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Synthesis and characterization of alumina-coated aluminum sponges manufactured by sintering and dissolution process as possible structured reactors

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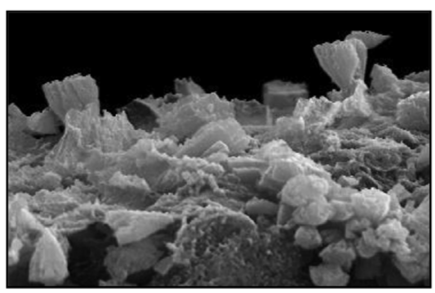
HIGHLIGHTS

- An efficient method for manufactured of aluminum sponges is reported.
- Methods for productions of superficial Al_2O_3 are studied.
- Al_2O_3–Al sponges could be used as structured reactors.

GRAPHICAL ABSTRACT



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ABSTRACT

Al_2O_3–Al sponges were manufactured by sintering and dissolution process with the aim of using these materials as structured catalytic reactors. For this purpose, several synthesis conditions were examined for the design of the cellular material, such as: particle size of NaCl, weight fraction of Al, compaction pressure, and sintering temperature or time. An alumina layers was grown on top of the aluminum surfaces during both: sintering and thermal treatment. The obtained results showed that the synthesized materials could be promising as structured reactors for endothermic or exothermic reactions.

1. Introduction

Industrial catalysis employs usually porous catalysts, *e.g.*, pellets, spheres or extrudates [1]. However, fuel processing [2] and some single/multiphasic reactions [2–6] often require a modification of the shape of the catalyst in order to improve the processes. Therefore, the science of the structured catalysts, *e.g.* monoliths, foams and membranes, has gained importance in the last decades [7,8].

Structured catalysts present many advantages, including low pressure drops, high geometric areas, possibility to induce turbulent flow (depending on design) and improved heat transfer [9].

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These characteristics are very important in industrial processes in which pressure drop, diffusional resistance and poor heat transfer properties generate some serious problems. Typical examples for this situation include reactions that are highly endothermic (*e.g.* steam reforming) or exothermic (*e.g.* selective hydrogenation or ethylene oxidation) [10,11]. In this regard, so-called metallic foams have received considerable attention. Foams are cellular materials consisting of dispersions of gas in liquid or solid, and which strictly speaking show only closed cells. This definition has been relaxed to include, in the case of metal or ceramic "foams" interconnecting open cells. However, it has been proposed that materials such as these, where "space is filled by pieces of metal that form a continuous network and co-exist with a network of empty space which is also interconnected" [12] should be named (metal) sponges. In the case of ceramic and metallic materials, technological applications had been few, generally as heat exchangers [13] but in the last decades new applications in catalytic processes have been proposed, for example: oxidation of ammonia [14], neutralization of exhaust gases during internal combustion engines [15], selective oxidation of alcohols [16], volatile organic compounds oxidation [17], among other reactions.

Sintering and dissolution process (SDP) [18] is a route based on powder metallurgy for fabrication of aluminum porous materials, described as aluminum "foams". In this process, an intimate mixture of aluminum and a soluble powdered substance are compacted and sintered. Then, the sintered material is placed in water to remove the soluble particles and thus porous aluminum materials are obtained [18]. This methodology has many advantages, *e.g.*: (i) the fully interconnected porosity can be easily and accurately controlled by adjusting the proportion of Al/soluble powder and selecting the appropriate soluble powder [19,20]; (ii) special geometries, *e.g.*, thin sheets of approximately 1-mm thickness can be obtained using soluble particles of several hundred micron size [21]; (iii) the soluble powders in the sintered mixture can be easily removed just by placing the sintered mixture in water and, (iv) the materials present reproducible properties.

Due to the many advantages presented by the structured catalysts in the industrial processes and the physicochemical properties exhibited by the aluminum "foams" manufactured by SDP, the aim of this contribution is to study the effects of some synthesis parameters on the formation of alumina over the surface of aluminum sponges.

