Study on Preparation and Properties of Fe₂O₃/Al₂O₃/CeO₂/ZrO₂ Material

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Abstract. Material is the material basis for human survival and development, and it has a very important role in the national economic and social development. With the development of electronics and new materials industry, nano ZrO₂ and its composite materials have been widely used. Twenty-first Century is the century of the development of new materials, so the development of new catalytic material is undoubtedly significant. This paper mainly introduced classification and the presentation of the catalytic material and zirconia properties and applications, by sol-gel method. The prepared a series of Fe₂O₃-Al₂O₃-CeO₂-ZrO₂ catalytic materials, respectively by IR, UV, scanning electron microscope(SEM), X-ray diffraction (XRD) and photocatalytic modern measurement analysis method on product was characterized. Based on the analysis of the influence of the composition on the properties of the material, the optimal composition is selected. The results show that, the thermal stability of the pure ZrO₂ is relatively low, with the addition of metal elements can effectively improve the ZrO₂; scanning electron microscope image analysis shows that adding metal element effectively avoid the agglomeration of the particles; photocatalytic experiments indicated that, the doping metal elements can improve the performance of the material of photocatalytic degradation of methyl orange and Rhodamine B.

1. Introduction
Catalytic materials play a very important role in the material. Therefore, it is very important to develop and study the new catalytic materials for human life. ZrO₂ is a new type of high-tech materials, it has many special properties, its high melting point, high hardness, small thermal conductivity, thermal expansion coefficient, high temperature resistance, good abrasion resistance, good chemical stability and excellent corrosion resistance. It is widely used in the manufacture of structural ceramics, functional ceramics and biological ceramics, as a result of ZrO₂ and oxidation reduction and acid and alkali, it can also be used as a catalyst and support or additives. In this study, a series of Fe₂O₃-Al₂O₃-CeO₂-ZrO₂ catalytic materials were prepared by sol-gel method, and the effects of different components on the properties of materials were discussed in order to obtain a more optimized ZrO₂ system [1-6].
The preparation of ZrO$_2$ powder and ZrOCl$_2$ as a precursor by sol-gel method with dilute ammonia as the precipitant after solubilization, hydrolysis, precipitation, and hydrated zirconia, after washing, dehydration, drying and calcination of ZrO$_2$ powder 8 hours. Sol-gel method has some special advantages. The reaction rate of this method is relatively fast, in a very short period of time can get the uniform molecules. The reaction temperature is low, the reaction is easy to carry out, and can make all kinds of new materials. But sometimes the process of sol-gel will be relatively long, especially the aging time [7-10].

2. Experiment
The experiment is based on the Fe element, the Al element, the same mole content, Zr for 0.03 mol. A series of Fe$_2$O$_3$-Al$_2$O$_3$-CeO$_2$-ZrO$_2$ powders were prepared by sol-gel method, and the components were calculated according to the following steps:

1) Weigh 2.5 ml ammonia, adding distilled water diluted to 100 ml, remove the 50 ml diluted ammonia water poured into the beaker, add a few drops of ethanol, stirring with a glass rod while adding dilute ammonia solution until the pH = 8.

2) Use the magnetons into the beaker, use plastic wrap beaker, prevent the solution from long time exposure in the air will be oxidized, with a magnetic stirrer for two hours.

3) After mixing the solution into the reaction kettle, and then placed in the oven, the temperature is set to 80 ℃, the heat reaction, 24 hours after the removal.

4) Remove the reaction product with anhydrous ethanol after washing with water circulating vacuum pump suction, repeated 3 times washing filtration.

5) Put the product in a crucible, again in the oven, the temperature is set to 80 ℃, removed after 24 hours, then, we can get the series of Fe$_2$O$_3$-Al$_2$O$_3$-CeO$_2$-ZrO$_2$ powder.

3. Results and Discussion
Fig.1 shows the IR images of Fe-Al-Ce-ZrO$_2$, Fe-Al-ZrO$_2$, Fe-Ce-ZrO$_2$, Al-Ce-ZrO$_2$, Fe-ZrO$_2$, Al-ZrO$_2$, Ce-ZrO$_2$, ZrO$_2$ composites, we can see, there is an absorption peak at 2025 cm$^{-1}$ C=O vibration, showed the product of organic compounds; in 1630 cm$^{-1}$ a small absorption peaks, which can be attributed to the O-H vibration of water and hydroxyl, 1575 cm$^{-1}$ of a peak, may be C-H single bond, some components will be around 1000 cm$^{-1}$ this is because the absorption peaks, doped metal elements and Zr-O vibration.

![Figure.1 IR images of Fe-Al-Ce-ZrO$_2$, Fe-Al-ZrO$_2$, Fe-Ce-ZrO$_2$, Al-Ce-ZrO$_2$, Fe-ZrO$_2$, Al-ZrO$_2$, Ce-ZrO$_2$, ZrO$_2$ composites](image-url)

Fig.2 shows the SEM images of Fe-Al-Ce-ZrO$_2$, Fe-Al-ZrO$_2$, Fe-Ce-ZrO$_2$, Al-Ce-ZrO$_2$, Fe-ZrO$_2$, Al-ZrO$_2$, ZrO$_2$ composites, we can see, two of the surface of zirconia only participate in a Fe or Al is smooth, component Fe-Al-ZrO$_2$ (b), Fe-Ce-ZrO$_2$ the total molar content of Ce elements for the total content of 15% , and in addition to the Zr element of each component of (c), Al-Ce-ZrO$_2$ (d), the surface of the
carrier is composed of fine particles are numerous, with more abundant surface structure, which proves that Fe-Al-Ce-ZrO$_2$ (a) more doping, grain the larger surface area, metal element doping can effectively avoid the agglomeration of particles.

