UNIVERSITI PUTRA MALAYSIA

PHYSICAL, STRUCTURAL AND MECHANICAL PROPERTIES OF FOAM GLASS-CERAMICS DERIVED FROM WASTE SODA-LIME-SILICA GLASS AND CLAMSHELL

NOOR AIZAT BIN NOOR HISHAM

FS 2021 40

PHYSICAL, STRUCTURAL AND MECHANICAL PROPERTIES OF FOAM GLASS-CERAMICS DERIVED FROM WASTE SODA-LIME-SILICA GLASS AND CLAMSHELL

By

NOOR AIZAT BIN NOOR HISHAM

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

April 2021

COPYRIGHT

DEDICATIONS

In the name Allah (S.W.T), the Most Gracious and Merciful
The thesis is dedicated

To my beloved mother and father, Sabariah Yatini and Noor Hisham Noordin

Who gave me unconditional love, support, and care

To siblings and families
Who are always there when in need

To my fiancé, Nurul Nadhirah Ahmad Shukri, and her family
For sharing their love and support throughout my study

To all my wonderful peers
For making my social life full of joy and happiness

To my supervisor, Dr. Mohd Hafiz Mohd Zaid, and member of supervisory committees
For helping me a lot throughout this journey and made my thesis materialize

This research is dedicated to you

Thank you

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the Degree of Master of Science

PHYSICAL, STRUCTURAL AND MECHANICAL PROPERTIES OF FOAM GLASS-CERAMICS DERIVED FROM WASTE SODA-LIME-SILICA GLASS AND CLAMSHELL

By

NOOR AIZAT BIN NOOR HISHAM

April 2021

Chairman : Mohd Hafiz Bin Mohd Zaid, PhD
Faculty : Science

Nowadays, municipal solid waste has risen to a very alarming level throughout the nation. Our country is heavily dependent on open dumping and landfills, although these methods are expensive and time-consuming. The enormous number of solid waste management problems has encouraged scientists and researchers to think about converting waste materials into other beneficial materials. Therefore, an initiative has been taken through this research to utilize the soda-lime-silica (SLS) waste as the glass matrix and the source of silicon (SiO_2) and clamshell (CS) as the foaming agent (pore former) to fabricate the light-weight foam glass-ceramics (FGC). A series of FGC samples with 1, 3, 6 and 9 wt.% CS were successfully prepared by the conventional solid-state sintering method at 700, 800 and 900 °C sintered for 30, 60 and 120 min. The physical, structural, and mechanical properties of the raw materials and FGC were characterized by wavelength dispersive X-ray fluorescence (WDXRF), thermogravimetric analysis (TGA) density, linear expansion, total porosity, X-ray diffraction (XRD), fourier transform infrared (FTIR), field-emission scanning electron spectroscopy (FESEM) and compressive strength measurement. From the result of WDXRF to study the chemical composition of raw materials, SLS glass mainly composed of 71.90 wt.% of SiO_2 meanwhile CS has high weight percentage of CaO which is 53.41 wt.%. Based on these results, CS is found to contain 98.60 wt.% $CaCO_3$. For the structural properties of raw materials, the XRD pattern of SLS glass reveals no continuous or discrete sharp peak with a broad feature of the amorphous halo at an angle around $2\theta = 20$ to 40° and meanwhile, the shape of the CS powder peak signifies the reflection of the aragonite crystalline phase with an orthorhombic crystal system. Based on TGA profile of CS, the thermal properties of CS indicate the gradual decline of $CaCO_3$ had occurred after undergoing the thermal treatment around 860 °C with a weight loss of approximately 43.56 %. The bulk density of the FGC samples is found to achieve minimum density (0.525 g/cm^3) with maximum expansion (83.98 %) at

3 wt.% CS sintered at an optimum sintering temperature and holding time which is 800 °C for 60 min. The bulk density increases as the linear expansion and total porosity decreases with the progression of CS contents, sintering temperature, and holding time, where the results agree with the FESEM micrograph. The result of XRD and FTIR transmittance spectra have shown the formation of wollastonite crystal starting at 3 wt.% CS sintered at 800 °C for 30 min. The crystallization of the wollastonite crystal phase increases with the progression of CS content, sintering temperature, and holding time. The trend of the compressive strength corresponds well with the trend of the bulk density. The highest mechanical performance (0.78 MPa) with an acceptable low bulk density (0.612 g/cm^3) and average total porosity (74.81 %) is obtained for the sample containing 3 wt.% CS sintered at an optimum temperature and holding time. It can be concluded that the compressive strength increases with the decrease in linear expansion and the total porosity value of the FGC. The overall result promotes that the FGC derived from SLS glass and CS waste materials have a high potential to be used as concrete aggregate materials in the building and construction industry.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Master Sains

SIFAT FIZIKAL, STRUKTURAL DAN MEKANIKAL KACA-SERAMIK BERLIANG BERDASARKAN DARIPADA BUANGAN KACA SODA-KAPUR-SILIKA DAN KULIT KERANG

Oleh

NOOR AIZAT BIN NOOR HISHAM

April 2021

Pengerusi : Mohd Hafiz Bin Mohd Zaid, PhD
Fakulti : Sains

Pada masa sekarang, bahan buangan pepejal perbandaran semakin meningkat hingga ke tahap yang membimbangkan di seluruh negara. Negara kita sangat bergantung kepada cara pembuangan secara terbuka dan tanah timbus, walaupun kaedah ini sebenarnya menelan belanja yang besar dan juga membazirkan masa. Percambahan masalah yang berkaitan dengan pengurusan bahan buangan ini telah mengubah cara berfikir para saintis dan pengkaji dalam mencari jalan untuk menukarkan bahan buangan kepada bahan yang mampu membawa manfaat. Oleh itu, satu inisiatif telah diambil melalui kajian ini untuk menggunakan soda-kapur-silika (SLS) terbuang sebagai matriks kaca, dan sumber silikat (SiO_2) and kulit kerang (CS) sebagai agen pembuihan (pembentuk liang) untuk membentuk kaca-seramik berliang (FGC) yang ringan. Satu siri sampel FGC dengan 1, 3, 6 dan 9 wt.% CS berjaya disiapkan dengan kaedah sintering konvensional keadaan pepejal pada suhu 700, 800 dan 900 °C yang disinter selama 30, 60 dan 120 min. Ciri-ciri fizikal, structural dan mekanikal bahan-bahan mentah dan FGC telah dicirikan melalui WDXRF, TGA, ketumpatan, pengembangan linear, jumlah keliangan, XRD, FTIR, FESEM dan pengukuran kekuatan mampatan. Dari hasil WDXRF untuk mengkaji komposisi kimia bahan mentah, kaca SLS terdiri terutamanya dari SiO_2 iaitu sebanyak 71.90 wt.% manakala CS mempunyai peratusan berat CaO yang tinggi iaitu sebanyak 53.41 wt.%. Berdasarkan keputusan ini, CS didapati mengandungi 98.60 wt.% $CaCO_3$. Untuk sifat struktur bahan mentah, corak XRD kaca SLS tidak menunjukkan puncak tajam berterusan atau diskrit dengan ciri luas lingkaran amorf pada sudut sekitar $2\theta = 20$ hingga 40° dan sementara itu, bentuk puncak serbuk CS menandakan pantulan fasa kristal aragonite dengan sistem kristal orthorhombik. Berdasarkan profil TGA CS, sifat termal CS menunjukkan penurunan $CaCO_3$ secara beransur-ansur berlaku setelah menjalani rawatan terma sekitar 860 °C dengan penurunan berat sekitar 43.56 %. Ketumpatan pukal FGC telah dipastikan mencecah ketumpatan minimum (0.525 g/cm^3)

dengan pengembangan maksima (83.98 %) pada 3 wt.% kandungan kulit kerang yang disinter pada suhu sinter dan masa pembakaran yang optimum iaitu 800 °C selama 60 min. Ketumpatan pukal meningkat apabila pengembangan linear dan jumlah keliangan berkurang sejajar dengan perkembangan kandungan kulit kerang, suhu sinter dan masa pembakaran, dimana hasilnya sepadan dengan graf mikro FESEM. Keputusan XRD dan spektrum FTIR telah menunjukkan pembentukan kristal wollastonite terjadi bermula pada 3 wt.% kandungan kulit kerang yang disinter pada 800 °C selama 30 min. Fasa pengkristalan kristal wollastonite meningkat sejajar dengan perkembangan kandungan kulit kerang, suhu pensinteran dan masa pembakaran. Aliran kekuatan mampatan adalah sepadan dengan aliran ketumpatan pukal. Prestasi tertinggi (0.78 MPa) dengan ketumpatan pukal rendah yang dapat diterima (0.612 g/cm^3) dengan purata keliangan (74.81 %) telah diperoleh untuk sampel yang mengandungi 3 wt.% kulit kerang yang disinter pada suhu dan masa pembakaran yang optimum. Kesimpulannya, kekuatan mampatan meningkat sejajar dengan penurunan pengembangan linear dan jumlah nilai keliangan FGC. Keputusan keseluruhan menyimpulkan bahawa pembuatan FGC yang dihasilkan daripada kaca buangan SLS dan CS sebagai agen pembuihan, mempunyai potensi yang tinggi untuk digunakan sebagai bahan agregat konkrit dalam industri pembinaan bangunan.

