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Photocatalytic degradation of phenol in aqueous media over $BaAl_2O_4$-SrO composite nanofibers

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ABSTRACT

Photocatalytic degradation of phenol in aqueous media over novel heterogeneous photocatalyst $BaAl_2O_4$-SrO composite nanofibers was investigated under UV irradiation. The catalyst was characterized by SEM and XRD analysis. The degradation yield of phenol could reach up to 95%. The higher yield of degradation was achieved under the following condition: solution concentration: 1g/L; catalyst: 0.05 g; t: 80 °C and pH: 5.

Keywords: *$BaAl_2O_4$-SrO composite; nanofibers; photocatalytic degradation; phenol.*

1. INTRODUCTION

Given the recent advances in various fields of science, single-material and alloys, in many cases, do not meet the needs of modern technology today. Instead of combining one or more materials as composites, these needs can be met. The advantages of these materials are to achieve a material whose properties are in the middle of their ingredients. These materials are classified according to the geometry of the reinforcing materials (particles, flaky parts, fibers or nanosets) or based on the type of matrix (polymer, metal, ceramic or carbon). Polymer composites are the most commonly used composites with polymer matrix phase. The high strength, the simplicity of the manufacturing process and the lower cost of production are the benefits of these materials. While low operating temperatures, high thermal expansion coefficients, radiation sensitivity and humidity, and low elastic properties are the most important disadvantages of these materials [1]. Polymer matrix composites are one of the most common and most significant composite materials for two reasons. First, the mechanical properties of these materials are very weak in comparison to other materials, such as metals and ceramics, which mean that the reinforcement of these useful materials is beneficial. The second reason is that due to the low working temperature of these materials, it is not necessary to use high processing temperatures, which will result in the use of a wide range of reinforcing materials and non-destruction of reinforcing materials. In addition, these composite materials are easier to use and , the polymer matrix composites are rapidly expanded and found [1-3].

The phenolic compounds spreading in sewage has increased the concern for public health due to the toxicity of most of phenols which are well-known for their biological toxicity. These compounds destroy the environment through various outputs of industrial and non-industrial industries. Therefore, purification of industrial wastewater from phenolic compounds is a necessary requirement for the safety of human health [4-7]. Traditional wastewater treatment methods, with some limitations and disadvantages, cannot break down all phenolic compounds. Therefore, the use of catalytic systems that can eliminate these compounds by breaking them into non-hazardous species represent a research area. Recently, photocatalytic degradation of phenolic compounds with or without ultraviolet light has been reported, which is a useful way to remove these compounds from sewage [8-15]. This method present some advantages like: cost-effective, environmentally friendly and capable of destroying a wide range of phenolic compounds without producing harmful side products. Some photocatalysts provide a good choice for effective removal of phenolic compounds [8-15].

In continuation of our current research devoted to the synthesis of nanomaterials [16-36], herein, we wish to report an efficient and facile procedure for the easy removal of phenol using $BaAl_2O_4$-SrO composite nanofibers as an effective catalyst.

2. EXPERIMENTAL SECTION

All reagents were purchased from Merck and Aldrich and used without further purification. All yields refer to isolated products after purification. The powder X-Ray diffraction patterns were measured with D_8, Advance, Bruker, axs, diffractometer using Cu-Kα irradiation. FE-SEM was taken by a Hitachi S-4160 photograph to examine the shape of the sample. The NMR spectra were recorded on a Bruker Avance DPX 400 MHz instrument. The spectra were measured in DMSO-d_6 relative to TMS (0.00 ppm). Elemental analysis was performed on a Heraeus CHN-O-Rapid analyzer.

2.1. Preparation of $BaAl_2O_4$-SrO composite nanofibers. A mixture of $BaAl_2O_4$ (0.7 mmol) and SrO (0.3 mmol) nanopowders was dispersed in one liter of water and combined with Polyvinyl alcohol (PVA) until a viscous gel was obtained. The above gel was put in a syringe. The positive terminal of a high voltage power supply was connected to the metallic syringe tip (a needle with diameter of 0.7 mm) while the negative terminal was connected to a conductive drum covered with aluminum foil as a collector of fibers. A voltage of 30 kV and a speed of 0.5 mlh^{-1} were applied to the solution and a dense web of fibers was collected on the aluminum foil. Finally, the sample was calcined at 500 °C.

