UNIVERSITI TEKNOLOGI MARA

INVESTIGATION ON THE EFFECT OF INFILTRATION PARAMETERS TO THE MECHANICAL PERFORMANCE OF BIOMORPHIC SILICON CARBIDE

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Thesis submitted in fulfilment
of the requirements for the degree of
Doctor of Philosophy
(Mechanical Engineering)

Faculty of Mechanical Engineering

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AUTHOR'S DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Teknologi MARA. It is original and is the results of my own work, unless otherwise indicated or acknowledged as referenced work. This thesis has not been submitted to any other academic institution or non-academic institution for any degree or qualification.

I, hereby, acknowledge that I have been supplied with the Academic Rules and Regulations for Post Graduate, Universiti Teknologi MARA, regulating the conduct of my study and research.

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ABSTRACT

Biomorphic Silicon Carbide (bioSiC) is a new class of porous ceramic materials derived directly from natural resources. Due to the increasing demand of global silicon carbide (nearly 16.1% from 2020 to 2027), this study is an attempt to overcome the depletion of petroleum resource faced by the commercial silicon carbide. The proposed bioSiC is an alternative to the expensive commercial silicon carbide by using the wood waste from furniture industry. Among the natural resources available, natural wood has been identified as an attractive option of carbon precursor due to the availability and its anisotropic nature which gives the unique feature as a hierarchical preform. This ceramic material is fabricated by pyrolysis of wood waste in an inert atmosphere leaving an amorphous carbon preform. The amorphous carbon is infiltrated with molten Si at elevated temperature forming a porous bioSiC with a microstructure that is analogous to the wood precursor. The objective of this study is to investigate the processing, microstructure, and properties of bioSiC produced using wood-derived preform. This was accomplished by analysis of bioSiC from three different wood precursors, obtained from Malaysian rainforest which covered a range of pore volumes, pore sizes, and pore size distributions. In this work, Kapur, Dark Red Meranti and Kempas were pyrolyzed at the temperature of 850 °C for 2 hours to produce the carbon preforms. BioSiC was prepared at two different temperatures, which were 1500 °C and 1600 °C. The silicon melt infiltration process was conducted at 1 to 5 hours holding time in order to investigate the effect of holding time on the properties of bioSiC. The decomposition behaviour of raw wood into carbon during pyrolysis was assessed using a thermo-gravimetric (TGA) system by heating the sample from 50 °C to 1000 °C. Scanning electron microscope (SEM) analysis of pyrolyzed samples and bioSiC showed that the structural feature preserved the original wood structure. Pore volume and porosity of the samples, as determined by mercury intrusion porosimetry, showed multimodal pore distribution of pyrolyzed samples from small to large pores. The density of bioSiC ranging from 0.6850 g/cm^3 to 0.9983 g/cm^3 was determined by the Archimedes method. The bioSiC phase of resulting product was analysed by X-ray diffraction (XRD), indicating that SiC has been produced without excess silicon after etching. The increasing holding time of infiltration enhanced the formation of bioSiC up to 3 hours. However, longer reaction to 5 hours reduced the bioSiC formation at infiltration temperature of 1500 °C. Scanning electron microscope (SEM) analysis showed that the silicon infiltrated both larger and smaller vessels by retaining the original wood structure without being affected by the closure of the small pore and reduction of pore diameter. The mechanical performance indicated that the formation of bioSiC obtained by Dark Red Meranti was optimum at 3 hours holding time and temperature of 1500 °C Therefore, among the three types of wood precursor selected, Dark Red Meranti showed more promising for the production of porous biomorphic silicon carbide compared to Kapur and Kempas. The synthesis of biomorphic porous SiC from sustainable and low-cost materials demonstrates the novelty of this study. The possibility of SiC production from Malaysian hardwood is promising with the prospect of potential application such as catalyst support, molten metal filter or high-performance advanced ceramics.

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