Chemical Engineering Journal 328 (2017) 1058–1065

Contents lists available at ScienceDirect

Chemical Engineering Journal

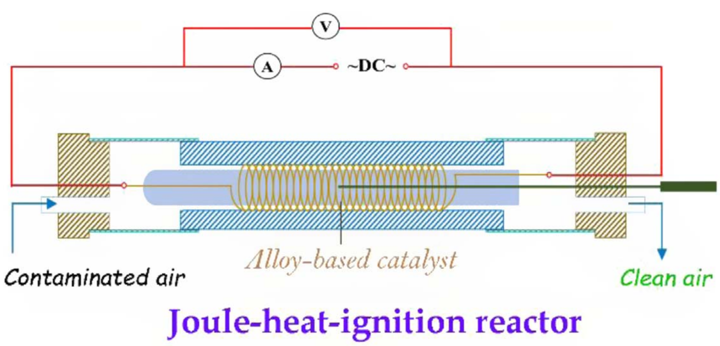
journal homepage: www.elsevier.com/locate/cej

Metallic-substrate-supported manganese oxide as Joule-heat-ignition catalytic reactor for removal of carbon monoxide and toluene in air

Jinjun Li*, Xiaofei Lu, Feng Wu, Shaoli Qin, Zhixiong You*

School of Resources and Environmental Sciences, Hubei Key Laboratory of Biomass-Resources, Wuhan University, Wuhan 430079, China

GRAPHICAL ABSTRACT



ARTICLE INFO

Keywords:
Volatile organic compounds
Catalytic oxidation
Manganese oxide
Zirconia
Washcoat
Structured catalyst

ABSTRACT

Structured catalysts and reactors have wide applications in environmental remediation and production of important energy-related chemicals. In thermal catalytic processes, external heater are often required to raise the temperature and ignite the reactions, which might lead to huge setups. Herein, we introduce a novel Joule-heat-ignition catalytic reactor. Using Fe-Cr-Al alloy as catalyst substrate, electric currents can pass directly through the substrate, generating Joule heat and bringing the catalysts to the target temperatures. Therefore, the setup can be simplified by omitting the additional heater; the heat produced inside the substrates can be transferred directly to the catalyst coat to achieve rapid ignition; and the reaction temperature can be flexibly controlled by adjusting the input power. In this work, we loaded manganese oxide catalyst onto an alloy wire and used it to build a Joule-heat-ignition reactor for the catalytic oxidation of carbon monoxide and toluene. The anodization pretreatment generated channels on the alloy surface, which effectively enhanced the catalyst loading. The use of alumina as a secondary support also favored catalyst loading and promoted catalyst dispersion. By adding proper amounts of zirconium, the mechanical stability of the catalyst layer increased. The Joule-heat-ignition catalytic system might provide some inspiration in related environmental catalysis.

1. Introduction

Monolithic catalysts and reactors contribute significantly to versatile heterogeneous reactions involved in environmental remediation and production of important energy-related chemicals, for example, complete oxidation of volatile organic compounds (VOCs) [1–3], decomposition or reduction of nitrogen oxide [4–6], purification of automotive exhaust gas [7], thiophene hydrodesulfurization [8], biodiesel synthesis [9], hydrogen production [10], and hydrocarbon production [11]. The well-established advantages of monolithic reactors over

* Corresponding authors.
E-mail addresses: lijinjun@whu.edu.cn (J. Li), zyou@whu.edu.cn (Z. You).

http://dx.doi.org/10.1016/j.cej.2017.07.128
Received 24 April 2017; Received in revised form 12 July 2017; Accepted 20 July 2017
Available online 21 July 2017
1385-8947/

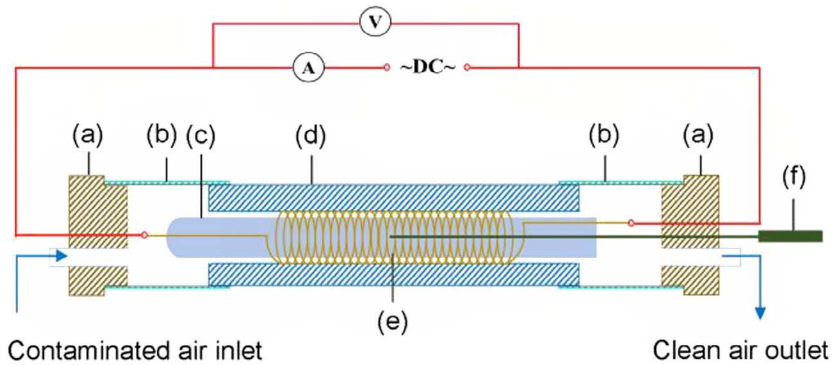


Fig. 1. Illustrative drawing of the Joule-heat-ignition catalytic reactor. (a) rubber stopper; (b) silicon tube; (c) small quartz tube; (d) big quartz tube; (e) alloy-based catalyst; (f) thermocouple.