2.2. Photocatalytic degradation procedure. The photocatalytic degradation of the phenol solution was performed using a solution of the phenol substrate in water, H_2O_2 as oxidant (1 mL) and $BaAl_2O_4$-SrO composite nanofibers as catalyst. The solution was stirred under UV irradiation (273 nm) with three 8W ultraviolet lamp as a source in Pyrex flasks at room temperature. The absorption spectrum of the suspension mixture was measured periodically using a GC spectrophotometer (Shimadzu, UV-2450, Japan) after centrifugation to ensure the degradation of phenol solution.

3. RESULTS SECTION

Figure 1 shows the SEM image of $BaAl_2O_4$-SrO composite nanofibers calcined at 500 °C for 2h. The composite consisted of long nanofibers with sturdy surface. The average diameter of size distribution of nanofibers is less than 300 nm. The XRD pattern shows a non-crystalline solid of $BaAl_2O_4$-SrO composite nanofibers.

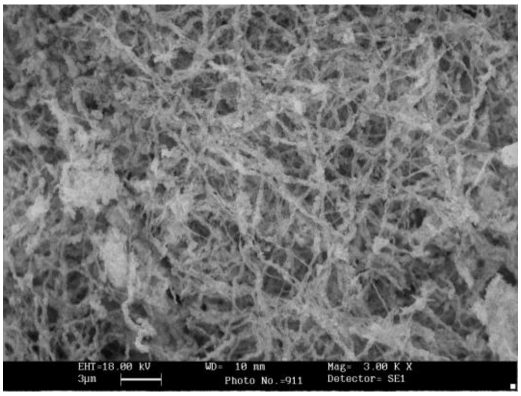

Figure 1. SEM image of $BaAl_2O_4$-SrO composite nanofibers.

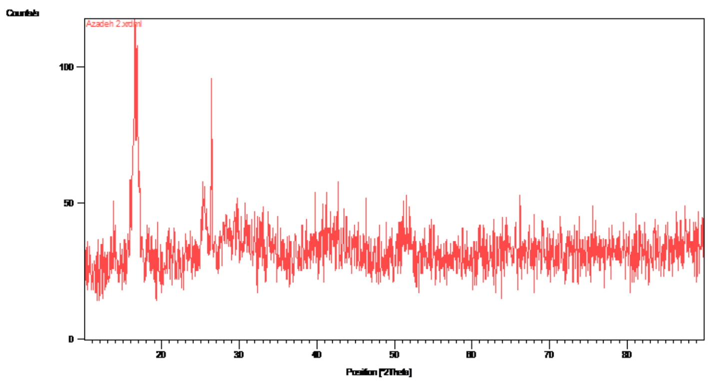

Figure 2. XRD pattern of $BaAl_2O_4$-SrO composite nanofibers.

The catalytic potential of the as prepared $BaAl_2O_4$-SrO composite nanofibers was investigated based on the photocatalytic degradation of phenol.

First, the photocatalytic degradation of phenol was studied at different temperatures including 50, 60, 80 °C. The degradation percentage against time is shown in Figure 3. At higher temperature decline of phenol concentration is much more than those of low temperature reaction medium. This may be due to the increased concentration of superoxide anion ($O_2^{\bullet -}$) and hydroxyl radicals ($HO^{\bullet}$) at higher temperatures.

Figure 4 shows the effect of catalyst concentration on the photodegradation activity of phenol under UV irradiation. The decrease of phenol concentration can be improved up to 0.05 g of the catalyst and the higher amount of the catalyst has a lower percent of degradation.

The influence of phenol concentration on degradation rate was studied from 0.05 to 2 g/L at a constant catalyst loading of 0.05 g and a solution pH of 5. The volume of phenol solution was 10 ml. It has been observed that the degradation rate increases with an increase in concentration of phenol up to 1 g/L and then decreases (Figure 5). The UV λ_{max} value of phenol is 280 nm.

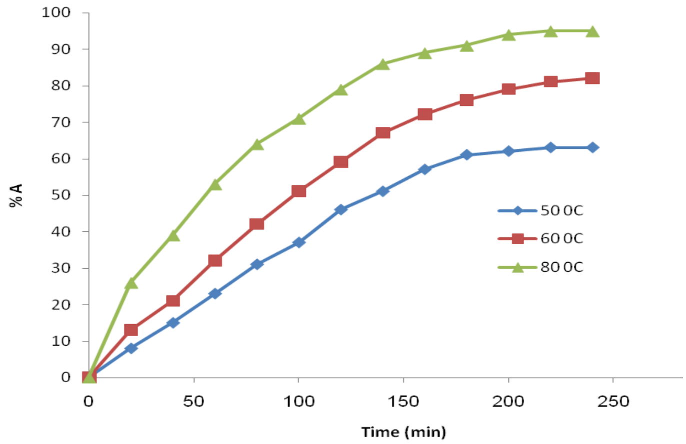

Figure 3. Photo-catalytic degradation of phenol: effect of temperature [catalyst: 0.05 g; solution concentration: 2 g/L; pH: 5]

