Noncontact Synergistic Effect between Au Nanoparticles and the Fe_2O_3 Spindle Inside a Mesoporous Silica Shell as Studied by the Fenton-like Reaction

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Abstract: An Au-Fe_2O_3@mesoporous SiO_2 nanoreactor with a multi-yolks/shell structure was synthesized through a multistep method. In this nanoreactor, the spindle Fe_2O_3 and Au nanoparticles were inside the same mesoporous SiO_2 shell as the yolks but in a noncontact manner. The noncontact synergistic effect between Au nanoparticles and the Fe_2O_3 spindle was studied with a Fenton-like reaction. The catalytic activity of the Au-Fe_2O_3@mesoporous SiO_2 nanoreactor to the Fenton-like reaction for the degradation of organic dyes was dramatically enhanced by the noncontact synergistic effect.

Keywords: Noncontact Synergistic Effect, Fenton-like Reaction, Fe_2O_3, Au

1. Introduction

For the catalytic application, multi-yolks/single shell structure normally provide better catalytic performance over single-yolk/shell structure with the same core material because multiple core particles provided more available surface area and more active sites [1, 2]. Till now, many multi-yolks/single shell nanostructures have been reported; among them, the multi-yolks were mostly noble metal nanoparticles while the outer shell was normally metal oxides, carbon or silica with hollow structure [3-5]. More than one kind of core materials inside the hollow mesoporous shell is promising in catalysis as one core material can act as catalyst while the others can act as co-catalyst. However, synthesis of this type of multi-yolks/single shell structure was still challenge and the synergistic effect between the cores was not fully studied. Synergistic effect arising between two or more agents that produces an effect greater than the sum of their individual effects commonly exists in chemistry and material science. In catalysis, the synergistic effect between catalyst and co-catalyst always generates more active catalyst [6, 7]. Several kinds of structures of catalysts such as doping, alloy, supported and core/shell structure have been developed to facilitate the synergistic effect[7-10]. In the above-mentioned structures, the catalyst and co-catalyst are closely contact with each other, resulting in more active catalyst due to the change of surface energy, electronic structure or oxidation state, etc caused by the contact. How the synergistic effect is if the catalyst and co-catalyst did not contact with each other was not clear as it was hard to produce the specific structure where the catalyst and cocatalyst was in non-contact manner. The multi-yolks/shell structured materials give us opportunities to study the non-contact synergistic effect because the catalyst and co-catalyst could be confined in the same space with non-contact manner in the yolk/shell structure.

Herein, a multi-yolks/single shell structured Au-Fe_2O_3@mesoporous SiO_2 nanoreactor was synthesized through a multi-step method. In this nanoreactor composite, two kinds of yolk materials, the spindle Fe_2O_3 and small Au nanoparticles were inside the hollow mesoporous silica shell as yolks with non-contact manner. The spindle Fe_2O_3 yolk was in the central space of the hollow mesoporous silica shell as planet while small Au nanoparticles was on the inner wall of the mesoporous silica shell as satellites surround the planet but not on the Fe_2O_3 spindle. The non-contact synergistic effect between the Fe_2O_3 spindle and Au nanoparticles to Fenton-like reaction for the degradation of organic dyes was further studied.

2. Experimental

As shown in Figure 1, the experimental route including: 1. Preparation of Spindle Fe_2O_3; 2. Polymeric carbon coated Fe_2O_3; 3. Loading Au nanoparticles; 4. Mesoporous SiO_2 coating; 5. Removal of carbon