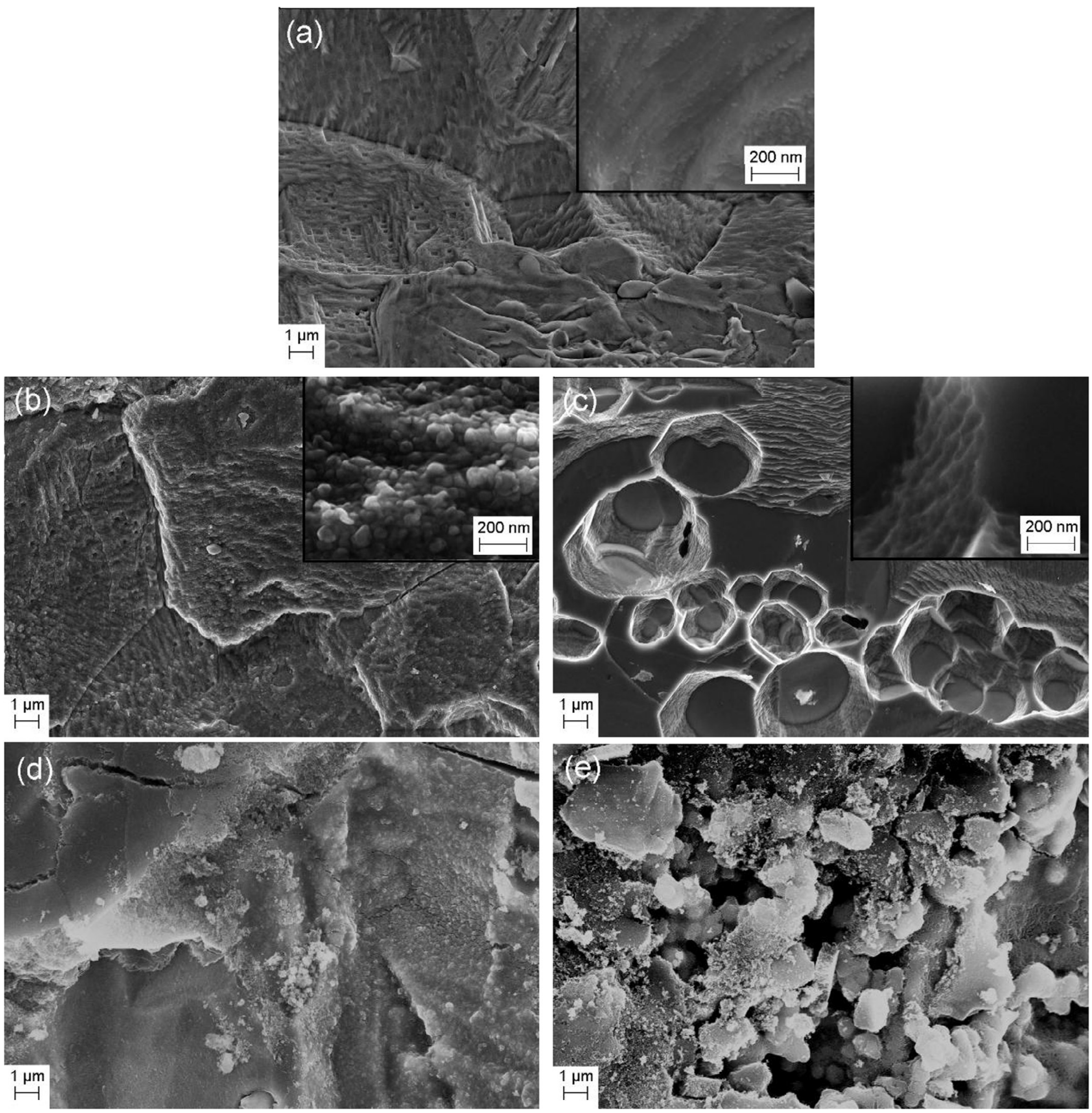


Fig. 2. Scanning electron microscopy images of the surfaces of the alloy substrates and the supported manganese oxide catalysts. (a) FeCrAl-par; (b) FeCrAl-cal; (c) FeCrAl-anod; (d) Mn/FeCrAl-cal; (e) Mn/FeCrAl-anod.

conventional pellet-catalysts-contained reactors include high geometric surface area, low pressure drop, faster mass and heat transfer, ease of product separation, and ease of scale-up [12–14]. The applications of metallic monoliths as catalyst substrates, including aluminum [11,15,16], stainless steel [8,17], and alloys [18–20], have attracted great interest because they exhibit good mechanical stability and high thermal conductivities [17,21,22], allow facile fabrication into various shapes and structures [8,11,14], and can be easily recycled [23].

In such heterogeneous catalytic systems, the maintenance of catalyst beds at appropriate temperatures is decisive for the achievement of the desired conversion of reactants and selectivity of products. For example, when removing VOCs from air by catalytic oxidation,