ACKNOWLEDGEMENTS

Alhamdulillah, first and foremost, I would like to thank Allah as I am able to finally finish my thesis as a requirement for the completion of Masters in Science. I am very grateful for Him, for giving me the strength, endurance, patience, compassion, and the ability to finish this project. I am tremendously fortunate to be able to complete this project despite all the challenges and hardships that I face along the way.

An utmost appreciation goes to my wonderful lecturer, Dr. Mohd Hafiz bin Mohd Zaid, for his continuous support, and for sharing his abundance of knowledge with me and for his suggestions towards accomplishing this research. His constructive comments, meaningful recommendations, and suggestions, as well as constructive corrections throughout the experimental and thesis works, are very invaluable and have contributed tremendously towards the success of this research. Apart from that, a big thank you is also given for the committee members Prof. Dr. Sidek Bin Abdul Aziz and Dr. Farah Diana Muhammad, for the tips and supervision in helping me complete my project. I am also humbled to extend my gratitude towards all the staff and technician of the Faculty of Science and Institute of Advance Technology (ITMA) Universiti Putra Malaysia for the cooperation and technical support provided.

In addition to that, I am also forever thankful for the help and guidance from my beloved friends upon completing this project. I would also love to lengthen my thankfulness and genuine love towards my parents, Sabariah binti Yatini and Noor Hisham bin Noordin, as well as my siblings who have always been there from day one, and who will always be my strength and motivation. Not forgetting, my fiancé, Nurul Nadhirah binti Ahmad Shukri, and her family, for always believing in me and keeping my spirit held high throughout the completion of my studies.

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

Mohd Hafiz bin Mohd Zaid, PhD
Senior Lecturer
Faculty of Science
Universiti Putra Malaysia
(Chairman)

Sidek bin Abdul Aziz, PhD
Professor
Faculty of Science
Universiti Putra Malaysia
(Member)

Farah Diana binti Muhammad, PhD
Senior Lecturer
Faculty of Science
Universiti Putra Malaysia
(Member)

ZALILAH MOHD SHARIFF, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 12 August 2021

Declaration by graduate student

I hereby confirm that:

- this thesis is my original work;
- quotations, illustrations, and citations have been duly referenced;
- this thesis has not been submitted previously or concurrently for any other degree at any other institutions;
- intellectual property from the thesis and copyright of thesis are fully-owned by Universiti Putra Malaysia, as according to the Universiti Putra Malaysia (Research) Rules 2012;
- written permission must be obtained from supervisor and the office of Deputy Vice-Chancellor (Research and Innovation) before thesis is published (in the form of written, printed or in electronic form) including books, journals, modules, proceedings, popular writings, seminar papers, manuscripts, posters, reports, lecture notes, learning modules or any other materials as stated in the Universiti Putra Malaysia (Research) Rules 2012;
- there is no plagiarism or data falsification/fabrication in the thesis, and scholarly integrity is upheld as according to the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) and the Universiti Putra Malaysia (Research) Rules 2012. The thesis has undergone plagiarism detection software.

Signature: ________________________ Date: __________________

Name and Matric No.: Noor Aizat bin Noor Hisham, (GS53014)

Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) are adhered to.

Signature: _________________________________
Name of Chairman
Of Supervisory
Committee: Mohd Hafiz bin Mohd Zaid, PhD

Signature: _________________________________
Name of Member of
Supervisory
Committee: Sidek bin Abdul Aziz, PhD

Signature: _________________________________
Name of Member of
Supervisory
Committee: Farah Diana binti Muhammad, PhD

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS AND SYMBOL

GC	Glass-ceramics
FGC	Foam glass-ceramics
SLS	Soda-lime-silica
$CaCO_3$	Calcium carbonate
CS	Clamshell
MS	Mussel shell
ES	Eggshell
OS	Oyster shell
SiO_2	Silicon dioxide
CO_2	Carbon dioxide
CaO	Calcium oxide
SiO_4	Silicate
$CaSiO_3$	Wollastonite
PVA	Polyvinyl alcohol
TGA	Thermogravimetric analysis
XRD	X-ray diffraction
WDXRF	Wavelength-dispersive X-ray fluorescence
FTIR	Fourier transform infrared
FESEM	Field emission scanning electron microscope
UTM	Universal testing machine
JCPDS	Join Committee on Powder Diffraction Standard
µm	Micrometre
mm	Millimetre

cm	Centimetre
MPa	Megapascal
Wt.%	Weight percentage
Pa.s	Pascal second
°C	Degree Celsius
h	Hour
g	Gram
g/cm^3	gram per cubic centimetre
T_g	Glass transition temperature

CHAPTER 1

INTRODUCTION

1.1 Research background

Municipal solid waste is dominated by the overall composition of solid waste in Malaysia, with the remaining composition being industrial waste, agricultural waste, and construction waste (Latifah *et al*., 2009). In Malaysia, 80% of solid waste categorized as recyclable waste is disposed of at landfills and glass has contributed to 3 % of the total recyclable solid waste composition (Moh and Latifah, 2017). Glass is known for its ability to provide fascinating properties in products based on ceramics (Zanotto *et al*., 2010). Glass with an acceptable chemical composition can be converted into glass-ceramics (GC) via a controlled heat treatment process (Rawlings *et al*., 2006).

Soda-lime-silica (SLS) glass is the most common glass type and is widely used for post-consumer containers and flat glass, such as window and door glass panels (Andela and Zavitz, 2004). SLS glass is manufactured by melting silicon dioxide (SiO_2), sodium carbonate (Na_2CO_3), calcium carbonate ($CaCO_3$) and other minor constituents (Silva *et al*., 2017). SLS glass's softening point temperature is slightly low compared to other silicate glass, promoting less energy usage during the sintering process. The softening temperature of SLS glass is about ~700 °C and this interesting feature may enable the production of GC at a lower temperature compared to the normal temperature used to crystallize the GC product (Ayadi *et al*., 2011).

Foam glass-ceramics (FGC) is a porous material that requires a foaming agent as a surfactant or a blowing agent to enhance foam formation. To obtain the porous material, the foaming agent usually made up of carbonaceous materials is mixed with the parent glass before any heat-treatment occurs (Silva *et al*., 2017). The foaming agent reaction occurs close to the parent glass sintering temperature to achieve optimum performance (Rawlings *et al*., 2006). The uses FGC from waste materials as aggregates for light-weight concrete have attracted significant interest from the construction industry because of a characteristic such as lightweight, water permeable, good compressive strength, and chemically inert and non-toxic (Da Silva Fernandes *et al*., 2019). For instance, these factors favour their uses in thermal and acoustic insulation applications such as catalytic support for liquid metal and gas filtration, electromagnetic radiation absorbers, mineral casting, combustion engineering membranes, and lightweight bearing structure (Petrella et al., 2010; Chinnam *et al*., 2013; Chakartnarodom and Ineure, 2014; Benhaoua *et al*., 2015).

Introducing a foaming agent or pore-forming agent into the ceramic matrix is the most common technique for the manufacture of FGC (Souza *et al*., 2017). The foaming ability usually depends on the decomposition process of the carbonates or sulphates. Moreover, the foaming agent's particle size also affects the size of the pores (Bernado *et al*., 2007). Various types of foaming agents had been used in previous studies, including aluminum nitride (AlN), calcium carbonate ($CaCO_3$), manganese dioxide (MnO_2), and silicon carbide (SiC), which have shown varying degrees of success (Llaudis *et al*., 2009; Francis *et al*., 2013; Tang *et al*., 2014; Ding *et al*., 2015).

