

## **Abstract**

Volatile organic compounds (VOCs) are mainly released into the atmosphere from industrial processes, transportation, and consumer products. VOCs represent a group of primary pollutants that also contribute to the formation of ozone in the troposphere. Abatement techniques for reducing VOC emissions from stationary sources include thermal oxidation (500-800 °C) and catalytic processes (room temperature - 500 °C). The most commonly used catalysts for VOC abatement are based on precious metals, such as gold, silver, palladium or transition metals and their oxides. Precious metal catalysts exhibit higher catalytic activity at lower temperatures (150-280 °C) compared to transition metal oxide catalysts (280-450 °C), which leads to lower operating costs. However, their drawbacks, including high cost, low availability, geographical distribution, and susceptibility to poisoning, have led to a rapidly developing field of transition metal and metal oxide-based catalysts with higher activity in lower temperature range.

This thesis is focusing on the development and study of composite bimetallic catalysts based on copper and iron oxides on a silicate and aluminate support and their performance in the oxidation of toluene in gas phase as a model VOC compound. The study showed that the Cu-Fe bimetallic catalyst's activity on a silicate support is strongly influenced by the ratio between the two metal oxides, and a synergistic effect is observed at a specific Cu/Fe molar ratio, leading to higher catalytic activity at lower temperatures. I wanted to achieve the observed effect on a aluminate carrier, which is more affordable and therefore more interesting for industrial use. To accomplish this, I first focused on the properties and origin of the aluminate support. I found that the properties and origin of the support significantly influence the activity of the Cu-Fe/Al<sub>2</sub>O<sub>3</sub> catalyst with a specific Cu/Fe ratio. Therefore, I delved into the preparation and influence of various aluminium oxide precursors and observed a strong influence on the Cu/Al<sub>2</sub>O<sub>3</sub> catalyst's activity. The activity is strongly influenced by the crystal structure of the support and the consequence it has on the structure, microstructure and surface of the catalyst. Different structures are achieved by using different precursors and transformation temperatures, as it can exist in several forms, from the thermodynamically least stable and widely used  $\gamma$ -Al<sub>2</sub>O<sub>3</sub> to the most stable  $\alpha$ -Al<sub>2</sub>O<sub>3</sub>.

Next, I determined the optimal concentration of CuO in Cu/Al<sub>2</sub>O<sub>3</sub> catalysts and investigated the influence of the Fe/Al ratio on the activity of Cu-Fe/Al<sub>2</sub>O<sub>3</sub> in the oxidation reaction of toluene as a model VOC pollutant. I prepared various composite catalysts, the supports of which have different origins, and observed an obvious improvement in the activity of the Cu-Fe/Al<sub>2</sub>O<sub>3</sub> composite catalyst. In that specific case, I studied the structure of this catalyst and attempted to explain the reasons for the enhanced activity and the emergence of a synergistic effect between Fe and Cu species and the respective carrier. I found that the presence of a specific amount of Fe and Cu (molar ratio Fe/Al =

0.007 and Cu/Al = 0.054) leads to the formation of an optimal concentration of Cu-O-Al and Fe-O-Al bridges, while an increase in iron oxide concentration or a change in the crystal structure of the support leads to a change in the ratio and consequently to a decrease in catalytic activity.

The most active catalyst prepared within the framework of this work, shows improved catalytic activity for toluene oxidation in the lower temperature range of 200-380 °C, due to the synergistic effect of metal oxide-metal oxide and metal oxide-support interactions. Understanding the functioning of this catalyst lead to the development of a catalyst with increased activity. I systematically examined the effects of the structures and properties of different aluminium oxides as carriers for this type of catalysts, and I demonstrated the importance of preparing or choosing the appropriate carrier in catalytic processes.