S., Xu, Z., & Zhu, D. (2012). Adsorption of aromatic compounds on porous covalent triazine-based framework. *Journal of Colloid and Interface Science, 372*(1), 99-107. doi: 10.1016/j.jcis.2012.01.011

Liu, L., Shi, J., Zhang, X., & Liu, J. (2015). Flower-Like Mn-Doped CeO_2 Microstructures: Synthesis, Characterizations, and Catalytic Properties. *Journal of Chemistry, 2015*, 254750. doi: 10.1155/2015/254750

Liu, M., Luo, G., Wang, Y., Xu, R., Wang, Y., He, W., Tan, J., Xing, M., & Wu, J. (2017). Nano-silver-decorated microfibrous eggshell membrane: processing, cytotoxicity assessment and optimization, antibacterial activity and wound healing. *Scientific reports, 7*(1), 1-14.

Liu, P., Chen, H., Yu, H., Liu, X., Jiang, R., Li, X., & Zhou, S. (2019). Oxygen vacancy in magnesium/cerium composite from ball milling for hydrogen storage improvement. *International Journal of Hydrogen Energy, 44*(26), 13606-13612. doi: 10.1016/j.ijhydene.2019.03.258

Liu, X., Song, K., Hu, J., Tian, C., & Liu, W. (2019). Effective destaining of methylene blue with low concentrations under visible light irradiation in the presence of $Mg(OH)_2$. *Surfaces and Interfaces, 17*, 100219. doi: 10.1016/j.surfin.2018.07.002

Liu, Z., Guan, D., Crawford-Brown, D., Zhang, Q., He, K., & Liu, J. (2013). A low-carbon road map for China. *Nature, 500*(7461), 143-145. doi:10.1038/500143a

Lu, C., & Chiu, H. (2006). Adsorption of zinc(II) from water with purified carbon nanotubes. *Chemical engineering science, 61*(4), 1138-1145. doi: 10.1016/j.ces.2005.08.007

Ma, X., Li, Y., Yan, X., Zhang, W., Zhao, J., & Wang, Z. (2019). Preparation of a morph-genetic CaO-based sorbent using paper fibre as a biotemplate for enhanced CO_2 capture. *Chemical Engineering Journal, 361*, 235-244.

Ma, X., & Scott, T. F. (2018). Approaches and challenges in the synthesis of three-dimensional covalent-organic frameworks. *Communications Chemistry, 1*(1), 98. doi: 10.1038/s42004-018-0098-8

Majlan, E. H., Wan Daud, W. R., Iyuke, S. E., Mohamad, A. B., Kadhum, A. A. H., Mohammad, A. W., Takriff, M. S., & Bahaman, N. (2009). Hydrogen purification using compact pressure swing adsorption system for fuel cell. *International Journal of Hydrogen Energy, 34*(6), 2771-2777. doi: 10.1016/j.ijhydene.2008.12.093

Malik, A. S., Zaman, S. F., Al-Zahrani, A. A., Daous, M. A., Driss, H., & Petrov, L. A. (2018). Development of highly selective PdZn/CeO_2 and Ca-doped PdZn/CeO_2 catalysts for methanol synthesis from CO_2 hydrogenation. *Applied Catalysis A: General, 560*, 42-53.

Mastuli, M. S., Ansari, N. S., Nawawi, M. A., & Mahat, A. M. (2012). Effects of Cationic Surfactant in Sol-gel Synthesis of Nano Sized Magnesium Oxide. *APCBEE Procedia*, *3*, 93-98. doi: 10.1016/j.apcbee.2012.06.052

Mittal, A., Teotia, M., Soni, R., & Mittal, J. (2016). Applications of egg shell and egg shell membrane as adsorbents: a review. *Journal of Molecular Liquids, 223,* 376-387.

