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Sol–gel synthesis, characterization and photocatalytic properties of $SrCrO_4$ particles

L. Krishna Bharat, L. Sivananda Reddy, Jae Su Yu *

Department of Electronics and Radio Engineering, Kyung Hee University, Yongin-si, Gyeonggi-do 446-701, Republic of Korea

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ABSTRACT

Sub-micro/microsized $SrCrO_4$ particles were synthesized by a sol–gel technique and their thermal stability was tested by thermo analytical methods like thermogravimetric analysis/differential thermal analysis. The as-prepared (calcined at 950 °C) powders were analyzed morphologically and their structural analysis was carried out by X-ray diffraction pattern and Fourier transform infrared spectroscopy. The as-prepared powders were used as photocatalysts under visible light irradiation. The photocatalytic activity of the $SrCrO_4$ particles was examined by varying the irradiation time in a solution containing photodegradable dye (Rhodamine B (RhB)). The photodegradation rates were found to be approximately 21.8% and 98.3% for RhB solutions without and with photocatalyst, respectively, at an irradiation time of 8 h.

1. Introduction

Over the past few decades, photocatalysts which respond to ultra-violet (UV) and visible lights have gained much attention [1–3]. The photocatalysts have been used in a wide variety of applications, specially related to energy and environment [4–6]. Recent progress in the development of photocatalysts, which can be activated by visible light irradiation and help to enable better and fast degradation of dyes, is still made. In general, the most widely used method for the synthesis of these photocatalytic materials is solid-state reaction which is a time-taking process and requires a high temperature during the synthesis. The synthesis method also results in impurity phases of the compound due to low reactivity and poor mixing during grinding. On the other hand, there are several wet chemical techniques which can overcome the above drawbacks. Among these wet chemical techniques, sol–gel process is one of the simple and easy approaches to get a novel chemical composition with excellent purity and unique properties at relatively low reaction temperatures.

Several catalysts have been developed by the wet chemical synthesis procedure, and the chromium-based compounds are very predominant, offering visible light activity and defined structures with high stability. In this context, a ternary metal oxide of general formula, i.e., $XCrO_4$, where X (Sr, Ba, and Pb) has +2 oxidation state, is synthesized by a sol–gel process. These compounds have unique properties and can be used in a wide range of applications such as photosensitization, photoluminescence, scintillation, photocatalysis, etc. [7–10]. The $XCrO_4$ structures consist of X atom coordinated by eight oxygen atoms and CrO_4 tetrahedra which is a flexible structure and accept paring of several charge ions. Up to now, only few reports have been found on the synthesis of $SrCrO_4$ and its photocatalytic applications. Jiang et. al. have reported the synthesis of polycrystalline $SrCrO_4$ and conducted the water splitting experiments for the evaluation of H_2 gas with Pt co-catalyst in CH_3OH/H_2O solution. They also studied the O_2 evolution in $AgNO_3$ solution under visible light illumination and in pure water under UV light irradiation [7]. Similarly, Tanmay et. al. have reported the synthesis of $SrCrO_4$–TiO_2 mixed oxides and its photocatalytic activity under UV light irradiation [11]. Thus, it is interesting to study the synthesis and photocatalytic activity of $SrCrO_4$ materials.

In this work, we synthesized the $SrCrO_4$ by a sol–gel technique and investigated its structural properties. Also, the photocatalytic experiments with Rhodamine B (RhB) solution were performed under visible light irradiation.

2. Experimental procedure

Synthesis of $SrCrO_4$ (SC): The sub-micron to micron range particles of SC were synthesized by the sol–gel technique using stoichiometric amounts of strontium nitrate ($Sr(NO_3)_2$), chromium nitrate nonahydrate ($Cr(NO_3)_3 \cdot 9H_2O$), and citric acid (CA) (HOC

* Corresponding author.
E-mail address: jsyu@khu.ac.kr (J.S. Yu).

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$(COOH)(CH_2COOH)_2$). All the used chemicals which were purchased from Sigma Aldrich Corporation were of high-purity grade. For preparing the SC particles, 1 mM of strontium and 1 mM of chromium were mixed in 200 ml of de-ionized water and after 10 min, 4 mM (1:2 ratio of metal to chelating agent (CA)) of CA was added under continuous magnetic stirring and the beaker was covered with a lid. The stirring was continued for 1 h until a homogenous solution was formed. Thereafter, the solution temperature was increased to 80 °C on a hot plate. The lid of the beaker was removed after 2 h of continuous stirring to allow the slow evaporation of solution. Then, the final gel was collected and dried in an oven at 70 °C for a day in an ambient atmosphere. The dried gel was then calcined at 400 °C and it was further calcined at 950 °C for 7 h to get the crystalline SC particles.