Various research has recently been conducted using waste products from animal shell waste containing carbonated as a foaming agent including clamshells (CS). CS consists of a relatively high content of $CaCO_3$ composition, which is approximately 97 wt.% and is a significant replacement for pure $CaCO_3$ (Scarinci *et al*., 2005). The use of CS waste in the manufacture of FGC may also be of significant environmental benefit.

From the recent research, the hypothesis that can be concluded for this study are as follows:

1. As the foaming agent content increases, the expansion and porosity formation of FGC increased.
2. As the sintering temperature increases, the density and compressive strength of FGC increased.
3. As the holding time increases, the coalescences of pores increased hence results in inhomogeneous pore distribution.

1.2 Problem statement

Nowadays, abundance of animal shells from food waste such as clamshell (CS), had been disposed of in landfill (Rahman *et al*., 2019). CS is disposed of without considering its benefit as a natural source of $CaCO_3$ (Ismail *et al*., 2016). Besides, the food waste would give a negative impact to the environment and ecosystem, consequently led to solid waste pollution. In this study, the FGC is fabricated from the SLS glass bottles and CS waste with the intention to reduce the solid waste in landfill. Moreover, there are limited reports and systematic study of the physical, structural, and mechanical properties of FGC derived from SLS glass bottles as the precursor glass and CS waste as a natural foaming agent. CS is a good candidate for a natural foaming agent because it contains about 95 to 90 % of $CaCO_3$ (Mo *et al*., 2018).

In recent times, FGC have captured an attention in building and construction industries due to its properties and wide range of application. The pore characteristics of the FGC such as size, distribution, and morphology may determine its basic properties such as low density, low thermal conductivity, high surface area, permeability, high chemical resistance, and incombustibility (Binner, 2005; Scarinci *et al*., 2005; Scheffler and Colombo, 2005). FGC has a porous structure that contributes to its light-weight characteristic. Kurpińska and Ferenc (2017) has reported that the uses of FGC as concrete aggregates has decreased the total weight of the concrete body. Light-weight concrete (LWC) has porosity with both open-pore and close-pore structures due to the addition of FGC and the porosity increases as the porosity of FGC increased (Li *et al*., 2015). However, some consideration regarding the strength of the FGC for building materials application needs to be given to ensure the stability of the porous structure. Furthermore, there is limited report regarding the mechanical properties of FGC as it is usually used in application such as heat insulation and sound absorption (Guo *et al*., 2020).

To address the problem, a comprehensive study on the effect of different composition of CS, sintering temperature and holding time of FGC derived from SLS glass bottles and CS waste is carried out to improve the physical, structural, and mechanical properties of the final product. The results of this study will be used to determine the potential application of FGC to be used as aggregates for lightweight concrete in building materials.

1.3 Research objectives

The main objective of this study is to fabricate and optimize the synthesis of foam glass-ceramics (FGC) derived from SLS glass and CS waste. This study involves designing suitable glass and foaming agent composition, heat treatment development, holding time progression, and a series of fundamental studies on the physical, structural, and mechanical strength of the final product. This research is conducted based on several objectives as follows:

1. To synthesize the SLS glass and CS waste as the raw material for the fabrication of FGC.
2. To elucidate the effect of different composition of CS on the formation of FGC.
3. To investigate the effect of different sintering temperature and holding time on the physical, structural, and mechanical properties of FGC.

To achieve those objectives, a series of FGC with 1, 3, 6 and 9 wt.% CS is prepared by a controlled sintering process at 700, 800 and 900 °C sintered for 30, 60 and 120 min by using the single-stage conventional solid-state method. The physical, structural, and mechanical properties of FGC have been characterized to investigate the effect of CS composition, progression of the sintering temperature, and holding time for the FGC formation. The physical, structural, and mechanical properties of FGC have been studied through measurements such as bulk density, linear expansion, total porosity, X-ray diffraction (XRD), fourier transform infrared (FTIR), field emission scanning electron microscope (FESEM), and compressive strength using universal test machine (UTM). The main purpose of this work is to fabricate FGC from waste materials as a potential concrete aggregate material for application in building and construction.

1.4 Outline of the thesis

The thesis arrangement for the study is organized as follows. Chapter 1 presents the introduction of SLS glass and CS as raw materials, FGC, problem statements, objectives, and research scopes. Chapter 2 addresses the theory of SLS glass, foaming agent, FGC, and previous work, including past and current work. Chapter 3 describes the process, methodology, and characterization of FGC. Results on the effect of different compositions of CS content, sintering temperature development, and progression of different holding time towards the physical, structural, and mechanical properties of FGC are analyzed and discussed in Chapter 4. Ultimately, Chapter 5 provides a conclusion and recommendation for future work.

REFERENCES

Abel, B. M., Mauro, J. C., Smedskjaer, M. M., Morgan, J. M., LaPierre, C. L., Swan, G. R., Mack, M. E., & Ellison, A. J. (2013). Liquidus surface of MgO-CaO-Al_2O_3-SiO_2 glass-forming systems. *Journal of Non-Crystalline Solids*, 363: 39-45.

Agarwal, A., Davis, K. M., & Tomozawa, M. (1995). A simple IR spectroscopic method for determining fictive temperature of silica glasses. *Journal of Non-Crystalline Solids*, 185(1-2): 191-198.

Agarwal, A., & Tomozawa, M. (1997). Correlation of silica glass properties with the infrared spectra. *Journal of Non-Crystalline Solids*, 209(1-2): 166-174.

Ahmadi, M., Janakiram, S., Dai, Z., Ansaloni, L., & Deng, L. (2018). Performance of mixed matrix membranes containing porous two-dimensional (2D) and three-dimensional (3D) fillers for CO_2 separation: A review. *Membranes*, 8(3): 50.

Ahmed, E. M. (2015). Hydrogel: preparation, characterization, and applications: A review. *Journal of Advanced Research*, 6(2): 105-121.

Almasri, K. A., Aziz, S. A., Matori, K. A., & Zaid, M. H. M. (2017). Effect of sintering temperature on physical, structural and optical properties of wollastonite based glass-ceramic derived from waste soda lime silica glasses. *Results in Physics,* 7: 2242-2247.

Almutawa, F., Vandal, R., Wang, S. Q., & Lim, H. W. (2013). Current status of photoprotection by window glass, automobile glass, window films, and sunglasses. *Photodermatology, Photoimmunology & Photomedicine*, 29(2): 65-72.

Al-Naib, U. M. B. (2018). Introductory chapter: A brief introduction to porous ceramic. In *Recent Advances in Porous Ceramics*. IntechOpen: London, EN, UK.

Amma, S. I., Luo, J., Pantano, C. G., & Kim, S. H. (2015). Specular reflectance (SR) and attenuated total reflectance (ATR) infrared (IR) spectroscopy of transparent flat glass surfaces: a case study for soda lime float glass. *Journal of Non-Crystalline Solids*, 428: 189-196.

Amrani, M., Taha, Y., Kchikach, A., Benzaazoua, M., & Hakkou, R. (2019). Valorization of phosphate mine waste rocks as materials for road construction. *Minerals*, 9(4): 237.

Andela, C., & Zavitz, A. *Environmental Mandates vs. Economic Realities-Can Both Be Satisfied?* Paper presented at the International Conference organised by the Concrete and Masonry Research Group at Kingston University, London. September 2004.

Ansari, S., Varghese, J. M., & Dayas, K. R. (2009). Polydimethylsiloxane–cristobalite composite adhesive system for aerospace applications. *Polymers for Advanced Technologies*, 20(5): 459-465.

Apkar'yan, A. S. (2014). Investigation of the density of granular foam-glass ceramic by mathematical modeling. *Glass and Ceramics*, 71(5-6): 194-197.

Apkar'yan, A. S., Gubaidulina, T. A., & Kaminskaya, O. V. (2015). Foam-glass ceramic-based filtering material for removing iron and manganese from drinking water. *Glass and Ceramics*, 71(11-12): 413–417.

