Removal of nitric oxide by perovskite $LaFeO_3$-$LaMnO_3$ composite nanoarray

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Abstract: Nitric oxide (NO) is one of the major air pollutants causing critical environmental and human health issues. Doping of transition metal on lanthanum perovskite catalyst has shown effectiveness in removing this air pollutant. The aim of this study is to prepare and evaluate one-dimensional ordered lanthanum iron oxide-lanthanum manganese oxide ($LaFeO_3$-$LaMnO_3$) composite nanoarrays using sol-gel method, with anodized aluminum oxide (AAO) as the array template. $LaMO_3$ and $LaFeO_3$ phases were identified with XRD; and the samples were found to be nanorod arrays of 15 μm long with diameters ranging from 0.5 to 1.0 μm. DRIFTs was used to evaluate the NO removal efficiency at different temperatures. The best sample was $LaFeO_3$-$LaMnO_3$ nanoarrays with $La(NO_3)_3$: $Mn(NO_3)_2$: $Fe(NO_3)_3$: $C_6H_8O_7$ volume ratio of 5: 2: 3: 10, which yielded 65% NO conversion at 200°C.

Keywords: Nitrous oxide, Nanoarray, Perovskite.

1. Introduction

Nitrous oxides (NOx) are one of the main hazardous sources and are poisonous not only to human health [1], but also one of the main culprits causing acid rain, photochemical smog, ozone depletion, and particulate matter [2]. In our previous study [3], 1D ordered zinc: copper indium sulfide has shown good performance in the photosynthesis of methanol. A number of studies have also shown that one-dimensional ordered nanostructure can significantly enhance the conversion rates due to the noticeable improvement of charge transfer. Therefore, this study aims to explore the feasibility of 1D ordered lanthanum iron oxide-lanthanum manganese oxide ($LaFeO_3$-$LaMnO_3$) composite nanoarrays for removal of nitric oxide (NO).

2. Experimental

The 1D ordered $LaFeO_3$-$LaMnO_3$ composite nanoarrays were prepared from the solutions of 5 M lanthanum (III) nitrate ($La(NO_3)_3$), 5 M manganese (II) nitrate ($Mn(NO_3)_2$), 5 M iron (III) nitrate ($Fe(NO_3)_3 \cdot 9H_2O$) and 1 M citric acid ($C_6H_8O_7$),. Anodized aluminum oxide (AAO) templates were soaked in the solutions for 10 min at 25°C. After the growth of nanoarrays in the AAO templates, the aluminum frameworks were etched by sodium hydroxide solution. Samples (a)–(f) as labelled in Table 1 were synthesized by soaking the AAO templates with different $LaFeO_3$-$LaMnO_3$ mixture solutions. The films were then dried in oven at 110°C for 1 h, followed by heat treatment in a furnace under argon/hydrogen gas at 650°C for 4 h. This annealing treatment is necessary as it provides better and stable crystal properties. Diffuse reflectance infrared Fourier transform spectroscopy (DRIFTs) was used to evaluate the efficiencies of NO removal at different temperatures with an initial NO concentration of 3,000 ppm, and a flow rate of 5 sccm. X-ray diffraction (XRD), field-emission scanning electron microscopy (FESEM) and photoluminescence (PL) characterization tests were carried out to evaluate the properties of the samples.

Table 1. The parameters of various samples prepared using sol-gel method.

Reagent/Sample	(a)	(b)	(c)	(d)	(e)	(f)
5M $La(NO_3)_3$ /mL	5	5	5	5	5	5
5M $Mn(NO_3)_2$ /mL	5	4	3	2	1	
5M $Fe(NO_3)_3 \cdot 9H_2O$ /mL	-	1	2	3	4	5
1M $C_6H_8O_7$ /mL	10	10	10	10	10	10

