Process Intensification and Nano-materials: A Short Review

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Abstract:

In the modern era of rapid industrialization, it is very important to carry out a process in such a way that there is minimum wastage of energy, land and labour. Process intensification includes minimization plant or equipment size. Process intensification is expected to bring dramatic improvements in the process. Sonochemistry, reactive chromatography, reactive distillation, hydrotropy, applications of nanomaterials are few techniques of process intensification. In the present review, the research carried on process intensification by nanomaterials is summarized with respect to method used and its effectiveness.

Keywords:

Nanotechnology, nanoparticles, spectroscopy, concentration

Introduction

Application of nanoparticles for various applications aimed at process modification and process intensification is very extensively studied area of research. Nanoparicles like silver are very useful because of antimicrobial activity. Nanomaterials finds wide applications in medicine, pharmaceutical industry, cosmetics and agricultural industries. Many nanoparticles, when mixed with working fluids, increases heat transfer. In reaction engineering the nanoparticles are used to optimize reaction conditions. The present review is aimed at reviewing the research carried out in the field of process intensification by using nanomaterials.

Process Intensification and Nanomaterials

An investigation was carried out for preparation of nanocrystalline silver with gelatin as stabilizing agent and glucose as reducing agent by Pulit and Banach [1]. They developed new environmental friendly method for the synthesis. Silver nitrate was used as a source of silver. They carried out spectrophotometric analysis for the samples. It was observed that three clusters were formed. The nanosuspensions prepared by them were stable for almost three months. During the analysis, it was observed that the average diameter of nanoparticles decreased with increase in gelatin content. With increase in temperature, the stability of suspension increased. According to Suppan, the use of nanomaterial for sustainable process intensification is very important in agricultural field [2]. The application of nanotechnology in crop input is one such sustainable technology. The technology includes reducing the volume of pesticides by adding silver nanoparticles, adding nanomaterials to target pathogens, adding nano-silicon to increase water uptake efficiency in plants; developing a DNA-based nanobiosensor in a polymer to coat fertilizers.Yu and Xie carried out review on preparation, stability mechanisms, and applications for nanofluids[3]. They discussed two step and one step method along with other novel methods. Different methods were used for different nanoparticles. The stability evaluation methods for nanoparticles included Sedimentation and Centrifugation Methods, Zeta Potential Analysis, Spectral Absorbency Analysis. The stability enhancement was carried out by methods such as use of surfactant in nanofluids, surface modification, and surface free method. Nanomaterials were very useful for heat transfer enhancement. It can be also used to increase cooling effect in various equipment. Nanomaterials find application for mass transfer enhancement, space, and defense, nuclear and solar applications. An investigation was carried out by Baronin et.al to improve the methods of solid-phase processing technology of difficult polymeric materials, thermally unstable polymers, ultra-high molecular weight polymers and nanomodified polymer composites [4]. They used electrophysical effects of ultrasound and microwave to improve the performance. They observed that the efficiency of microwave technology increases the efficiency of solid phase polymer processing. There was significant increase in rates of physical and mechanical

properties, tensile failure stress, modulus of elasticity at 20 to 50%, failure stress in shear of 30 to 35%, as compared with materials before treatment to 1.5 to 2.5 times. The molding pressure decreased by 20-30%.Aimable et.al carried out investigation on nanoparticles and their application in Segmented Flow Tubular Reactor (SFTR) [5]. They presented process intensification using a segmented flow tubular reactor (SFTR) for ultrafine $CaCO_3$, $BaTiO_3$, and nanosized ZnO from optimized minibatch (20 mL) conditions. With SFTR, it was possible to scale out the powder production from very low optimization volumes (40 cm^3) at the laboratory scale without changes in powder quality. They concluded that the SFTR was a powerful tool for the production of powders and nanocrystals.

An investigation on precipitation system for zinc oxide and aluminum doped zinc oxide nanoparticles was carried out by Aimable et.al [6].They used mild hydrothermal conditions by using the Segmented Flow Tubular Reactor (SFTR) for synthesis of zinc oxide nanoparticles. Microwave assisted hydrothermal process was having advantage of directly forming fully crystalline powder. It was also observed that with addition of aluminum and polyacrylic acid, a better control on size and morphology was possible. Principles and processes for carbon nanotube(CNT) production were studied by Zhang et.al [7]. They described various techniques for the synthesis of nanotubes.Large volume application requires require large amounts of CNTs of good quality, while limited-volume applications require high structure and reproducibility standards. Various process intensification technologies have been employed successfully by various researchers such as catalyst route innovation, feedstock saving, and a coupled process. By using these methods it was possible to improve the quality of CNT and decrease the cost of production. They concluded that the CNTs are far from large scale applications because of difficulties in the synthesis and subsequent product treatments.Zou et.al carried out investigation real time high performance and facile hydrogen sensing with bare palladium nano-rosettes [8]. They synthesized nano-rosettes by reduction of palladium with hydrogen at atmospheric pressure. By using this technique, it was possible to synthesize surfactant free palladium. Because of this process it was possible to minimize down stream processing.Daramola et.al discussed potential applications of zeolite membranes in reaction coupling separation processes[9].According to them the future challenge for fine and specialty chemical lies in use of limited resources and energy for the production processes. Chomistek and Panagiotou investigated large scale microfluidizer production. They used microfluidizer high shear processing for the purpose[10]. According to their discussion the microfluidics require in-depth understanding of applications, unique design of high shear fluid processors, and development of processes tailored for each individual application. Microfluidics finds many applications in pharmaceuticals and biotech, energy, specialty chemicals, cosmetics and nutraceuticals fields. Pharmaceutical and biotechnological applications includes the development of

various types of drugs and polymeric proteins. The chemical applications included ink, fuel cell and battery electrodes, and carbon nanotube dispersion.Stankiewicz and Moulijn discussed various process intensification techniques such as multifunctional reactors, membrane reactors, hybrid separations , use of alternate energy sources[11].

Conclusion

The application of nanomaterials for process intensification is very widely studied area of research. The use of nanomaterials in the field of heat transfer, mass transfer and reaction engineering is growing day by day. The problem in large scale application is large scale production. The nanomaterials find the major application in the field of specialty and fine chemicals. It can be concluded that there is scope for research in this field in order to economic and large scale synthesis of nonmaterial and explore their application in order to intensify various processes.

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