3. Results and discussion

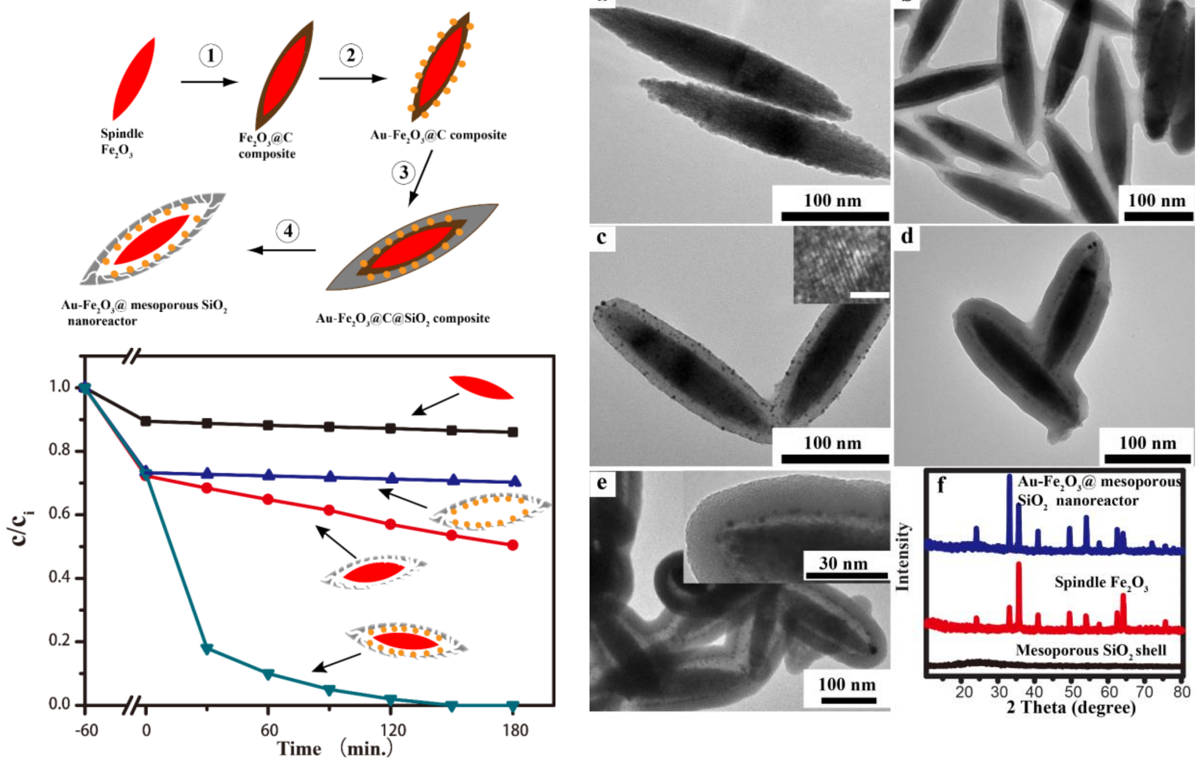

Figure 1. (1) The synthesize method of Au-Fe_2O_3@mesoporous SiO2 nanoreactor. (2) The TEM images and XRD patterns of Au-Fe_2O_3@mesoporous SiO_2 nanoreactor. (3) The catalytic performance of different catalysts.

4. Conclusions

In summary, a multi-yolks/shell structured Au-Fe_2O_3@mesoporous SiO_2 nanoreactor were fabricated through a multi-step method. In the Au-Fe_2O_3@mesoporous SiO_2 nanoreactor, Au nanoparticles and Fe_2O_3 spindle were inside one same mesoporous SiO_2 shell as yolks with the structure that Au nanoparticles were surround the Fe_2O_3 spindle but not on it. The synergistic effect between the non-contact Au nanoparticles and the Fe_2O_3 spindle was further studied by Fenton-like reaction as model reaction. When used as catalyst for Fenton-like reaction to the degradation of MB, multi-yolks/shell structured Au-Fe_2O_3@mesoporous SiO_2 nanoreactor showed much higher activity not only than the Fe_2O_3@mesoporous SiO_2 nanoreactor but also higher than Au nanoparticles@mesoporous SiO_2 composite. The non-contact synergistic effect induced by the planet-satellites location of metal oxides and Au nanoparticles inside the mesoporous SiO_2 shell played the key role in the higher activity of Au-Fe_2O_3@mesoporous SiO_2 nanoreactor. The detailed and more accurate mechanism of the non-contact synergistic effect between the planet-satellites like Au- Fe_2O_3 yolks in the multi-yolks/shell structured Au-Fe_2O_3@mesoporous SiO_2 nanoreactor to Fenton-like reaction will be studied in the future.

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