Modak, A., & Jana, S. (2019). Advancement in porous adsorbents for post-combustion CO_2 capture. *Microporous and mesoporous materials, 276*, 107-132. doi: 10.1016/j.micromeso.2018.09.018

Montanari, T., Finocchio, E., Salvatore, E., Garuti, G., Giordano, A., Pistarino, C., & Busca, G. (2011). CO_2 separation and landfill biogas upgrading: A comparison of 4A and 13X zeolite adsorbents. *Energy, 36*(1), 314-319. doi: 10.1016/j.energy.2010.10.038

Morin-Crini, N., Fourmentin, M., Fourmentin, S., Torri, G., & Crini, G. (2019). Synthesis of silica materials containing cyclodextrin and their applications in wastewater treatment. *Environmental Chemistry Letters, 17*(2), 683-696. doi: 10.1007/s10311-018-00818-0

Mousavi-Kamazani, M., & Azizi, F. (2019). Facile sonochemical synthesis of Cu doped CeO_2 nanostructures as a novel dual-functional photocatalytic adsorbent. *Ultrasonics sonochemistry, 58*, 104695.

Murugan, R., Ravi, G., Vijayaprasath, G., Rajendran, S., Thaiyan, M., Nallappan, M., Gopalan, M., & Hayakawa, Y. (2017). Ni–CeO_2 spherical nanostructures for magnetic and electrochemical supercapacitor applications. *Physical Chemistry Chemical Physics, 19*(6), 4396-4404. doi:10.1039/C6CP08281E

Nemade, K. R., & Waghuley, S. A. (2014). Synthesis of MgO Nanoparticles by Solvent Mixed Spray Pyrolysis Technique for Optical Investigation. *International Journal of Metals, 2014*, 1-4. doi: 10.1155/2014/389416

Ni, Z., Jerrell, J. P., Cadwallader, K. R., & Masel, R. I. (2007). Metal−Organic Frameworks as Adsorbents for Trapping and Preconcentration of Organic Phosphonates. *Analytical Chemistry, 79*(4), 1290-1293. doi: 10.1021/ac0613075

NSTOnline. (2017). Positioning Malaysia at the forefront of low carbon cities. Retrieved from https://www.nst.com.my/news/nation/2017/08/264908/positioning-malaysia-forefront-low-carbon-cities

Nunez C. (2019). Sea level rise, explained. Retrieved from https://www.nationalgeographic.com/environment/global-warming/sea-level-rise/

Nyoka, M., Choonara, Y. E., Kumar, P., Kondiah, P. P., & Pillay, V. (2020). Synthesis of Cerium Oxide Nanoparticles Using Various Methods: Implications for Biomedical Applications. *Nanomaterials, 10*(2), 242.

Ochs, D., Brause, M., Braun, B., Maus-Friedrichs, W., & Kempter, V. (1998). CO_2 chemisorption at Mg and MgO surfaces: a study with MIES and UPS (He I). *Surface Science, 397*(1), 101-107. doi: 10.1016/S0039-6028(97)00722-X

Osaki, T. (2017). Effect of ethylene glycol on structure, thermal stability, oxygen storage capacity, and catalytic CO and CH_4 oxidation activities of binary CeO_2–Al_2O_3 and ternary CeO_2–ZrO_2–Al_2O_3 cryogels. *Journal of Sol-Gel Science and Technology, 82*(1), 133-147.

Pardakhti, M., Jafari, T., Tobin, Z., Dutta, B., Moharreri, E., Shemshaki, N. S., Suib, S., & Srivastava, R. (2019). Trends in Solid Adsorbent Materials Development for CO_2 Capture. *ACS Applied Materials & Interfaces, 11*(38), 34533-34559. doi: 10.1021/acsami.9b08487

Park, S., Choi, K. S., Lee, D., Kim, D., Lim, K. T., Lee, K. H., Seonwoo, H., & Kim, J. (2016). Eggshell membrane: Review and impact on engineering. *Biosystems engineering, 151*, 446-463.

Peng, Y., & Bai, X. (2018). Experimenting towards a low-carbon city: Policy evolution and nested structure of innovation. *Journal of Cleaner Production, 174,* 201-212. doi: 10.1016/j.jclepro.2017.10.116

Periyat, P., Laffir, F., Tofail, S. A. M., & Magner, E. (2011). A facile aqueous sol–gel method for high surface area nanocrystalline CeO_2. *RSC Advances, 1*(9), 1794-1798. doi: 10.1039/C1RA00524C

Perveen, H., Farrukh, M. A., Khaleeq-ur-Rahman, M., Munir, B., & Tahir, M. A. (2015). Synthesis, structural properties and catalytic activity of MgO-SnO_2 nanocatalysts. *Russian Journal of Physical Chemistry A, 89*(1), 99-107. doi: 10.1134/S0036024415010094