Arai, Y., Aoki, Y., & Kagawa, Y. (2017). Effect of cristobalite formation on the delamination resistance of an oxide/Si/(SiC/SiC) environmental barrier coating system after cyclic high temperature thermal exposure. *Scripta Materialia*, 139: 58-62.

Aras, A., & Kristaly, F. (2019). α-cristobalite formation in ceramic tile and sewage pipe bodies derived from westerwald ball clay and its effect on elastic-properties. *Applied Clay Science*, 178: 105126.

Attila, Y., Güden, M., & Taşdemirci, A. (2013). Foam glass processing using a polishing glass powder residue. *Ceramics International*, 39(5): 5869-5877.

Ayadi, A., Stiti, N., Boumchedda, K., Rennai, H., & Lerari, Y. (2011). Elaboration and characterisation of porous granules based on waste glass. *Powder Technology,* 208(2): 423-426.

Babapoor, A., Asl, M. S., Ahmadi, Z., & Namini, A. S. (2018). Effects of spark plasma sintering temperature on densification, hardness and thermal conductivity of titanium carbide. *Ceramics International*, 44(12): 14541-14546.

Bai, J., Yang, X., Xu, S., Jing, W., & Yang, J. (2014). Preparation of foam glass from waste glass and fly ash. *Materials Letters*, 136: 52-54.

Baltrus, J. P., Wells, A. W., Fauth, D. J., Diehl, J. R., & White, C. M. (2001). Characterization of carbon concentrates from coal-combustion fly ash. *Energy & Fuels*, 15(2): 455-462.

Bell, R. J., & Dean, P. (1972). The structure of vitreous silica: validity of the random network theory. *Philosophical Magazine*, 25(6): 1381-1398.

Belluci, D., Cannilo, V., Sola, A., Chiellini, F., Gazzarri, M., & Migone, C. (2011). Microporous Bioglass®-derived scaffolds for bone tissue regeneration. *Ceramics International*, 37(5): 1575-1585.

Benhaoua, F., Ayadi, A., Stiti, N., Lamri, Y., & Ratni, H. (2015). Elaboration and characterisation of a cellular glass-based cullet loaded with carbon fibers. *Materials Letters,* 160: 278-281.

Bernado, E., Cedro, R., Florean, M., & Hreglich, S. (2007). Reutilisation and stabilisation of wastes by the production of glass foams. *Ceramics International*, 33(6): 603-608.

Binner, J. (2005). Ceramics foams. In M. Scheffler & P. Colombo (Eds.), *Cellular Ceramics: Structure, Manufacturing, Properties and Applications* (pp. 31-56). Wiley-VCH: Weinheim, Germany.

Blengini, G. A., Busto, M., Fantoni, M., & Fino, D. (2012). Eco-efficient waste glass recycling: integrated waste management and green product development through LCA. *Waste Management,* 32(5): 1000-1008.

Bonfiglio, P., & Pompoli, F. (2013). Inversion problems for determining physical parameters of porous materials: Overview and comparison between different methods. *Acta Acustica United with Acustica*, 99(3): 341-351.

Broxtermann, S., Taherishargh, M., Belova, I. V., Murch, G. E., & Fiedler, T. (2017). On the compressive behaviour of high porosity expanded Perlite-Metal Syntactic Foam (P-MSF). *Journal of Alloys and Compounds*, 691: 690-697.

Brusatin, G., Bernardo, E., & Scarinci, G. (2004). Production of foam glass from glass waste. In M. C. Limbachiya & J. J. Roberts (Eds.), *Sustainable Waste Management and Recycling: Glass Waste* (pp. 67-82). Thomas Telford Publishing: Westminster, London, UK.

Butler, J. H., & Hooper, P. D. (2019). Glass waste. In T. M. Letcher & D. A. Vallero (Eds.), *Waste (2nd ed.): A Handbook for Management* (pp. 307-322). Academic Press: Cambridge, MA, USA.

Casas-Luna, M., Torres-Rodríguez, J. A., Valdés-Martínez, O. U., Obradović, N., Slámečka, K., Maca, K., Kaiser, J., Montúfar, E. B. & Čelko, L. (2020). Robocasting of controlled porous $CaSiO_3$–SiO_2 structures: architecture–strength relationship and material catalytic behavior. *Ceramics International*, 46(7): 8853-8861.

Chahour, K., Aboutaleb, D., Safi, B., Mazari, T., & Zeghad, M. (2017). Granulated foam glass based on mineral wastes used for building materials. *Building Acoustics*,24(4): 281-294.

Chakartnarodom, P., & Ineure, P. (2014). Foam glass development using glass cullet and fly ash or rice husk ash as the raw materials. In S. Sirisoonthorn, S. Jiemsirilers, S. Nilpairach, T. Wasanapianpong, P. Sujaridworakun & N. Chuankrerkkul (Eds.), *Key Engineering Materials* (Vol. 608, pp. 73-78). Trans Tech Publications Ltd.: Bäch, SZ, Switzerland.

Chang, S. Y., Wang, C., & Sun, C. C. (2019). Relationship between hydrate stability and accuracy of true density measured by helium pycnometry. *International Journal of Pharmaceutics*, 567: 118444.

Chen, G. H. (2008). Sintering, crystallization, and properties of CaO doped cordierite-based glass–ceramics. *Journal of Alloys and Compounds*, 455(1-2): 298-302.

Chen, M. M. (2016). Thermal analysis. In *Materials Science and Engineering of Carbon* (pp. 249-272). Butterworth-Heinemann.

Chen, Q. Z., Thompson, I. D., & Boccaccini, A. R. (2006). 45S5 Bioglass®-derived glass-ceramic scaffold for bone tissue engineering. *Biomaterials*, 27(11): 2414-2425.

Chen, Z., Wang, H., Ji, R., Liu, L., Cheeseman, C., & Wang, X. (2019). Reuse of mineral wool waste and recycled glass in ceramic foams. *Ceramics International,* 45(12): 15057-15064.

Chinnam, R. K., Francis, A. A., Will, J., Bernado, E., & Boccaccini, A. R. (2013). Functional glass and glass-ceramic derived from iron rich waste and combination of industrial residues. *Journal of Non-Crystalline Solids,* 365: 63-74.

Condon, J. B. (2019). *Surface Area and Porosity Determinations by Physisorption: Measurement, Classical Theories and Quantum Theory*. Elsevier Publishing: Edinburgh, London, UK.

Correia, L. M., Saboya, R. M. A., de Sousa Campelo, N., Cecilia, J. A., Rodríguez-Castellón, E., Cavalcante Jr, C. L., & Vieira, R. S. (2014). Characterization of calcium oxide catalysts from natural sources and their application in the transesterification of sunflower oil. *Bioresource technology*, 151: 207-213.

Da Costa, F. P., Da Silva Morais, C. R., & Rodrigues, A. M. (2020). Sustainable glass-ceramic foams manufactured from waste glass bottles and bentonite. *Ceramics International*, 46(11): 17957-17961.

Da Silva Fernandes, F. A., Arcaro, S., Junior, E. F. T, Serra, J. C. V., & Bergmann, C. P. (2019). Glass foams produced from soda-lime glass waste and rice husk ash applied as partial substitutes for concrete aggregates. *Process Safety and Environmental Protection,* 128: 77-84.

Da Silva, R. C., Kubaski, E. T., Tenório-Neto, E. T., Lima-Tenório, M. K., & Tebcherani, S. M. (2019). Foam glass using sodium hydroxide as foaming agent: study on the reaction mechanism in soda-lime glass matrix. *Journal of Non-Crystalline Solids*, 511: 177-182.

Deer, W. A., Howie, R. A., & Zussman, J. (1997). *Rock Forming Minerals: Single Chain Silicates, Volume 2A*. The Geological Society Publishing: Bath, EN, UK.

Devine, R. A. B. (1993). Ion implantation-and radiation-induced structural modifications in amorphous SiO_2. *Journal of Non-Crystalline Solids*, 152(1): 50-58.

Ding, L., Ning, W., Wang, Q., Shi, D., & Luo, L. (2015). Preparation and characterisation of glass-ceramic foams from blast furnace slag and waste glass. *Materials Letters*, 141: 327-329.

Dollase, W. A. (1965). Reinvestigation of the structure of low cristobalite. *Crystalline Materials*, 121(5): 369-377.

