Chapter 7
Advances in Surface Functionalization of Diatomite for Multidisciplinary Applications From Adsorption to Drug Delivery and Catalysis

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ABSTRACT

Diatomite, a naturally occurring porous silica-based material, has gained significant attention for its versatility in various applications. Surface modification of diatomite is crucial to enhance its physicochemical properties, compatibility, and performance in specific applications. This review explores recent advances in modifying diatomite surfaces through diverse techniques. A particular focus is placed on the functionalization using organosilanes, such as aminopropyl-triethoxysilane (APTES) and (phenyltriethoxysilane) PTES which introduces functional groups that improve chemical reactivity, hydrophobicity, or other targeted properties. Methods including grafting and coating, are discussed, highlighting their efficiency, simplicity, and impact on the structural integrity of diatomite. Applications

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in catalysis, adsorption, drug delivery, and environmental remediation are reviewed to emphasise the enhanced capabilities of modified diatomite.

INTRODUCTION

Diatomite, has garnered significant attention in both academic and industrial research. Its highly porous nature, large surface area, and chemical versatility make it an ideal candidate for applications spanning environmental, biomedical, and industrial fields (Smol & Stoermer, 2010; Yuan et al., 2006). Over the years, the scientific community has increasingly explored methods to enhance the performance of diatomite through surface modifications. These modifications, achieved through various chemical and physical techniques, have unlocked new possibilities for leveraging diatomite's potential in fields such as catalysis, drug delivery, adsorption, and energy storage. This surge of interest reflects the critical role of diatomite in addressing contemporary challenges, from environmental remediation to the development of advanced functional materials. This review aims to provide an overview of recent advances in the functionalization of diatomite, emphasizing the techniques and strategies employed to tailor its surface for specific applications. By synthesizing the current knowledge on diatomite's modification and its resulting benefits, this work seeks to highlight the transformative potential of this naturally abundant resource. The discussion underscores the importance of continued research and innovation in optimizing diatomite's properties to meet the demands of multidisciplinary applications, further contributing to sustainable technological progress.

BACKGROUND

Diatomite, also known as diatomaceous earth or kieselguhr, is a siliceous sedimentary rock primarily formed from the fossilized microscopic shells (frustules) of diatoms (Smol & Stoermer, 2010; Yuan et al., 2006), which are composed of amorphous silica. These frustules, with their intricate porous structures, contribute to diatomite's high porosity, low density, and large specific surface area, with pores at the nanoscale (Du et al., 2018; Zhao et al., 2019). Diatomite is categorized into two types, centric (radial symmetry) and pennate (bilateral symmetry) (De Stefano & De Stefano, 2005; Losic, Mitchell, & Voelcker, 2009; Maher et al., 2015; Mann, 1999; Sun, Zhang, & Losic, 2017), Diatoms, microscopic algae with intricate and hierarchical porous frustules, exhibit remarkable diversity in shapes, morphologies, and pore architectures. As illustrated in Figure 1, these structures demonstrate the precision of natural design at the micro- and nanoscale, offering immense potential for broad applications. This diversity has catalyzed the emergence of "diatom nanotechnology," a field that explores the applications of diatom silica across disciplines such as molecular biology, materials science, biotechnology, and photonics (Losic et al., 2009). Historically, during the Late Miocene, vast accumulations of biogenic silica, particularly in the Mediterranean region, led to the formation of diatomite (El Ouahabi, Saint Martin, Saint Martin, Moussa, & Conesa, 2007). This deposition, driven by tectonic, climatic, and biological factors, highlights the environmental synergy behind diatomite formation (Pellegrino, Pierre, Natalicchio, & Carnevale, 2018). The material's unique properties—such as acid resistance, low thermal conductivity, and eco-compatibility—make it valuable in applications including adsorbents (S.-C. Ma, Zhang, Sun, & Liu, 2015), filters (Lyngsie, Katika, Fabricius, Hansen, & Borggaard, 2019; Man, Gao, Yan, Liu, &