Pezoti, O., Cazetta, A. L., Bedin, K. C., Souza, L. S., Martins, A. C., Silva, T. L., Júnior, O. O. S., Visentainer, J. V., & Almeida, V. C. (2016). NaOH-activated carbon of high surface area produced from guava seeds as a high-efficiency adsorbent for amoxicillin removal: Kinetic, isotherm and thermodynamic studies. *Chemical Engineering Journal, 288*, 778-788. doi: 10.1016/j.cej.2015.12.042

Preda, N., Costas, A., Beregoi, M., & Enculescu, I. (2018). A straightforward route to obtain organic/inorganic hybrid network from bio-waste: Electroless deposition of ZnO nanostructures on eggshell membranes. *Chemical Physics Letters, 706*, 24-30.

Preda, N., Costas, A., Enculescu, M., & Enculescu, I. (2020). Biomorphic 3D fibrous networks based on ZnO, CuO and ZnO–CuO composite nanostructures prepared from eggshell membranes. *Materials Chemistry and Physics, 240,* 122205.

Prekajski, M. D., Babić, B. M., Bučevac, D., Pantić, J. R., Gulicovski, J. J., Miljkovic, M., & Matović, B. (2014). Synthesis and characterization of biomorphic CeO_2 obtained by using egg shell membrane as template. *Processing and Application of Ceramics, 8*(2), 81-85.

Rafiaani, P., Dikopoulou, Z., Van Dael, M., Kuppens, T., Azadi, H., Lebailly, P., & Van Passel, S. (2020). Identifying Social Indicators for Sustainability Assessment of CCU Technologies: A Modified Multi-criteria Decision Making. *Social Indicators Research, 147*(1), 15-44. doi: 10.1007/s11205-019-02154-4

Rahimi, K., Riahi, S., Abbasi, M., & Fakhroueian, Z. (2019). Modification of multi-walled carbon nanotubes by 1,3-diaminopropane to increase CO_2 adsorption capacity. *Journal of Environmental Management, 242,* 81-89. doi: 10.1016/j.jenvman.2019.04.036

Ren, N., Wu, Y.-t., Ma, C.-f., & Sang, L.-x. (2014). Preparation and thermal properties of quaternary mixed nitrate with low melting point. *Solar Energy Materials and Solar Cells, 127,* 6-13.

Richie H, R. M. (2017). CO_2 and Greenhouse Gas Emissions. Retrieved from https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions

Sabouni, R., Kazemian, H., & Rohani, S. (2014). Carbon dioxide capturing technologies: a review focusing on metal organic framework materials (MOFs). *Environmental Science and Pollution Research, 21*(8), 5427-5449. doi: 10.1007/s11356-013-2406-2

Sabu, U., Rashad, M., Logesh, G., Kumar, K., Lodhe, M., & Balasubramanian, M. (2018). Development of biomorphic alumina using egg shell membrane as bio-template. *Ceramics International, 44*(5), 4615-4621.

Salomão, R., Arruda, C. C., & Antunes, M. L. P. (2020). Synthesis, Dehydroxylation and Sintering of Porous $Mg(OH)_2$-MgO Clusters: Evolution of Microstructure and Physical Properties. *Interceram - International Ceramic Review, 69*(1), 52-62. doi: 10.1007/s42411-019-0067-y

Sandhyarani, N. (2019). Chapter 3 - Surface modification methods for electrochemical biosensors. In A. A. Ensafi (Ed.), *Electrochemical Biosensors* (pp. 45-75): Elsevier.