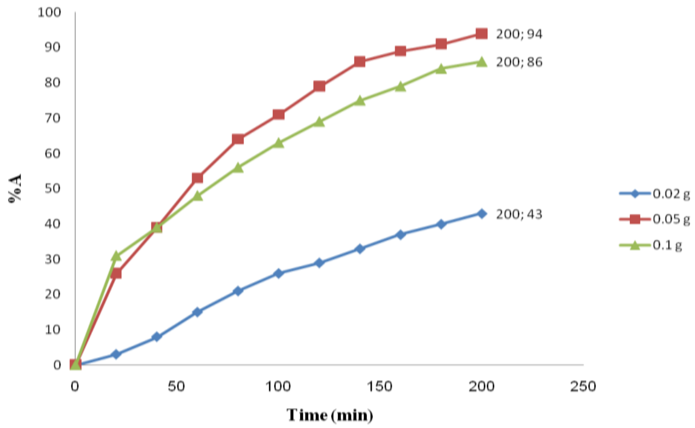

Figure 4. Photo-catalytic degradation of phenol: effect of catalyst dosage [t: 80 °C; solution concentration: 2 g/L; pH: 5].

Next, under optimized condition (solution concentration: 1g/L; catalyst: 0.05 g; t: 80 °C and pH: 5) the photocatalytic degradation potential of $BaAl_2O_4$-SrO composite nanofibers was investigated for a variety of phenolic compounds including 4-chlorophenol, 3-chlorophenol, 2-chlorophenol, 4-nitrophenol, 3-nitrophenol, 4-bromophenol, 2-methylphenol, 4-methoxyphenol and 4-methylphenol. The results were summarized in Figure 6. As it was shown in Figure 6, excellent yields of degradation could be achieved using $BaAl_2O_4$-SrO composite nanofibers for different substituted phenols.

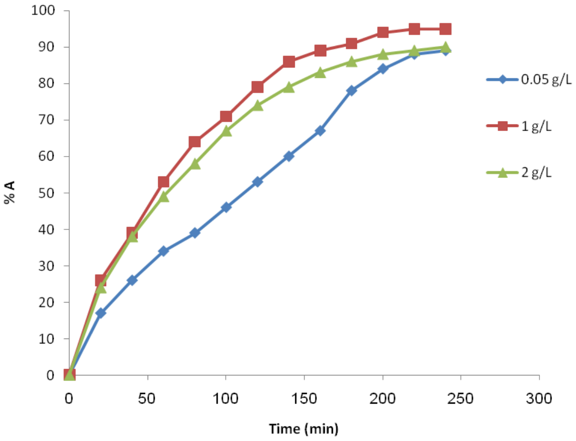

Figure 5. Photo-catalytic degradation of phenol: effect of solution concentration [catalyst: 0.05 g; t: 80 °C; pH: 5].

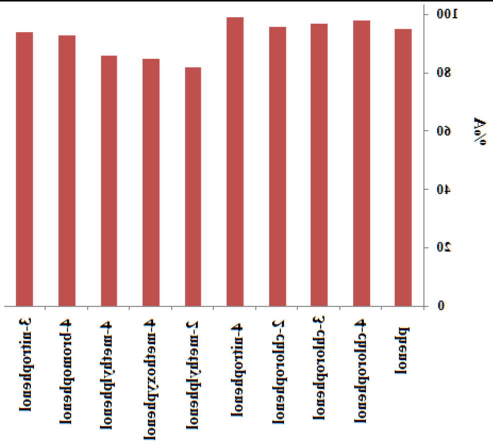

Figure 6. photocatalytic degradation of substituted phenols over $BaAl_2O_4$-SrO composite nanofibers.

4. CONCLUSIONS

$BaAl_2O_4$-SrO composite nanofibers were prepared via a simple procedure and were found to be an effective catalyst for the photocatalytic degradation of phenol. The higher yield of degradation was achieved under the following condition: solution concentration: 1g/L; catalyst: 0.05 g; t: 80 °C and pH: 5. The catalyst could be efficiently used for the photocatalytic degradation of substituted phenols.

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