Donnelly, F. C., Purcell-Milton, F., Dunne, P. W., Rulikowska, A., Alguacil, V., & Gun'ko, Y. K. (2019). Luminescent calcium carbonate micro 'bowties'. *Materials Today Communications*, 20: 100590.

Dorcheh, A. S., & Abbasi, M. H. (2008). Silica aerogel; synthesis, properties and characterization. *Journal of Materials Processing Technology*, 199(1-3): 10-26.

Dussauze, M., Rodriguez, V., Lipovskii, A., Petrov, M., Smith, C., Richardson, K., Cardinal, T., Fargin, E., & Kamitsos, E. I. (2010). How does thermal poling affect the structure of soda-lime glass?. *The Journal of Physical Chemistry C*, 114(29): 12754-12759.

Efimov, O. M., Glebov, L. B., Glebova, L. N., Richardson, K. C., & Smirnov, V. I. (1999). High-efficiency Bragg gratings in photothermorefractive glass. *Applied Optics*, 38(4): 619-627.

ElBatal, H. A., Hassaan, M. Y., Fanny, M. A., & Ibrahim, M. M. (2017). Optical and FT infrared absorption spectra of soda lime silicate glasses containing nano Fe_2O_3 and effects of gamma irradiation. *Silicon*, 9(4): 511-517.

Falliano, D., De Domenico, D., Ricciardi, G., & Gugliandolo, E. (2018). Experimental investigation on the compressive strength of foamed concrete: effect of curing conditions, cement type, foaming agent and dry density. *Construction and Building Materials*, 165: 735-749.

Farooq, M., Ramli, A., Naeem, A., Mahmood, T., Ahmad, S., Humayun, M., & Islam, M. G. U. (2018). Biodiesel production from date seed oil (Phoenix dactylifera L.) via eggshell derived heterogeneous catalyst. *Chemical Engineering Research and Design*, 132: 644-651.

Fernandes, H. R., Andreola, F., Barbieri, L., Lancellotti, I., Pascual, M. J., & Ferreira, J. M. F. (2013). The use of eggshells to produce cathode ray tube (CRT) glass foams. *Ceramics International*, 39(8): 9071-9078.

Fernandes, H. R., Tulyaganov, D. U., & Ferreira, J. M. F. (2009). Preparation and characterisation of foams from sheet glass and fly ash using carbonates as foaming agents. *Ceramics International*, 35(1): 229-235.

Florian, P., Fayon, F., & Massiot, D. (2009). ^{2}J Si-O-Si scalar spin-spin coupling in the solid state: crystalline and glassy wollastonite $CaSiO_3$. *Journal of Physical Chemistry C*, 113(6): 2562-2572.

Folk, R. L. (1964). Some aspects of recrystallization of ancient limestones. *American Association of Petroleum Geologists Bulletin*, 48(4): 525-525.

Francis, A. A., Abdel Rahman, M. K., & Daoud, A. (2013). Processing, structures, and compressive properties of porous glass-ceramic composites prepared from secondary by-product materials. *Ceramics International*, 39(6): 7089-7095.

Fujita, S., Kato, Y., & Tomozawa, M. (2003). IR peak shift due to phase separation of Na_2O–SiO_2 system glasses. *Journal of Non-Crystalline Solids*, 328(1-3): 64-70.

Galante, R., Figueiredo-Pina, C. G., & Serro, A. P. (2019). Additive manufacturing of ceramics for dental applications: A review. *Dental Materials*, 35(6): 825-846.

Gigante, V., Cinelli, P., Righetti, M. C., Sandroni, M., Tognotti, L., Seggiani, M., & Lazzeri, A. (2020). Evaluation of mussel shells powder as reinforcement for pla-based biocomposites. *International Journal of Molecular Sciences*, 21(15): 5364.

Gong, Y., Dongol, R., Yatongchai, C., Wren, A. W., Sundaram, S. K., & Mellott, N. P. (2016). Recycling of waste amber glass and porcine bone into fast sintered and high strength glass foams. *Journal of Cleaner Production*, 112: 4534-4539.

Gonzenbach, U. T., Studart, A. R., Tervoort, E., & Gauckler, L. J. (2007). Macroporous ceramics from particle-stabilized wet foams. *Journal of the American Ceramic Society*, 90(1): 16-22.

Guo, H. W., Gong, Y. X., & Gao, S. Y. (2010). Preparation of high strength foam glass–ceramics from waste cathode ray tube. *Materials Letters*, 64(8): 997-999.

Habte, L., Khan, M. D., Shiferaw, N., Farooq, A., Lee, M. H., Jung, S. H., & Ahn, J. W. (2020). Synthesis, characterization and mechanism study of green aragonite crystals from waste biomaterials as calcium supplement. *Sustainability*, 12(12): 5062.

Handke, M., & Mozgawa, W. (1995). Model quasi-molecule SiO_2 as an approach in the IR spectra description glassy and crystalline framework silicates. *Journal of Molecular Structure*, 348: 341-344.

Hanshaw, B. B., & Back, W. (1979). Major geochemical processes in the evolution of carbonate aquifer systems. *Journal of Hydrology*, 43(1-4): 287-312.

Harada, T., Ikeda, N., Ota, T., Hikichi, Y., Unuma, H., Takahashi, M., & Suzuki, H. (1996). Preparation of graphite/cristobalite/silicone rubber PTC composites. *Journal of the Ceramic Society of Japan*, 104(1216): 1133-1136.

Hasheminia, S., Nemati, A., Yekta, B. E., & Alizadeh, P. (2012). Preparation and characterisation of diopside-based glass-ceramic foams. *Ceramics International*, 38(3): 2005-2010.

Hay, R. S., & Corns, R. (2018). Passive oxidation kinetics for glass and cristobalite formation on Hi-Nicalon™-S SiC fibers in steam. *Journal of the American Ceramic Society*, 101(11): 5241-5256.

Hossain, A., Bhattacharyya, S. R., & Aditya, G. (2015). Biosorption of cadmium from aqueous solution by shell dust of the freshwater snail Lymnaea luteola. *Environmental Technology and Innovation*, 4: 82-91.

Hossain, S. S., Yadav, S., Majumdar, S., Krishnamurthy, S., Pyare, R., & Roy, P. K. (2020). A comparative study of physico-mechanical, bioactivity and hemolysis properties of pseudo-wollastonite and wollastonite glass-ceramic synthesized from solid wastes. *Ceramics International*, 46(1): 833-843.

Ismail, S., Ahmed, A. S., Anr, R., & Hamdan, S. (2016). Biodiesel production from castor oil by using calcium oxide derived from mud clam shell. *Journal of Renewable Energy*, 2016.

Issaadi, N., Aît-Mokhtar, A., Belarbi, R., & Hamami, A. (2018). Effect of variability of porous media properties on drying kinetics: application to cement-based materials. In F. Nicot & O. Millet (Eds.), *Advances in Multi-Physics and Multi-Scale Couplings in Geo-Environmental Mechanics* (pp. 243-289). Elsevier Publishing: Edinburgh, London, UK.

Jaafar, S. H., Zaid, M. H. M., Matori, K. A., Ghazali, M. S. M., Shofri, M. F. S. M., Hisham, N. A. N., & Saparudin, D. I. (2020). Effect of sintering temperatures and foaming agent content to the physical and structural properties of wollastonite based foam glass-ceramics. *Science of Sintering*, 52(3): 1-13.

Johnston, J. (1916). The several forms of calcium carbonate. *American Journal of Science*, 4(246): 473-512.

Jusoh, W. N., Matori, K. A., Zaid, M. H. M., Zainuddin, N., Khiri, M. Z., Rahman, N. A., Jalil. R., & Kul, E. (2019). Effect of sintering temperature on physical and structural properties of alumino-silicate-fluoride glass ceramics fabricated from clam shell and soda lime silicate glass. *Results in Physics,* 12: 1909-1914.

Kang, S. J. L. (2004). *Sintering: Densification, Grain Growth and Microstructure*. Elsevier Publishing: Edinburgh, London, UK.

Kato, Y., Yamazaki, H., & Tomozawa, M. (2001). Detection of phase separation by FTIR in a liquid-crystal-display substrate aluminoborosilicate glass. *Journal of the American Ceramic Society*, 84(9): 2111-2116.

Kim, C. H., & Oh, T. (2011). Synthesis of polycrystalline cristobalite balls through reversible replication of colloid-imprinted carbon. *Bulletin of the Korean Chemical Society*, 32(9): 3483-3485.