Saucier, C., Adebayo, M. A., Lima, E. C., Cataluña, R., Thue, P. S., Prola, L. D. T., Puchana-Rosero, M. J., Machado, F. M., Pavan, F. A., & Dotto, G. L. (2015). Microwave-assisted activated carbon from cocoa shell as adsorbent for removal of sodium diclofenac and nimesulide from aqueous effluents. *Journal of hazardous materials, 289*, 18-27. doi: 10.1016/j.jhazmat.2015.02.026

Sharma, R. K., Yadav, P., Yadav, M., Gupta, R., Rana, P., Srivastava, A., Zbořil, R., Varma, R. S., Antonietti, M., & Gawande, M. B. (2020). Recent development of covalent organic frameworks (COFs): synthesis and catalytic (organic-electro-photo) applications. *Materials Horizons, 7*(2), 411-454. doi: 10.1039/C9MH00856J

Sifontes, A. B., Rosales, M., Méndez, F. J., Oviedo, O., & Zoltan, T. (2013). Effect of Calcination Temperature on Structural Properties and Photocatalytic Activity of Ceria Nanoparticles Synthesized Employing Chitosan as Template. *Journal of Nanomaterials, 2013*, 265797. doi: 10.1155/2013/265797

Singh, R., & Geetanjali. (2018). 25 - Metal organic frameworks for drug delivery. In Inamuddin, A. M. Asiri, & A. Mohammad (Eds.), *Applications of Nanocomposite Materials in Drug Delivery* (pp. 605-617): Woodhead Publishing.

Sivasankari, J., Selvakumar, S., Sivaji, K., & Sankar, S. (2014). Structural and optical characterization of MgO: X (X=Li, Na, and K) by solution combustion technique. *Journal of Alloys and Compounds, 616*, 51-57. doi: 10.1016/j.jallcom.2014.07.052

Slesinski, A., Fic, K., & Frackowiak, E. (2018). Chapter Six - New Trends in Electrochemical Capacitors. In R. van Eldik & W. Macyk (Eds.), *Advances in Inorganic Chemistry* (Vol. 72, pp. 247-286): Academic Press.

Soren, S., Bessoi, M., & Parhi, P. (2015). A rapid microwave initiated polyol synthesis of cerium oxide nanoparticle using different cerium precursors. *Ceramics International, 41*(6), 8114-8118. doi: 10.1016/j.ceramint.2015.03.013

Spigarelli, B. P., & Kawatra, S. K. (2013). Opportunities and challenges in carbon dioxide capture. *Journal of CO_2 Utilization, 1*, 69-87. doi: 10.1016/j.jcou.2013.03.002

Storck, S., Bretinger, H., & F. Maier, W. (1998). N_2. *Characterization of micro- and mesoporous solids by physisorption methods and pore-size analysis*.

Sun, Q., Hu, X., Zheng, S., Sun, Z., Liu, S., & Li, H. (2015). Influence of calcination temperature on the structural, adsorption and photocatalytic properties of TiO_2 nanoparticles supported on natural zeolite. *Powder Technology, 274*, 88-97. doi: 10.1016/j.powtec.2014.12.052

Tomkute, V., Solheim, A., & Olsen, E. (2014). CO_2 capture by CaO in molten CaF_2–$CaCl_2$: optimization of the process and cyclability of CO_2 capture. *Energy & fuels, 28*(8), 5345-5353.

Triviño, M. L. T., Hiremath, V., & Seo, J. G. (2018). Stabilization of $NaNO_3$-Promoted Magnesium Oxide for High-Temperature CO_2 Capture. *Environmental science & technology, 52*(20), 11952-11959.

Tuan, V. A., & Lee, C. H. (2018). Preparation of rod-like MgO by simple precipitation method for CO_2 capture at ambient temperature. *Vietnam Journal of Chemistry, 56*(2), 197-202. doi:10.1002/vjch.201800013

Varghese, A. M., & Karanikolos, G. N. (2020). CO_2 capture adsorbents functionalized by amine – bearing polymers: A review. *International Journal of Greenhouse Gas Control, 96*, 103005. doi: 10.1016/j.ijggc.2020.103005

Vedyagin, A., Bedilo, A., Mishakov, I., & Shuvarakova, E. (2017). Study of MgO transformation into MgF_2 in the presence of CF_2Cl_2. *Journal of the Serbian Chemical Society, 82*, 37-37. doi: 10.2298/JSC161020037V

Victor, D. G., Zhou, D., Ahmed, E. H. M., Dadhich, P. K., Olivier, J. G. J., Rogner, H-H., Sheikho K., & Yamaguchi, M. (2014). Climate Change 2014: Mitigation of Climate Change. *Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, 111-150.

