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Surface Chemistry Studies of Emission and Thermal Behaviour of Developed Composites for Building Ceiling Materials

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Abstract

The emission of harmful elements from burning building ceiling materials and their attendant health effects on inhabitants within the vicinity of the emitted harmful elements is increasingly becoming a source of concern globally. Hence, the need to develop eco-friendly flame-retardant composite materials suitable for house ceiling purposes to forestall unwanted toxic emissions. This work identified the chemical structure of developed composite products and their emission performance during combustion. X-ray Diffraction (XRD) analysis was used for phase quantification and E550 combustion gas analyzer for emission characterization of the developed composites. Thermolyne 950 °C oven was employed for the combustion analysis of the prepared composite at 500 °C. Quasi negligible SO2 and CO2 levels existed, while A4, 0.3Aldr0.23Cmt0.3Si0.05G0.12CS recorded maximum CO level, indicating toxic affluence. The low mass losses of all composite materials, especially for A2, 0.6Aldr0.34Cmt0.05G0.01OBSretard significantly due to its activities by the retardant constituent. The flame retardant nature of all produced composites was evidenced in their elemental composition. There was an absence of a flammable element and stable insulating compounds providing retardance to flame occurrences. These suppressions in flame inclination of the reinforced materials were noticed within the boundaries of the ceiling crystals from the structural examination. The intermetallic phase from the diffraction intensities showed the presence of a significant second bond interstitial solid-phase across the matrix, especially for 0.6Aldr0.34Cmt0.05G0.01OBS ceiling material. This study has established the eco-friendliness of developed building ceiling composite and the potential to reduce the importation of building ceilings. The developed ceiling composite evidently demonstrated high potential to compete favourably with imported ceiling materials in terms of fire resistance performance, low cost of production, and abundant availability of raw materials in the environment. Oil beanstalk is a novel material introduced as a reinforcement to developed building ceiling composite. This research provides a blueprint for manufacturers, construction and allied industry, and stakeholders in developing eco-friendly flame retardant composite ceilings whose materials can be readily sourced locally available in the environment.

References

Bulle C, Margni M, Patouillard L, Boulay AM, Bourgault G, De Bruille V, Cao V, Hauschild M, Henderson A, Humbert S, Kashef-Haghighi S (2019) IMPACT world+: a globally regionalized life cycle impact assessment method. Int J Life Cycle Assess 24(9):1653–1674

Adeodu A, Mudashiru L, Daniyan I, Awodoyin A (2020) Effect of silver nanoparticle (AgNp) mixed with calcium carbonate on impact, hardness and tensile strength properties of aluminium 6063. J Compos Mater 4:0021998320923141

Google Scholar

Dietsch P, Winter S (2018) Structural failure in large-span timber structures: a comprehensive analysis of 230 cases. Struct Saf 71:41–46

Wang P, Cai Z (2017) Highly efficient flame-retardant epoxy resin with a novel DOPO-based triazole compound: thermal stability, flame retardancy and mechanism. Polym Degrad Stab 137:138–150

Jin S, Qian L, Qiu Y, Chen Y, Xin F (2019) High-efficiency flame retardant behavior of bi-DOPO compound with hydroxyl group on epoxy resin. Polym Degrad Stab 166:344–352

Hejna A, Kosmela P, Kirpluks M, Cabulis U, Klein M, Haponiuk J, Piszczyk Ł (2018) Structure, mechanical, thermal and fire behavior assessments of environmentally friendly crude glycerol-based rigid polyisocyanurate foams. J Polym Environ 26(5):1854–1868

Dirisu JO, Fayomi OS, Oyedepo SO, Jolayemi KJ, Moboluwarin DM (2018) Critical evaluation of aluminium dross composites and other potential building ceiling materials. Procedia manufacturing. 2019 Jan 1;35:1205-10. Mahinroosta M, Allahverdi a. hazardous aluminum dross characterization and recycling strategies: a critical review. J Environ Manag 223:452–468

