Chapter 3
Nanomaterials for Catalysis and Photocatalysis

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ABSTRACT

The remarkable features of nanotechnologies have made them extremely valuable in the domains of photocatalysis and catalysis because of their remarkable advancements in selectivity and efficacy. Nanomaterials are versatile materials that can be electronically, optically, and structurally modified to improve their performance in catalytic application. Some recent developments in nanotechnology have led to atomic-level understanding of many mechanisms underlying nanocatalysis and photocatalysis such as surface imperfections, electron transports, and photon captures. This chapter shows how nanomaterials have transformed catalysis and photocatalysis process which may change energy conversion methods through environmentally friendly techniques for environmental protection including pollution prevention and chemical manufacturing processes. It is also a possibility that continued evolvement in nanotechnology will provide answers to global issues related to the development of sustainable energy sources.

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INTRODUCTION

Nanomaterials become the most promised candidates for the application catalysis and photocatalysis due to their unique properties, nanoscale dimensions and their high surface energies, quantum confinenment effects and high surface area to volume ratio which significantly influence their catalytic and phtocatalytic activities(Astruc, 2020). Diverse industrial applications, environmental remediation and energy production all rely on catalysis and photocatalysis. This has made nanomaterials the focus of intense research as scientists strive to develop more efficient catalysts and photocatalysts because they have unique properties that arise from being nanosized (Kangas & Pitkänen, 2019). In this chapter, we explore the diverse nanomaterials utilized in catalysis and photocatalysis, and their applications in various fields.

CATALYSIS WITH NANOMATERIALS

Catalysis engages in accelerating chemical reactions by increasing the reaction rates thereby lowering the activation energy without more consuming of in the reaction process (Shaker Ardakani et al., 2021).

Nanomaterials offer several advantages in catalysis because of different reason.

High Surface Area

Nanomaterials possess a high surface area-to-volume ratio, providing ample active sites for catalytic reactions(Abbasi et al., 2023, Saka, Gudata, et al., 2022). This increased surface area enhances the contact between reactants and catalysts, promoting efficient catalytic activity. A higher surface area means more catalytic sites available for reactant molecules to bind to.

A catalyst with a larger surface area can lead to more efficient use of resources since it allows for lower operating temperatures and pressures. This is because the increased surface area provides more active sites, reducing the energy barrier for the reaction to occur(Joudeh & Linke, 2022). Certain shapes may expose more active sites or provide better geometric arrangements for reactant adsorption and product desorption (Cao et al., 2016).

Tailored Properties

The properties of nanomaterials, such as size, shape, composition, and surface structure, can be precisely controlled during synthesis, allowing for the design of catalysts with specific properties tailored for desired reactions. The tailored properties of nanomaterials influence catalysis in different ways (Ahmadi et al., 2016). The size and shape of nanomaterials can be precisely controlled during synthesis. This allows for the optimization of catalytic activity since the surface atoms' coordination and electronic properties can be tailored to promote specific reaction pathways (Y. M. Li et al., 2021, Abel, Tesfaye, et al., 2022).

Nanoscale materials often exhibit enhanced adsorption properties due to their high surface area and surface energy. This facilitates the adsorption of reactant molecules onto the catalyst surface, thereby accelerating reaction rates. This can reduce diffusion limitations and improve overall catalytic efficiency, particularly in gas-phase reactions or reactions involving bulky molecules (Manyangadze et al., 2020).

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