Vu, A. T., Jiang, S., Ho, K., Lee, J. B., & Lee, C. H. (2015). Mesoporous magnesium oxide and its composites: Preparation, characterization, and removal of 2-chloroethyl ethyl sulfide. *Chemical Engineering Journal, 269*, 82-93. doi: 10.1016/j.cej.2015.01.089

Vu, A. T., Park, Y., Jeon, P. R., & Lee, C. H. (2014). Mesoporous MgO sorbent promoted with KNO_3 for CO_2 capture at intermediate temperatures. *Chemical Engineering Journal, 258*, 254-264. doi: 10.1016/j.cej.2014.07.088

Wahono, S. K., Stalin, J., Addai-Mensah, J., Skinner, W., Vinu, A., & Vasilev, K. (2020). Physico-chemical modification of natural mordenite-clinoptilolite zeolites and their enhanced CO_2 adsorption capacity. *Microporous and mesoporous materials, 294*, 109871. doi: 10.1016/j.micromeso.2019.109871

Wang, J., Huang, L., Yang, R., Zhang, Z., Wu, J., Gao, Y., Wang, Q., O'Hare, D., & Zhong, Z. (2014). Recent advances in solid sorbents for CO_2 capture and new development trends. *Energy & Environmental Science, 7*(11), 3478-3518.

Wang, J., Li, M., Lu, P., Ning, P., & Wang, Q. (2019). Kinetic study of CO_2 capture on ternary nitrates modified MgO with different precursor and morphology. *Chemical Engineering Journal*, 123752.

Wang, K., Zhao, Y., Clough, P. T., Zhao, P., & Anthony, E. J. (2019). Structural and kinetic analysis of CO_2 sorption on $NaNO_2$-promoted MgO at moderate temperatures. *Chemical Engineering Journal, 372*, 886-895.

Wang, L., Zhang, J., & Chen, F. (2009). Synthesis of hydrothermally stable MCM-48 mesoporous molecular sieve at low cost of CTAB surfactant. *Microporous and mesoporous materials, 122*(1), 229-233. doi: 10.1016/j.micromeso.2009.03.004

Wang, Q., Luo, J., Zhong, Z., & Borgna, A. (2011). CO_2 capture by solid adsorbents and their applications: current status and new trends. *Energy & Environmental Science, 4*(1), 42-55. doi: 10.1039/C0EE00064G

Wang, S., & Peng, Y. (2010). Natural zeolites as effective adsorbents in water and wastewater treatment. *Chemical Engineering Journal, 156*(1), 11-24. doi: 10.1016/j.cej.2009.10.029

Wang, S., Yan, S., Ma, X., & Gong, J. (2011). Recent advances in capture of carbon dioxide using alkali-metal-based oxides. *Energy & Environmental Science, 4*(10), 3805-3819. doi: 10.1039/C1EE01116B

Wang, Y., Yin, C., Qin, H., Wang, Y., Li, Y., Li, X., Zuo, Y., Kang, S., & Cui, L. (2015). A urea-assisted template method to synthesize mesoporous N-doped CeO_2 for CO_2 capture. *Dalton Transactions, 44*(43), 18718-18722. doi: 10.1039/C5DT03562G

Wei, H., Deng, S., Hu, B., Chen, Z., Wang, B., Huang, J., & Yu, G. (2012). Granular bamboo-derived activated carbon for high CO_2 adsorption: the dominant role of narrow micropores. *ChemSusChem, 5*(12), 2354-2360.

Witoon, T. (2012). Polyethyleneimine-loaded bimodal porous silica as low-cost and high-capacity sorbent for CO_2 capture. *Materials Chemistry and Physics, 137*(1), 235-245. doi: 10.1016/j.matchemphys.2012.09.014

Witoon, T., Mungcharoen, T., & Limtrakul, J. (2014). Biotemplated synthesis of highly stable calcium-based sorbents for CO_2 capture via a precipitation method. *Applied energy, 118,* 32-40.

Xiao, C., & Wang, S. (2019). 11 - Radionuclide sequestration by metal-organic frameworks. In S. K. Ghosh (Ed.), *Metal-Organic Frameworks (MOFs) for Environmental Applications* (pp. 355-382): Elsevier.