Samat N, Sabaruddin FA, Yusoff MM, Habibah AD (2017) Evaluation of waste from aluminum industry as filler in polypropylene composites. JOM 69(4):790–795

Mohajerani A, Suter D, Jeffrey-Bailey T, Song T, Arulrajah A, Horpibulsuk S, Law D (2019) Recycling waste materials in geopolymer concrete. Clean Techn Environ Policy 21(3):493–515

Akçaözoğlu K, Akçaözoğlu S (2017) The effect of elevated temperature on the lightweight concrete produced by expanded clay aggregate and calcium aluminate cement. Bilge Int J Sci Technol Res 1(2):59–70

Sufian AS, Samat N, Sulaiman MY, Paulus W (2020) Alumina recovery from industrial waste: study on the thermal, tensile and Wear properties of polypropylene/alumina nanocomposites. Int J Precision Eng Manufact-Green Technol 7(1):163–172

Sanni O, Fayomi OS (2018) The inhibitive study of egg shell powder on uns n08904 austenitic stainless steel corrosion in chloride solution. Defence Technol 14(5):463–468

Sanni O, Fayomi OS (2019) Temperature Effect, Activation Energies and Adsorption Studies of Waste Material as Stainless Steel Corrosion Inhibitor in Sulphuric Acid 0.5 M. J Bio-and Tribo-Corrosion 5(4):88

Dirisu JO, Oyedepo SO, Fayomi OS (2019) Thermal energy assessment of oil bean stalk as a novel additive to building ceilings. InAIP conference proceedings (Vol. 2190, no. 1, p. 020076). AIP Publishing LLC

Inegbenebor AO, Fayomi OS, Joshua O, Jolayemi KJ, Inegbenebor AI, Joseph OO (2018) Assessment of some clay south west and Aluminmium dross as roofing tile materials. InIOP conference series: materials science and engineering (Vol. 391, no. 1, p. 012009). IOP Publishing

Ogunyemi SA, Ajileye OO, Muibi KH, Alaga AT, Eguaroje OE, Samson SA, ..., Omisore OO (2017) Geo-information and distribution pattern of petrol Service Station in Sango–Ota Metropolis in ado–Odo Ota local government area, Ogun state. Nigeria Asian Res J Arts Social Sci 1–11

Popoola SI, Atayero AA, Arausi OD, Matthews VO (2018) Path loss dataset for modeling radio wave propagation in smart campus environment. Data in brief 17:1062–1073

Article

Google Scholar

Gnyrya A, Abzaev Y, Korobkov S, Mokshin D, Gauss K, Boyarintsev A (2017) High-temperature structure formation in cement depending on curing time. In AIP Conference Proc 1899(1):040005

Article

CAS

Google Scholar

Go Y, Jo SM, Park SH, Kim HS, You BS, Kim YM (2018) Microstructure and mechanical properties of non-flammable mg-8Al-0.3 Zn-0.1 Mn-0.3 ca-0.2 Y alloy subjected to low-temperature, low-speed extrusion. J Alloys Compounds 739:69–76

Article

CAS

Google Scholar

Gneiger S, Papenberg N, Frank S, Gradinger R (2018) Investigations on microstructure and mechanical properties of non-flammable mg–Al–Zn–ca–Y alloys. In TMS annual meeting & exhibition. Springer, Cham, pp 105–113

Google Scholar

Maruta K, Tsuboi K, Takahashi S (2017) Limiting oxygen concentration of flame resistant material in microgravity environment. Int J Microgravity Sci Appl 34(3):2340304

Google Scholar

Davis LB, Saxen MA, Jones JE, McGlothlin JD, Yepes JF, Sanders BJ (2018) The effects of different levels of ambient oxygen in an oxygen-enriched surgical environment and production of surgical fires. Anesthesia Progress 65(1):3–8