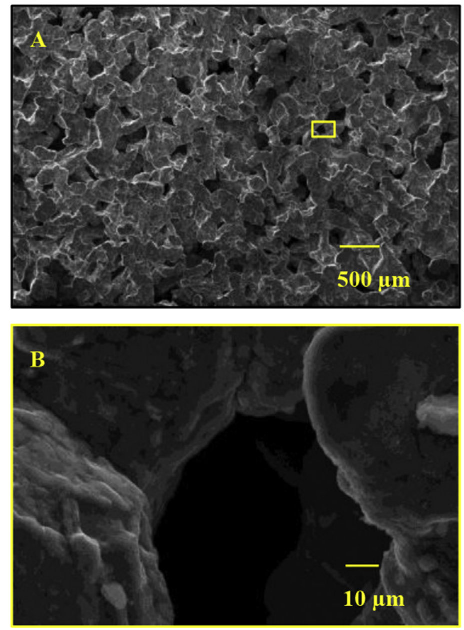

Fig. 2. (A) Representative SEM image of Al_2O_3–Al sponge, and (B) Magnified SEM image of the inset. $t_{p\text{-}NaCl}$ = 150–212 µm, f_{Al} = 0.50, P_c = 15 MPa, T_s = 640 °C and t_s = 2 h.

2. Materials and methods

2.1. Synthesis of aluminum sponges

The synthesis of the metallic sponges was carried out according to an experimental procedure described elsewhere (Fig. 1) [18,22].

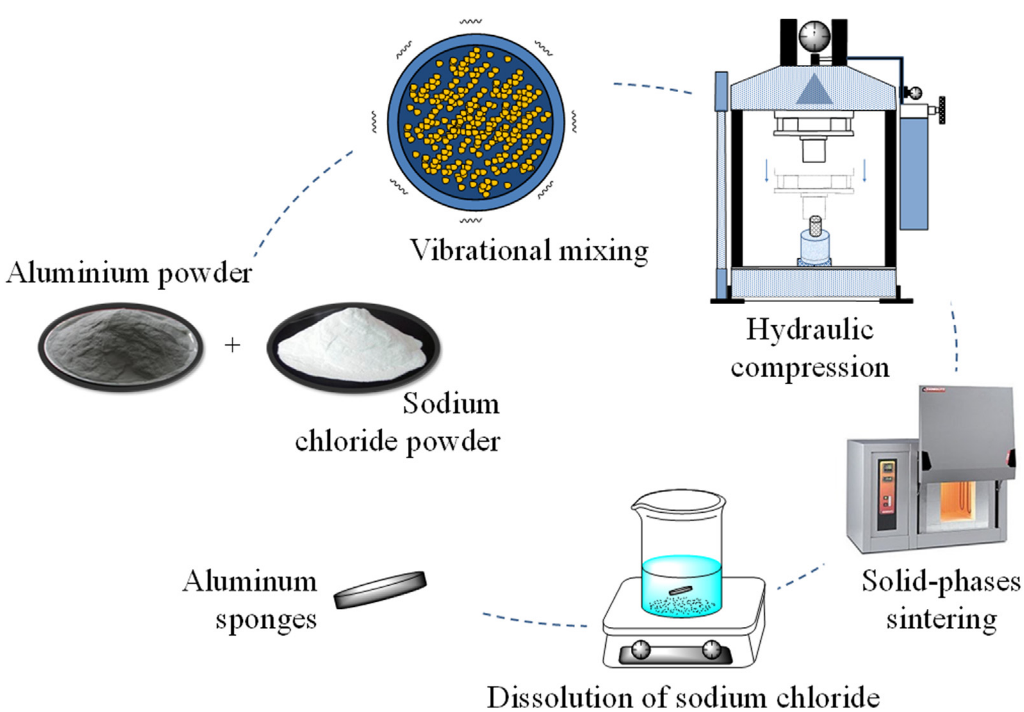

Fig. 1. Manufacture of aluminum sponges by sintering and dissolution process.