Yan, K. L., & Wang, Q. (2018). Adsorption characteristics of the silica gels as adsorbent for gasoline vapors removal. *IOP Conference Series: Earth and Environmental Science, 153*(2), 022010.
doi: 10.1088/1755-1315/153/2/022010

Yanase, I., Maeda, T., & Kobayashi, H. (2017). The effect of addition of a large amount of CeO_2 on the CO_2 adsorption properties of CaO powder. *Chemical Engineering Journal, 327*, 548-554.

Yancheshmeh, M. S., Radfarnia, H. R., & Iliuta, M. C. (2017). Sustainable production of high-purity hydrogen by sorption enhanced steam reforming of glycerol over CeO_2-promoted $Ca_9Al_6O_{18}$-CaO/NiO bifunctional material. *ACS Sustainable Chem Eng, 5,* 9774-9786.

Yang, G., & Park, S. J. (2019). Deformation of Single Crystals, Polycrystalline Materials, and Thin Films: A Review. *Materials (Basel, Switzerland), 12*(12), 2003. doi: 10.3390/ma12122003

Yang, N., Ning, P., Li, K., & Wang, J. (2018). MgO-based adsorbent achieved from magnesite for CO_2 capture in simulate wet flue gas. *Journal of the Taiwan Institute of Chemical Engineers, 86,* 73-80.

Yang, X. Y., Chen, L. H., Li, Y., Rooke, J. C., Sanchez, C., & Su, B. L. (2017). Hierarchically porous materials: synthesis strategies and structure design. *Chemical Society Reviews, 46*(2), 481-558.

Yong, Z., Mata, V., & Rodrigues, A. r. E. (2002). Adsorption of carbon dioxide at high temperature—a review. *Separation and Purification Technology, 26*(2), 195-205. doi: 10.1016/S1383-5866(01)00165-4

Yoshikawa, K., Kaneeda, M., & Nakamura, H. (2017). Development of Novel CeO_2-based CO_2 adsorbent and analysis on its CO_2 adsorption and desorption mechanism. *Energy Procedia, 114,* 2481-2487.

Yoshikawa, K., Sato, H., Kaneeda, M., & Kondo, J. N. (2014). Synthesis and analysis of CO_2 adsorbents based on cerium oxide. *Journal of CO_2 Utilization, 8,* 34-38.

Yousefi, S., Ghasemi, B., Tajally, M., & Asghari, A. (2017). Optical properties of MgO and $Mg(OH)_2$ nanostructures synthesized by a chemical precipitation method using impure brine. *Journal of Alloys and Compounds, 711*, 521-529. doi: 10.1016/j.jallcom.2017.04.036

Yu, C. H., Huang, C. H., & Tan, C. S. (2012). A review of CO_2 capture by absorption and adsorption. *Aerosol Air Qual. Res, 12*(5), 745-769.

Yu, C., Ding, J., Wang, W., & Wei, X. (2019). Characteristics of Alkali Nitrates Molten Salt-Promoted MgO as a Moderate-Temperature CO_2 Absorbent. *Energy Procedia*, *158,* 5776-5781.

Yu, H., Wang, X., Shu, Z., Fujii, M., & Song, C. (2018). Al_2O_3 and CeO_2-promoted MgO sorbents for CO_2 capture at moderate temperatures. *Frontiers of Chemical Science and Engineering, 12*(1), 83-93.

Yuan, R., Kang, W., & Zhang, C. (2018). Rational Design of Porous Covalent Triazine-Based Framework Composites as Advanced Organic Lithium-Ion Battery Cathodes. *Materials, 11*(6), 937.

Zamiri, R., Ahangar, H. A., Kaushal, A., Zakaria, A., Zamiri, G., Tobaldi, D., & Ferreira, J. (2015). Dielectrical properties of CeO_2 nanoparticles at different temperatures. *PLoS One, 10*(4).

Zeng, Y., Zou, R., & Zhao, Y. (2016). Covalent Organic Frameworks for CO_2 Capture. *Advanced Materials*, *28*(15), 2855-2873. doi: 10.1002/adma.201505004

Zhang, L., Tu, L. Y., Liang, Y., Chen, Q., Li, Z. S., Li, C. H., Wang, Z. H., & Li, W. (2018). Coconut-based activated carbon fibers for efficient adsorption of various organic dyes. *RSC Advances*, *8*(74), 42280-42291.