3. Results and discussion

Figure 1 shows the XRD patterns of different 1D ordered $LaFeO_3$-$LaMnO_3$ composite nanoarrays. The diffraction peaks of all samples were indexed to the standard cards of $LaMO_3$ (JCPDS NO. 01-075-0440) and $LaFeO_3$ (JCPDS NO. 01-075-0541). In addition, a shift of the main peak to a higher 2θ angle was observed in samples with the increasing Fe concentrations, due to an intrinsic defect of the $LaFeO_3$-$LaMnO_3$ composite nanoarrays crystal structure. According to the FESEM micrographs in Figure 2, nanorod arrays were 15 µm long with diameters ranging from 0.5 to 1.0 µm. Figure 3 shows the removal efficiencies of NO by 1D ordered LaFeO3-LaMnO3 composite nanoarrays. Apparently, higher temperatures favor NO removal. Sample (d) was found to be the best sample, yielding NO removal efficiency of 65% at 200ºC. As supported by the PL result (not shown), sample (d) shows a lower photoluminescence intensity, indicating lower recombination rate of photo-generated electron charges and thus higher activity.

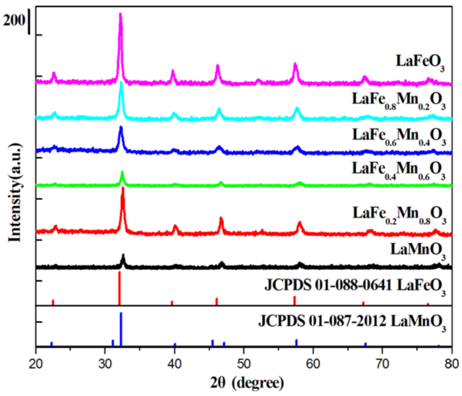

Figure 1. XRD patterns.

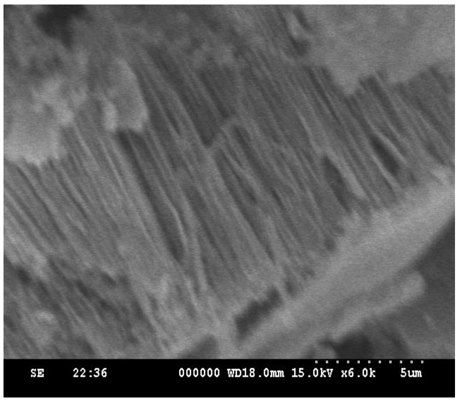

Figure 2. FESEM image of 1D $LaFeO_3$-$LaMnO_3$ sample.

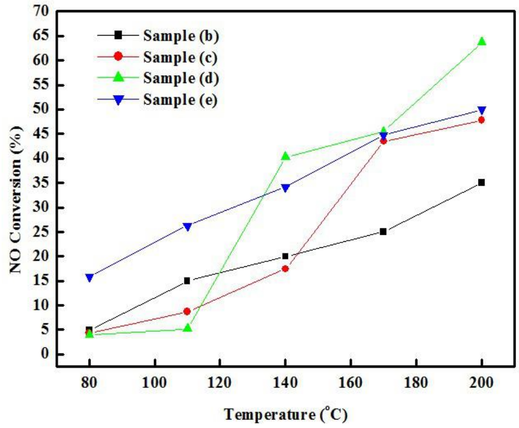

Figure 3. NO removal efficiencies of different $LaFeO_3$-$LaMnO_3$ samples.

4. Conclusions

1D ordered $LaFeO_3$-$LaMnO_3$ composite nanoarrays were successfully prepared using sol-gel method with AAO templates. XRD showed that the $LaMO_3$ and $LaFeO_3$ phases were the major crystal structures. NO removal efficiency increases with the operating temperature. Highest NO conversion of 65% was achieved by $LaFeO_3$-$LaMnO_3$ nanoarray with $La(NO_3)_3$: $Mn(NO_3)_2$: $Fe(NO_3)_3$: $C_6H_8O_7$ volume ratio of 5: 2: 3: 10. In conclusion, $LaFeO_3$-$LaMnO_3$ composite nanoarray has shown its potential in removing NOx.

References

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