![Figure 2](image)

**Figure 2** SEM images of Fe-Al-Ce-ZrO$_2$ (a), Fe-Al-ZrO$_2$ (b), Fe-Ce-ZrO$_2$ (c), Al-Ce-ZrO$_2$ (d), Fe-ZrO$_2$ (e), Al-ZrO$_2$ (f).

Fig. 3 shows the XRD images of Fe-Al-Ce-ZrO$_2$, Fe-Al-ZrO$_2$, Fe-Ce-ZrO$_2$, Al-Ce-ZrO$_2$, Fe-ZrO$_2$, Al-ZrO$_2$, Ce-ZrO$_2$, ZrO$_2$ composites, we can see, from 10 to 70 degrees in the figure, Fe-Al-ZrO$_2$ (b), Ce-ZrO$_2$ (g), ZrO$_2$ (h) has strong diffraction peak, indicating that these three substances are not formed crystal, belonging to amorphous or microcrystalline, Fe-Ce-ZrO$_2$ (c), Al-Ce-ZrO$_2$ (d), Fe-ZrO$_2$ (e), Al-ZrO$_2$ (f), Fe-Al-Ce-ZrO$_2$ (a) at 33 degrees have a relatively strong zirconia characteristic peak, but the peak sharp enough, that may have good crystallinity products.

![Figure 3](image)

**Figure 3.** XRD images of Fe-Al-Ce-ZrO$_2$ (a), Fe-Al-ZrO$_2$ (b), Fe-Ce-ZrO$_2$ (c), Al-Ce-ZrO$_2$ (d), Fe-ZrO$_2$ (e), Al-ZrO$_2$ (f), Ce-ZrO$_2$ (g), ZrO$_2$ (h).

Figure 4(a) shows the Uv images of Fe-Al-Ce-ZrO$_2$, Fe-Al-ZrO$_2$, Fe-Ce-ZrO$_2$, Al-Ce-ZrO$_2$, Fe-ZrO$_2$, Al-ZrO$_2$, we can seen in the figure, all the samples in the range of 375 nm absorption range is wide, this phenomenon is mainly caused by the ZrO$_2$ nanocrystals valence electrons to the conduction band absorption transition. Figure 1 and 3 coincident curves, which show that the addition of ZrO$_2$ absorption Al element has no effect, Al-ZrO$_2$, compared with the other samples have a blue shift of the optical
absorption increases, this phenomenon is due to the interaction between the metal element doped with ZrO$_2$ matrix.

**Figure. 4** (a) ultraviolet spectrum images of Fe$_2$O$_3$-Al$_2$O$_3$-CeO$_2$-ZrO$_2$, Fe$_2$O$_3$-Al$_2$O$_3$-ZrO$_2$, Fe$_2$O$_3$-CeO$_2$-ZrO$_2$, Al$_2$O$_3$-CeO$_2$-ZrO$_2$, Fe$_2$O$_3$-ZrO$_2$, Al$_2$O$_3$-CeO$_2$-ZrO$_2$. Figure. 4 (b) ultraviolet spectrum images of Fe$_2$O$_3$-Al$_2$O$_3$-CeO$_2$-ZrO$_2$, Fe$_2$O$_3$-Al$_2$O$_3$-ZrO$_2$, Fe$_2$O$_3$-CeO$_2$-ZrO$_2$, Al$_2$O$_3$-CeO$_2$-ZrO$_2$.

Figure 4(b) shows the Uv images of Fe-Al-Ce-ZrO$_2$, Fe-Al-ZrO$_2$, Fe-Ce-ZrO$_2$, Al-Ce-ZrO$_2$, we can see in the figure, In the catalytic adsorption experiments of organic dye-Rhodamine B, with the same amount of Fe$_2$O$_3$-Al$_2$O$_3$-CeO$_2$-ZrO$_2$, Fe$_2$O$_3$-Al$_2$O$_3$-ZrO$_2$, Fe$_2$O$_3$-CeO$_2$-ZrO$_2$, Al$_2$O$_3$-CeO$_2$-ZrO$_2$ at the wavelength of 280 nm and 680 nm has a strong absorption peak can be seen from the figure from 0-135 min has the very big change during this period of adsorption is very fast, the adsorption time in subsequent agents may be close to saturation, adsorption intensity.

4. Conclusion

1) This experiment used the sol-gel method to get a higher degree of crystallinity of the powder, good particle purity, good dispersion, grain development integrity.

2) The experimental part of the component doped with metal elements, improve the performance of some aspects of ZrO$_2$.

3) Photocatalytic experiments indicated that, the doping metal elements can improve the performance of the material of photocatalytic degradation of methyl orange and Rhodamine B. for the doping of different metal components of the ZrO$_2$ series of catalytic materials, Fe$_2$O$_3$/Al$_2$O$_3$/CeO$_2$/ZrO$_2$ than other metal catalytic performance is better.

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