Zhang, M., Zhang, X.-F., Deng, Z.-P., Huo, L.-H., & Gao, S. (2018). Synthesis and characterization of novel hierarchical metal oxide using scallion root as biotemplate. *Materials Letters*, *223*, 61-64.

Zhang, P., Chen, Y. P., Wang, W., Shen, Y., & Guo, J. S. (2016). Surface plasmon resonance for water pollutant detection and water process analysis. *TrAC Trends in Analytical Chemistry, 85*, 153-165.

Zhang, W., Li, S., Zhang, J., Zhang, Z., & Dang, F. (2019). Synthesis and adsorption behavior study of magnetic fibrous mesoporous silica. *Microporous and mesoporous materials, 282*, 15-21. doi: 10.1016/j.micromeso.2019.03.022

Zhang, Z., Li, J., Sun, J., Wang, H., Wei, W., & Sun, Y. (2016). Bimodal mesoporous carbon-coated MgO nanoparticles for CO_2 capture at moderate temperature conditions. *Industrial & Engineering Chemistry Research*, *55*(29), 7880-7887.

Zhao, J., Syed, J. A., Wen, X., Lu, H., & Meng, X. (2019). Green synthesis of FeS anchored carbon fibers using eggshell membrane as a bio-template for energy storage application. *Journal of Alloys and Compounds, 777*, 974-981.

Zhao, R., Zhang, X., Peng, S., Hong, P., Zou, T., Wang, Z., Xing, X., Yang, Y., & Wang, Y. (2020). Shaddock peels as bio-templates synthesis of Cd-doped SnO_2 nanofibers: A high performance formaldehyde sensing material. *Journal of Alloys and Compounds, 813*, 152170.

Zhao, X., Ji, G., Liu, W., He, X., Anthony, E. J., & Zhao, M. (2018). Mesoporous MgO promoted with $NaNO_3$/$NaNO_2$ for rapid and high-capacity CO_2 capture at moderate temperatures. *Chemical Engineering Journal, 332*, 216-226.

Zhu, Q. (2019). Developments on CO_2-utilization technologies. *Clean Energy, 3*(2), 85-100. doi: 10.1093/ce/zkz008

Zukal, A., Kubů, M., & Pastva, J. (2017). Two-dimensional zeolites: Adsorption of carbon dioxide on pristine materials and on materials modified by magnesium oxide. *Journal of CO_2 Utilization, 21*, 9-16. doi: 10.1016/j.jcou.2017.06.013

LIST OF PUBLICATION

Journal with Impact Factor

1. **A.H.Ruhaimi,** M.A.A. Aziz, A.A. Jalil. (2021). Magnesium oxide-based adsorbent for carbon dioxide capture: Current progress and future opportunities. *Journal of CO_2 Utilisation, 43,* 101357. https://doi.org/10/1016/j.jcou.2020.101357 **(Q1, IF:7.132)**

2. **A.H. Ruhaimi** and M.A.A. Aziz, (2021). High-performance flake-like mesoporous magnesium oxide prepared by eggshell membrane template for carbon dioxide capture. *Journal of Solid State Chemistry,* 300, 122242. **(Q2, IF:2.726)**

3. **A.H. Ruhaimi** and M.A.A. Aziz, (2021). Spherical CeO_2 nanoparticles prepared using an egg-shell membrane as a bio-template for high CO_2 adsorption. *Chemical Physics Letters*, 779, 138842. **(Q2, IF:2.328)**

Indexed Journal

4. **Amirul Hafiiz Ruhaimi**, Haziq Fikri Zaini and Muhammad Arif Ab Aziz. (2020). Effect of ceria/surfactant molar ratios on the formation of mesoporous ceria nanoparticles and its application in CO_2 capture. *Malaysian Journal of Catalysis, 4,* 44-48. **(Indexed by ROAD)**

5. **A.H. Ruhaimi**, C.C. Teh, M.A.A. Aziz, (2021). Mesoporous Magnesium Oxide Adsorbent Prepared via Lime (Citrus aurantifolia) Peel Bio-templating for CO_2 Capture. *Bulletin of Chemical Reaction Engineering & Catalysis*. 16(2), 36673. **(Indexed by Scopus, Q3)**