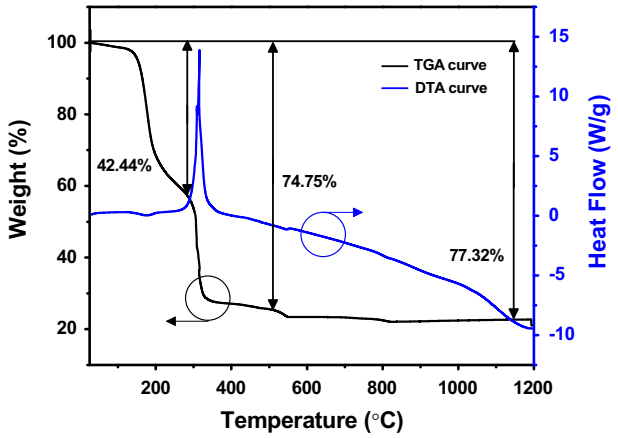

Fig. 1. TGA/DTA curves of the precursor powder from room temperature to 1200 °C.

Photocatalysis: The photocatalytic experiments were carried out for the SC particles under visible light irradiation by varying the irradiation time. The photocatalysis was done by using a xenon arc lamp with a cut-on filter to absorb only visible light. For this, the photodegradable dye, RhB was mixed in water at a concentration of 1 mg/l. The activities were performed by adding 50 mg of photocatalyst in 50 ml of dye solution. The process was repeated by changing the reaction time. After the completion of reaction, the solution was filtered using a filter paper and 3 ml of the filtered solution was used to acquire the absorption spectrum by using a UV/VIS spectrophotometer (CARY 300 Bio (Varian)).

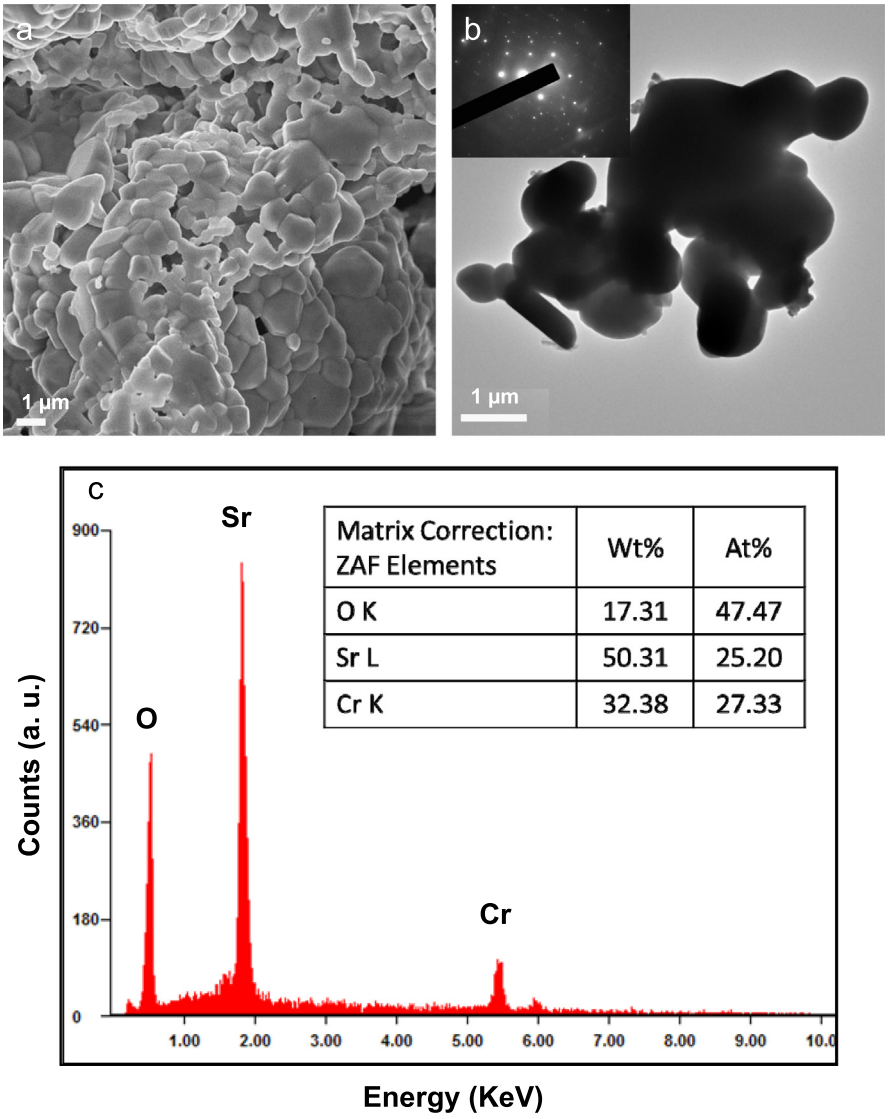

Fig. 2. (a) FE-SEM image, (b) TEM image, and (c) EDAX spectrum of the sample calcined at 950 °C. The inset of (b) shows the SAED pattern of the sample.