Chapter 1

Introduction

1.1 Introduction

1.1.1 Motivation & Objectives

In the realm of porous ceramic fabrication, there is a pressing need to develop a simple and economically viable process that incorporates various functionalities. This concern arises from the limitations of traditional methods, which are often time-consuming and costly. One promising technique that holds significant advantages is the "direct foaming technique." This innovative approach enables the production of porous ceramics with improved properties, including high porosity, low density, and enhanced thermal and mechanical performance. However, despite its potential, further refinement and advancement of this technique are necessary to fully harness its benefits. Additionally, in addition to developing a cost-effective and straightforward process, there is also a requirement for a method capable of generating hierarchical structures with pores in a single step. The demand for porous ceramics with distinct sizes or gradient microstructure is high in order to achieve a proper balance between conflicting properties. As a result, these materials find applications in diverse fields such as energy, construction, aerospace, filtration, and bioengineering

Another critical concern that demands attention is the ever-increasing accumulation of industrial solid waste, which poses a severe threat to the environment and ecology. To address this issue, it is imperative to explore sustainable solutions that promote waste valorization and sustainable development. Here lies a remarkable opportunity to utilize industrial solid waste in the fabrication of porous ceramic composites. By harnessing the potential of waste materials and integrating them into the direct foaming technique, we can not only contribute to the development of cost-effective porous products but also mitigate the adverse environmental impacts caused by industrial waste. This approach aligns with the principles of waste valorization and sustainable development, driving us towards a more environmentally conscious and responsible future.

Considering the wide range of applications and advantages of porous ceramic material, as well as the environmental concerns associated with Coal mine Overburden Waste (MW waste), the objective of the present work is to develop a novel porous fabrication process with effective and economic methodologies. These methodologies can be widely used to fabricate low-cost porous composites and foams with various functionalities. Additionally, these novel techniques have also been employed to fabricate porous aluminosilicate-based composites using coal overburden waste, providing an efficient solution to the mass conversion of MW waste and reducing its harmful impact on the environment.

1.1.2 Thesis Organization

The structure of the thesis is as follows.

Chapter 2 provides a concise introduction to porous ceramic materials, discussing various fabrication methods and recent advancements in direct foaming techniques. It explores the use of industrial solid waste in porous ceramics and addresses environmental concerns related to coal overburden waste. The chapter concludes with remarks on porous ceramic fabrication, incorporating industrial solid waste, and identifies research gaps in the field.

Chapter 3 presents a novel approach for fabricating porous ceramics by employing alumina dissolution in aqueous acidified media.

Chapter 4 introduces a novel method for fabricating ceramic foam through the dehydration of sucrose with sulphuric acid. This process not only creates ceramic foam but also incorporates functionalities in the form of a gradient in microstructure, making it a distinctive feature of this innovative technique.

Chapter 5 elucidates the efficient utilization of the "Alumina dissolution process" to convert "Coal overburden waste" into highly porous aluminosilicate-based composites. The chapter also investigates the suitability of these porous composites for insulation applications through thermo-mechanical characterization.

Chapter 6 Chapter 6 outlines the effective utilization of the "Sucrose Dehydration process" to transform "Coal overburden waste" into aluminosilicate-based composite foams. The chapter focuses on characterizing the gradient microstructure of these foams and proposes suitable applications for them.

Chapter 7 explores the potential of the "Sucrose Dehydration process" by expanding its applicability to fabricate Silicon carbide (SiC) foams. Additionally, the chapter demonstrates the successful utilization of coal overburden in the cost-effective fabrication of SiC foam using the reaction bonding technique. This technique involves bonding SiC particles with in-situ developed mullite phases at lower sintering temperatures.

Chapter 8 explores the extended use of coal overburden waste in producing porous composites with a broader range of porosities beyond those achieved through the "Alumina dissolution process" and "Sucrose Dehydration process." This is achieved by employing a fugitive method using Rice Husk to create porous composites.

Chapter 9 offers a comprehensive and comparative analysis of the three methods utilized for fabricating porous structures, taking into account factors such as porosity, pore size, density, mechanical properties, and thermal properties. The chapter also presents a graph chart that highlights the suitable applications for these porous composites based on their properties.

Chapter 10 concludes the thesis by providing a comprehensive summary of the entire work undertaken. It offers conclusive remarks on the findings, achievements, and contributions made throughout the research. Additionally, this chapter presents future directions for research that can be pursued to further enhance the field of porous ceramic fabrication and utilization of industrial solid waste.