Kirkham, M. B. (2014). *Principles of Soil and Plant Water Relations*. Academic Press: Cambridge, MA, USA.

Koleleni, Y. I., & Tafisa, S. (2019). Assessment of vegetables and soils from Minjingu Village-Tanzania using WDXRF technique. *Asian Journal of Research and Reviews in Physics*, 1-14.

König, J., Lopez-Gil, A., Cimavilla-Roman, P., Rodriguez-Perez, M. A., Peterson, R. R., Østergaard, M. B., Iversen, N., Yue, Y., & Spreitzer, M. (2020). Synthesis and properties of open-and closed-porous foamed glass with a low density. *Construction and Building Materials*, 247: 118574.

König, J., Peterson, R. R., & Yue, Y. (2014). Influence of the glass-calcium carbonate mixture's characteristics on the foaming process and the properties of the foam glass. *Journal of the European Ceramic Society*, 34(6): 1591-1598.

König, J., Peterson, R. R., & Yue, Y. (2015). Fabrication of highly insulating foam glass made from CRT panel glass. *Ceramics International*, 41(8): 9793-9800.

Kunzler, R. H., & Goodell, H. G. (1970). The aragonite-calcite transformation; a problem in the kinetics of a solid-solid reaction. *American Journal of Science*, 269(4): 360-391.

Kurpińska, M., & Ferenc, T. (2017). Effect of porosity on physical properties of lightweight cement composite with foamed glass aggregate. In *ITM Web of Conferences* (Vol. 15, pp. 06005). EDP Sciences: Les Ulis, FR.

Küther, J., Seshadri, R., Knoll, W., & Tremel, W. (1998). Templated growth of calcite, vaterite and aragonite crystals on self-assembled monolayers of substituted alkylthiols on gold. *Journal of Materials Chemistry*, 8(3): 641-650.

Lakov, L., Gacheva, M., & Jivov, B. (2019). Stimulation of the crystallization processes of casts of petrurgical materials obtained by the gas counter-pressure casting method. *Materials Science. Non-Equilibrium Phase Transformations*, 5(2): 37-37.

Landi, E., Tampieri, A., Celotti, G., & Sprio, S. (2000). Densification behaviour and mechanisms of synthetic hydroxyapatites. *Journal of the European Ceramic Society*, 20(14-15): 2377-2387.

Latifah, A. M., Mohd Armi, A. S., & Nur Ilyana, M. Z. (2009). Municipal solid waste management in Malaysia: practices and challenges. *Waste Management*, 29(11): 2902-2906.

Leenakul, W., Tunkasiri, T., Tongsiri, N., Pengpat, K., & Ruangsuriya, J. (2016). Effect of sintering temperature variations on fabrication of 45S5 bioactive glass-ceramics using rice husk as a source for silica. *Materials Science and Engineering: C,* 61: 695-704.

Li, H. Y., Tan, Y. Q., Zhang, L., Zhang, Y. X., Song, Y. H., Ye, Y., & Xia, M. S. (2012). Bio-filler from waste shellfish shell: preparation, characterization, and its effect on the mechanical properties on polypropylene composites. *Journal of Hazardous Materials*, 217: 256-262.

Li, L., Poon, C. S., Xiao, J., & Xuan, D. (2017). Effect of carbonated recycled coarse aggregate on the dynamic compressive behavior of recycled aggregate concrete. *Construction and Building Materials*, 151: 52-62.

Li, X., Peng, M., Cao, J., Yang, Z., & Xu, S. (2018). Distribution and stabilization of bismuth NIR centers in Bi-doped aluminosilicate laser glasses by managing glass network structure. *Journal of Materials Chemistry C*, 6(29): 7814-7821.

Li, Z., Luo, Z., Li, X., Liu, T., Guan, L., Wu, T., & Lu, A. (2016). Preparation and characterization of glass-ceramic foams with waste quartz sand and coal gangue in different proportions. *Journal of Porous Materials*, 23(1): 231-238.

Lima, L. F., Mantas, P. Q., Segadães, A. M., & Cruz, R. C. D. (2020). Processing and characterization of sinter-crystallized basalt glass-ceramics. *Journal of Non-Crystalline Solids*, 538: 120019.

Liu, B., Yang, Q. W., & Zhang, S. G. (2019). Integrated utilization of municipal solid waste incineration fly ash and bottom ash for preparation of foam glass-ceramics. *Rare Metals*, 38(10): 914-921.

Liu, P., & Chen, G. F. (2014). Porous materials: processing and applications. Elsevier Publishing: Edinburgh, London, UK.

Liu, T., Lin, C., Liu, P., Liu, J., Li, C., Han, L., Zhou, X., Yang, Q., & Lu, A. (2019). Preparation and characterization of partially vitrified ceramic material. *Journal of Non-Crystalline Solids,* 505: 92-101.

Liu, X., Zhou, J., Zhou, S., Yue, Y., & Qiu, J. (2018). Transparent glass-ceramics functionalized by dispersed crystals. *Progress in Materials Science*, 97: 38-96.

Llaudis, A. S., Tari, M. J. O., Ten, F. J. G., Bernardo, E., & Colombo, P. (2009). Foaming of flat glass cullet using Si_3N_4 and MnO_2 powders. *Ceramics International*, 35(5): 1953-1959.

Lóh, N. J., Simão, L., Jiusti, J., De Noni Jr, A., & Montedo, O. R. K. (2017). Effect of temperature and holding time on the densification of alumina obtained by two-step sintering. *Ceramics International*, 43(11): 8269-8275.

Lu, J., & Onitsuka, K. (2004). Construction utilisation of foamed waste glass. *Journal of Environmental Science*, 16(2): 302-307.

Ma, Q., Wang, Q., Luo, L., & Fan, C. (Eds.). (2018). Proceedings from ICMSE ‘18: 6th Annual International Conference on Material Science and Engineering. Suzhou, Jiangsu: IOP Publishing Ltd: Bristol, EN, UK.

Marangoni, M., Secco, M., Parisatto, M., Artioli, G., Bernardo, E., Colombo, P., Altlasi, H., Binmajed, M., & Binhussain, M. (2014). Cellular glass-ceramics from a self-foaming mixture of glass and basalt scoria. *Journal of Non-Crystalline Solids*, 403: 38-46.

Martínez-García, C., González-Fonteboa, B., Carro-López, D., & Martínez-Abella, F. (2019). Recycled mollusc shells. In J. de Brito & F. Agrela (Eds.), *New Trends in Eco-efficient and Recycled Concrete* (pp. 191-205). Woodhead Publishing: Sawston, EN, UK.

Martínez-García, C., González-Fonteboa, B., Carro-López, D., Martínez-Abella, F., & Ordóñez, J. P. (2019). Characterization of mussel shells as a bio-based building insulation material. *Academic Journal of Civil Engineering*, 37(2): 525-531

Matusita, K., Komatsu, T., & Yokota, R. (1984). Kinetics of non-isothermal crystallization process and activation energy for crystal growth in amorphous materials. *Journal of Materials Science*, 19(1): 291-296.

Mo, K. H., Alengaram, U. J., Jumaat, M. Z., Lee, S. C., Goh, W. I., & Yuen, C. W. (2018). Recycling of seashell waste in concrete: A review. *Construction and Building Materials*, 162: 751-764.

Moh, Y. C., & Latifah, A. M. (2017). Solid waste management transformation and future challenges of source separation and recycling practice in Malaysia. *Resources, Conservation and Recycling,* 116: 1-14.

Mohamed, M., Yusup, S., Quitain, A. T., & Kida, T. (2019). Utilization of rice husk to enhance calcium oxide-based sorbent prepared from waste cockle shells for cyclic CO_2 capture in high-temperature condition. *Environmental Science and Pollution Research*, 26(33): 33882-33896.

Mohammadi, M., Alizadeh, P., & Atlasbaf, Z. (2011). Effect of frit size on sintering, crystallization and electrical properties of wollastonite glass-ceramics. *Journal of Non-Crystalline Solids*, 357(1): 150-156.

Monich, P. R., Romero, A. R., Höllen, D., & Bernardo, E. (2018). Porous glass-ceramics from alkali activation and sinter-crystallization of mixtures of waste glass and residues from plasma processing of municipal solid waste. *Journal of Cleaner Production*, 188: 871-878.