Article

Google Scholar

Li J, Chang J (2019) Effect of crystal/amorphous ratio on mechanical properties in a C4A3 $-C2S hydration system with or without gypsum addition. Constr Build Mater 208:36–45

Article

CAS

Google Scholar

Rejmak P, Dolado JS, Aranda MA, Ayuela A (2019) First-principles calculations on polymorphs of Dicalcium silicate—Belite, a Main component of Portland cement. J Phys Chem C 123(11):6768–6777

Article

CAS

Google Scholar

Zhang Y, Rimstidt DJ, Huang Y, Zhu C (2019) Kyanite far from equilibrium dissolution rate at 0–22° C and pH of 3.5–7.5. Acta Geochimica 38(4):472–480

Article

CAS

Google Scholar

Shevchenko VY, Medrish IV, Ilyushin GD, Blatov VA (2019) From clusters to crystals: scale chemistry of intermetallics. Struct Chem, 1–13

Jose S, Shanmugam N, Das S, Kumar A, Pandit P (2019) Coating of lightweight wool fabric with nano clay for fire retardancy. J Textile Institute 110(5):764–770

Article

CAS

Google Scholar

Yang F (2017) Fire-retardant carbon-fiber-reinforced thermoset composites. In novel fire retardant polymers and composite materials (pp. 271-293). Woodhead publishing

Jin J, Long Y, Gao H, Ren Z (2019) Flotation behavior and mechanism of andalusite and kyanite in the presence of sodium oleate. Sep Sci Technol 54(11):1803–1814

Article

CAS

Google Scholar

Drysdale D (2011) An introduction to fire dynamics. John Wiley & Sons

Sharma G, Sinha B, Hakkim H, Chandra BP, Kumar A, Sinha V (2019) Gridded emissions of CO, NOx, SO2, CO2, NH3, HCl, CH4, PM2.5, PM10, BC, and NMVOC from open municipal waste burning in India. Environmental science & technology

Winkler HC, Notter T, Meyer U, Naegeli H (2018) Critical review of the safety assessment of titanium dioxide additives in food. J Nanobiotechnol 16(1):51

Article

CAS

Google Scholar

Tranchida D, Gloger D, Gahleitner M (2017) A critical approach to the Kissinger analysis for studying non-isothermal crystallization of polymers. J Therm Anal Calorim 129(2):1057–1064

Article

CAS

Google Scholar

Kiselev EG, Kuzmin AP, Nemtsev IV (2019) Thermal and mechanical studies of biofiller/Poly-3-Hydroxybutyrate biocomposites. Journal of Siberian Federal University. Biology 12(3):302–310

Google Scholar

Weber J, Schlimbach J (2019) Co-consolidation of CF/PEEK tape-preforms and CF/PEEK organo sheets to manufacture reinforcements in stamp-forming process. Advanced Manufact: Polymer Composites Sci 5(4):172–183

CAS

Google Scholar

Philip P, Fagbenle L (2014) Design of Lee's disc electrical method for determining thermal conductivity of a poor conductor in the form of a flat disc. International Journal of Innovation and Scientific Research ISSN 2351–8014 Vol. 9 No. 2 pp 335–343

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Contributions

Dr. Dirisu conceived and performed the analysis. Prof. Oyedepo and Dr. Fayomi guided in the data analysis; while Engr. Efenwenkiekie, Dr. Enesi, Prof. Asere and Prof. Oyekunle gave other contributions in the technicality of the write-up of this manuscript.

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Ethics declarations

The authors; Joseph Dirisu, Sunday Oyedepo, Ojo Fayomi Engr. Efenwenkiekie, Dr. Enesi, Prof. Asere and Prof. Oyekunle declare that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

Consent to Participate

The manuscript does not contain humans as a subject and does not involve a vulnerable group as a subject matter, so it is not applicable in this section.

Consent for Publication

The authors give consent for the publication of this manuscript in Silicon. The manuscript does not contain data of an individual person, so there is no breach of privacy.

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