Chapter 3
Sustainable Developments in Nano-Fluid Synthesis for Various Industrial Applications

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ABSTRACT

Nanofluids are a class of fluids that contain dispersed nanoparticles, offering unique properties and promising applications. This chapter explored different types of nanofluids and their synthesis methods, with the one-step method offering simplicity and efficiency, the two-step method providing precise control, the micro-emulsion method providing excellent stability, the sol-gel method providing well-defined nanoparticles, the chemical reduction method offering versatility, the laser ablation method offering high purity, the green synthesis method highlighting eco-friendliness, and the plasma-based method requiring sophisticated equipment.

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INTRODUCTION

Nanotechnology has transformed industries and applications in recent decades, with nanofluids being a prime example. These unique properties and promising applications in energy, medicine, electronics, and environmental protection make nanofluids highly sought after for their exceptional material properties and performance. Nanofluids are engineered materials with uniformly dispersed nanoparticles in liquid mediums like water or organic fluids. These materials alter thermal, electrical, optical, and rheological properties, resulting in enhanced heat transfer efficiency, electrical conductivity, optical characteristics, and mechanical strength. These properties make them attractive for various applications(Maji & Chakraborty, 2019).

The growing demand for nanofluids in industries calls for sustainable synthesis methods. Traditional methods are energy-intensive and environmentally harmful, raising concerns about their impact on the environment and natural resources. Researchers are working on eco-friendly, sustainable routes for nanofluid synthesis. Green synthesis methods are environmentally friendly and sustainable for producing nanoparticles in nanofluid formulations. These techniques use natural precursors, plant extracts, microorganisms, or eco-friendly reducing agents, reducing hazardous chemicals and energy consumption, making them a viable alternative to conventional methods(Abdolhosseinzadeh & Khodamoradi, 2014).

Nanofluid synthesis can be achieved using bottom-up and top-down methods. Bottom-up involves constructing nanoparticles atom by atom or molecule by molecule, allowing precise control over particle properties. Top-down involves breaking down bulk materials into nanoparticles, optimizing resource utilization and minimizing waste generation(Boopathi, Umareddy, et al., 2023). This sustainable process optimizes material utilization and minimizes waste generation. Continuous flow synthesis, also known as microfluidic synthesis, is a promising technique for sustainable nanofluid production. It involves controlled precursor mixing in microchannels, allowing precise control over reaction parameters and uniform nanoparticle production. This method offers improved scalability, reduced reagent consumption, and enhanced reproducibility, making it an attractive option for large-scale nanofluid synthesis with minimal environmental impact(Ma & Banerjee, 2017).

To fully comprehend and optimize the properties of nanofluids for specific applications, comprehensive characterization is essential. Various advanced techniques, such as transmission electron microscopy (TEM), scanning electron microscopy (SEM), X-ray diffraction (XRD), dynamic light scattering (DLS), and Fourier-transform infrared spectroscopy (FTIR), are employed to analyze the size, shape, composition, stability, and surface chemistry of nanoparticles within nanofluids(Boopathi, 2023a; Boopathi & Davim, 2023; Fowziya et al., 2023). Nanofluids offer promising applications in improving heat transfer performance