Montanaro, L., Jorand, Y., Fantozzi, G., & Negro, A. (1998). Ceramic foams by powder processing. *Journal of the European Ceramic Society*, 18(9): 1339-1350.

Mucsi, G., Csőke, B., Kertész, M., & Hoffmann, L. (2013). Physical characteristics and technology of glass foam from waste cathode ray tube glass. *Journal of Materials*, 2013.

Mugoni, C., Montorsi, M., Siligardi, C., Andreola, F., Lancellotti, I., Bernardo, E., & Barbieri, L. (2015). Design of glass foams with low environmental impact. *Ceramics International,* 41: 3400-3408.

Munusamy, Y., Sethupathi, S., & Choon, C. H. (2019). Potential use of waste cockle shell as filler for thermoplastic composite. *Journal of Material Cycles and Waste Management*, 21(5): 1063-1074.

Niaounakis, M. (2015). Chapter 9-Foaming and foamed products. In *Biopolymers: Processing and Products* (pp. 327-359). William Andrew Publishing: Norwich, NY, USA.

Niu, Y. H., Fan, X. Y., Ren, D., Wang, W., Li, Y., Yang, Z., & Cui, L. (2020). Effect of Na_2CO_3 content on thermal properties of foam-glass ceramics prepared from smelting slag. *Materials Chemistry and Physics*, 256: 123610.

Núñez, D., Elgueta, E., Varaprasad, K., & Oyarzún, P. (2018). Hydroxyapatite nanocrystals synthesized from calcium rich bio-wastes. *Materials Letters*, 230: 64-68.

Owoeye, S. S., Matthew, G. O., Ovienmhanda, F. O., & Tunmilayo, S. O. (2020). Preparation and characterization of foam glass from waste container glasses and water glass for application in thermal insulations. *Ceramics International,* 46: 11770-11775.

Pabst, W., & Gregorová, E. V. A. (2013). Elastic properties of silica polymorphs–A review. *Ceramics-Silikaty*, 57(3): 167-184.

Peak, D. (2005). Fourier transform infrared spectroscopy. *Encyclopedia of Soils in the Environment*, 80-85.

Peterson, R. R., Konig, J., & Yue, Y. (2015). The mechanism of foaming and thermal conductivity of glasses foamed with MnO_2. *Journal of Non-Crystalline Solids,* 425: 74-82.

Peterson, R. R., Konig, J., & Yue, Y. (2017). The viscosity window of the silicate glass foam production. *Journal of Non-Crystalline Solids*, 456(15): 49-54.

Petit, S., & Madejova, J. (2013). Fourier transform infrared spectroscopy. In *Developments in Clay Science* (Vol. 5, pp. 213-231). Elsevier Publishing: Edinburgh, London, UK.

Petrella, A., Petruzzelli, V., Basile, T., Petrella, M., Boghetich, G., & Petruzzelli, D. (2010). Recycled porous glass from municipal/industrial solid wastes sorting operations as a lead ion sorbent from wastewaters. *Reactive and Functional Polymers,* 70(4): 203-209.

Pliya, P., & Cree, D. (2015). Limestone derived eggshell powder as a replacement in Portland cement mortar. *Construction and Building Materials*, 95: 1-9.

Prado, M. O., & Zanotto, E. D. (2002). Glass sintering with concurrent crystallization. *Comptes Rendus Chimie*, 5(11): 773-786.

Rahman, N. A. A., Matori, K. A., Zaid, M. H. M., Zainuddin, N., Ab Aziz, S., Khiri, M. Z. A., Jalil, R. A., & Jusoh, W. N. W. (2019). Fabrication of alumino-silicate-fluoride based bioglass derived from waste clam shell and soda lime silica glasses. *Results in Physics*, 12: 743-747.

Rainer, A., Giannitelli, S. M., Abbruzzese, F., Traversa, E., Licoccia, S., & Trombetta, M. (2008). Fabrication of bioactive glass-ceramic foams mimicking human bone portions for regenerative medicine. *Acta Biomaterialia*, 4(2): 362-369.

Rawlings, R. D., Wu, J. P., & Boccaccini, A. R. (2006). Glass-ceramics: their production from wastes: A review. *Journal of Materials Science*, 41(3): 733-761.

Ringdalen, E., & Tangstad, M. (2016). Softening and melting of SiO_2, an important parameter for reactions with quartz in Si production. In *Advances in Molten Slags, Fluxes, and Salts: Proceedings of the 10th International Conference on Molten Slags, Fluxes and Salts 2016* (pp. 43-51). Springer International Publishing: Cham, Switzerland.

Risso, R., Ferraz, P., Meireles, S., Fonseca, I., & Vital, J. (2018). Highly active CaO catalysts from waste shells of egg, oyster and clam for biodiesel production. *Applied Catalysis A: General*, 567: 56-64.

Roschat, W., Siritanon, T., Yoosuk, B., & Promarak, V. (2016). Biodiesel production from palm oil using hydrated lime-derived CaO as a low-cost basic heterogeneous catalyst. *Energy Conversion and Management*, 108: 459-467.

Ryshkewitch, E. (1953). Compression strength of porous sintered alumina and zirconia: 9th communication to ceramography. *Journal of the American Ceramic Society*, 36(2): 65-68.

Saparuddin, D. I., Hisham, N. A. N., Sidek H. A. A., Matori, K. A., Honda, S., Iwamoto, Y., & Zaid, M. H. M. (2020). Effect of sintering temperature on the crystal growth, microstructure and mechanical strength of foam glass-ceramic from waste materials. *Journal of Materials Research and Technology*, 9(3): 5640–5647.

Saparuddin, D. I., Zaid, M. H. M., Sidek, H. A. A., & Matori, K. A. (2020). Reuse of eggshell waste and recycled glass in the fabrication porous glass-ceramics. *Applied Sciences*, 10(16): 5404.

Sarfraz, A., Raza, A. H., Mirzaeian, M., Abbas, Q., & Raza, R. (2020). Electrode materials for fuel cells. In *Reference Module in Materials Science and Materials Engineering*. Elsevier Publishing: Edinburgh, London, UK.

Sasmal, N., Garai, M., & Karmakar, B. (2015). Preparation and characterization of novel foamed porous glass-ceramics. *Materials Characterization*, *103*: 90-100.

Scarinci, G., Brusatin, G., & Bernado, E. (2005). Glass Foam. In Scheffler, M., Colombo (Eds.), *Cellular Ceramics: Structure, Manufacturing, Properties and Applications* (pp. 158-176). Wiley-VCH: Weinheim, Germany.

Scheffler, M., & Colombo (Eds.) (2005). *Cellular Ceramics: Structure, Manufacturing, Properties and Applications*. Wiley-VCH: Weinheim, Germany.

Sen, S. (1992). *Ceramic Whitewares: Their Technologies and Application*. Oxford & IBH Publishing Co. (Pvt) Ltd.: Shahpur Jat, DL, IN.

Shafiu Kamba, A., Ismail, M., Tengku Ibrahim, T. A., Zakaria, Z. A. B., & Hassan Gusau, L. (2014). In vitro ultrastructural changes of MCF-7 for metastasise bone cancer and induction of apoptosis via mitochondrial cytochrome C released by CaCO3/Dox nanocrystals. *BioMed Research International*, 2014.

Sharma, R., & Bansal, P. P. (2016). Use of different forms of waste plastic in concrete-A review. *Journal of Cleaner Production*, 112: 473-482.

Sheth, N., Luo, J., Banerjee, J., Pantano, C. G., & Kim, S. H. (2017). Characterization of surface structures of dealkalized soda lime silica glass using X-ray photoelectron, specular reflection infrared, attenuated total reflection infrared and sum frequency generation spectroscopies. *Journal of Non-Crystalline Solids*, 474: 24-31.

Silva, R. V., Brito, J., & Dhir, R. K. (2017). The role of glass waste in the production of ceramic-based products and other applications: A review. *Journal of Cleaner Production.* 167: 346-364.

Sima, F., Ristoscu, C., Duta, L., Gallet, O., Anselme, K., & Mihailescu, I. N. (2016). Laser thin films deposition and characterization for biomedical applications. *Laser Surface Modification of Biomaterials*, 77-125.

Siriprom, W., Chumnanvej, N., Choeysuppaket, A., & Limsuwan, P. (2012). A biomonitoring study: trace metal elements in *Perna Viridis* shell. *Procedia Engineering*, 32: 1123-1126.

Souza, M. T., Maia, B. G. O., Teixeira, L. B., Oliveira, K.G., Teixeira, A. H. B., & Oliveira, A. P. N. (2017). Glass foams produced from glass bottles and eggshell wastes. *Process Safety and Environmental Protection,* 111: 60-64.

Swart, P. K., Grady, M. M., & Pillinger, C. T. (1982). Isotopically distinguishable carbon phases in the Allende meteorite. *Nature*, 297(5865): 381-383.

Tabia, Z., Akhtach, S., El Mabrouk, K., Bricha, M., Nouneh, K., & Ballamurugan, A. (2020). Tantalum doped SiO_2-CaO-P_2O_5 based bioactive glasses: investigation of in vitro bioactivity and antibacterial activities. *Biomedical Glasses*, 6(1): 10-22.

Tang, B., Lin, J., Qian, S., Wang, J., & Zhang, S. (2014). Preparation of glass-ceramic foams from the municipal solid waste slag produced by plasma gasification process. *Materials Letters,* 128: 68-70.

Tang, C., Zhu, J., Li, Z., Zhu, R., Zhou, Q., Wei, J., He, H. & Tao, Q. (2015). Surface chemistry and reactivity of SiO_2 polymorphs: a comparative study on α-quartz and α-cristobalite. *Applied Surface Science*, 355: 1161-1167.

Taylor, M. A., Garboczi, E. J., Erdogan, S. T., & Fowler, D. W. (2006). Some properties of irregular 3-D particles. *Powder Technology*, 162(1): 1-15.

Teixeira, L. B., Fernandes, V. K., Maia, B. G. O., Arcaro, S., & de Oliveira, A. N. (2017). Vitrocrystalline foams produced from glass and oyster shell wastes. *Ceramics International*, 43(9): 6730-6737.

Tomita, T., Kawasaki, S., & Okada, K. (2005). Effect of viscosity on preparation of foamed silica ceramics by a rapid gelation foaming method. *Journal of Porous Materials*, 12(2): 123-129.

Vaickelionis, G., & Vaickelioniene, R. (2006). Cement hydration in the presence of wood extractives and pozzolan mineral additives. *Ceramics Silikaty*, 50(2): 115.

Vellini, M., & Savioli, M. (2009). Energy and environmental analysis of glass container production and recycling. *Energy*, 34(12): 2137-2143.

Vishwakarma, V., & Uthaman, S. (2020). Environmental impact of sustainable green concrete. In *Smart Nanoconcretes and Cement-Based Materials* (pp. 241-255). Elsevier Publishing: Edinburgh, London, UK.

Vossberg, C., Mason-Jones, K., & Cohen, B. (2014). An energetic life cycle assessment of C&D waste and container glass recycling in Cape Town, South Africa. *Resources, Conservation and Recycling*, 88: 39-49.

Wallenberger, F. T., & Smrček, A. (2010). The liquidus temperature; its critical role in glass manufacturing. *International Journal of Applied Glass Science*, 1(2): 151-163.

Wang, H., Chen, Z., Ji, R., Liu, L., & Wang, X. (2018). Integrated utilization of high alumina fly ash for synthesis of foam glass ceramic. *Ceramics International*, 44(12): 81-88.

Wang, H., Feng, K., & Sun, Q. (2018). Effect of calcium carbonate on the preparation of glass ceramic foams from water-quenched titanium-bearing blast furnace slag and waste glass. *Advances in Applied Ceramics*, 117(5): 312-318.

Wang, Z., Maotsela, T., Toperesu, P. M., Kale, G. M., Daji, J., & Parkinson, D. (2019). Dynamic and static corrosion of alpha-alumina bonded refractory in contact with molten soda-lime-silica (SLS) glass. *Ceramics International*, 45(1): 725-732.

Wei, H., Thompson, R. B., Park, C. B., & Chen , P. (2010). Surface tension of high density polyethylene (HDPE) in supercritical nitrogen: Effect of polymer crystallization. *Colloids and Surfaces A: Physicochemical and Engineering Aspects,* 354: 347-352.

West, M., Ellis, A. T., Potts, P. J., Streli, C., Vanhoof, C., & Wobrauschek, P. (2014). Atomic spectrometry update: A review of advances in X-ray fluorescence spectrometry. *Journal of Analytical Atomic Spectrometry*, 29(9): 1516-1563.

Wu, J. P., Boccaccini, A. R., Lee, P. D., Kershaw, M. J., & Rawlings, R. D. (2006). Glass-ceramic foams from coal ash and waste glass: production and characterisation. *Advances in Applied Ceramics*, 105(1): 32-39.

Xiao, R., Polaczyk, P., Zhang, M., Jiang, X., Zhang, Y., Huang, B., & Hu, W. (2020). Evaluation of glass powder-based geopolymer stabilized road bases containing recycled waste glass aggregate. *Transportation Research Record*, 2674(1): 22-32.

Xi, C., Zheng, F., Xu, J., Yang, W., Peng, Y., Li, Y., Li, P., Zhen, Q., Bashir, S., & Liu, J. L. (2018). Preparation of glass-ceramic foams using extracted titanium tailing and glass waste as raw materials. *Construction and Building Materials,* 190: 896-909.

Xie, W., Xie, R., Pan, W. P., Hunter, D., Koene, B., Tan, L. S., & Vaia, R. (2002). Thermal stability of quaternary phosphonium modified montmorillonites. *Chemistry of Materials*, 14(11): 4837-4845.

Yadav, S. R., & Pathak, S. R. (2009, August). Use of recycled concrete aggregate in making concrete-An overview. In *34th Conference on Our World in Concrete & Structures* (Vol. 16, pp. 18). Singapore.

Yan, Z., Feng, K., Tian, J., & Liu, Y. (2019). Effect of high titanium blast furnace slag on preparing foam glass-ceramics for sound absorption. *Journal of Porous Materials*, 26(4): 1209-1215.

Yang, Z. Z., He, L. N., Gao, J., Liu, A. H., & Yu, B. (2012). Carbon dioxide utilization with C–N bond formation: carbon dioxide capture and subsequent conversion. *Energy & Environmental Science*, 5(5): 6602-6639.

Yatsenko, E. A., Goltsman, B. M., Smoliy, V. A., Kosarev, A. S., & Bezuglov, R. V. (2015). Investigation of the influence of foaming agents' type and ratio on the foaming and reactionary abilities of foamed slag glass. *Biosciences Biotechnology Research Asia*, 12: 625-632.

Yin, H., Ma, M., Bai, J., Li, Y., Zhang, S., & Wang, F. (2016). Fabrication of foam glass from iron tailings. *Materials Letters*, 185: 511-513.

Yoon, T., Milien, M. S., Parimalam, B. S., & Lucht, B. L. (2017). Thermal decomposition of the solid electrolyte interphase (SEI) on silicon electrodes for lithium ion batteries. *Chemistry of Materials*, 29(7): 3237-3245.

Yoshioka, S., & Kitano, Y. (1985). Transformation of aragonite to calcite through heating. *Geochemical Journal*, 19(4): 245-249.

Zachariasen, W. H. (1932). The atomic arrangement in glass. *Journal of the American Chemical Society*, 54(10): 3841-3851.

Zanotto, E. D. (2010). Bright future for glass-ceramics. *American Ceramics Society Bulletin*, 89(8): 19-27.

Zhang, Q., He, F., Shu, H., Qiao, Y., Mei, S., Jin, M., & Xie, J. (2016). Preparation of high strength glass ceramic foams from waste cathode ray tube and germanium tailings. *Construction and Building Materials,* 111: 105-110.

Zhao, X., Gao, C., & Li, B. (2020). Effect of CeO_2 on sintering behavior, crystallization, and properties of $CaO-Al_2O_3-SiO_2$ glass-ceramics for packages. *Journal of Materials Science: Materials in Electronics*, 31(20): 17718-17725.

Zhu, M., Ji, R., Li, Z., Wang, H., Liu, L., & Zhang, Z. (2016). Preparation of glass ceramic foams for thermal insulation applications from coal fly ash and waste glass. *Construction and Building Materials*, 112: 398-405.