

NANOSCALE AND NANOSTRUCTURED
MATERIALS AND COATINGS

An Investigation of Surface Transformations of Nickel Highly Porous Cellular Material with an Applied Alumina Layer during Its Synthesis

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Abstract—For the development of a composite of nickel highly porous permeable cellular material with an applied secondary layer of alumina, transformation of the surface of the highly porous permeable cellular material is investigated at the stages of electrochemical synthesis and stages of alumina application on its surface. Etching of foamed-polyurethane bondings with 20% potassium hydroxide solution is accompanied by destruction of their surface and the formation of defective areas in the form of hillocks, hollows, and other imperfections acting as tin-hydroxide crystallization nuclei. Application of tin chloride with its subsequent hydrolysis leads to the formation of hemispherical tin-hydroxide grains with a mean size of about 80 nm uniformly distributed over the surface. The optimum values of temperature (50°C), solution pH (9–10), and electroless-nickel-plating duration (20–30 min), providing the formation of a conductive sublayer of chemically reduced nickel, are established. Nickel electroplating for 30 to 35 h at a current density of 0.1 A/dm² yields high uniformity of a metal coating of foamed-polyurethane bondings across the thickness both in the bulk and at the outer periphery of a sample of 30 μm. A composite of nickel highly porous permeable cellular material with an applied alumina secondary layer is synthesized. The latter shows a high degree of uniformity and uniform thickness over the whole surface of bondings of the obtained composite.

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INTRODUCTION

Industrial processes of purification of C₂–C₅₊ hydrocarbon fractions from acetylenic and diene hydrocarbons for subsequent polymerization are carried out by means of selective hydrogenation in reactors with a nonregular granular catalyst bed [1]. The catalyst is palladium dispersed at an alumina surface [2–7]. The employed catalyst should enjoy high activity providing a residual content of acetylenic and diene compounds in the reaction products up to ~0.0001 wt %, high selectivity (for hydrogenation of acetylenic and diene hydrocarbons into corresponding olefinic compounds), and long catalyst lifespan due to the low capability to initiate formation of oligomers deactivating the catalyst [8, 9].

Granular catalysts with a nonregular bed in the form of spheres, cylinders, or other geometric shapes applied currently in industrial processes of selective hydrogenation of acetylenic and diene hydrocarbons suffer from the following drawbacks.

– Unsatisfactory heat and mass transfer leading to local overheating and nonuniformity in distribution of a hydrocarbon flow across the catalyst-bed cross section. This accelerates side reactions of deep hydrogenation of acetylenic and diene hydrocarbons into alkanes and oligomerization processes, impairing selectivity to the main component.

– Diffusion limitations due to the active component occurrence deep in the support grain. This results in low efficiency of utilization of the active component and proceeding of side reactions of deep hydrogenation of acetylenic and diene hydrocarbons into alkanes, reducing the catalyst activity and selectivity.

Against this background, in addition to optimization of the catalyst chemical composition with variation of characteristics of the active component and support, the issue of importance in the development of the catalyst is the choice of the geometry of the support and its shape and texture characteristics providing efficient heat and mass transfer, low pressure drop of the catalyst bed, and optimum distribution of the active component with its high accessibility to reacting molecules.

These requirements are readily met by catalysts based on a new material in the form of a highly porous permeable cellular material (HPCM), which is a cellular metal framework with a secondary layer of alumina attached to it. In comparison with conventional granular aluminas, these materials have a high porosity (97–80%), a permeation coefficient that is one to five orders of magnitude higher, enhanced heat and mass transfer, and availability of the active component to reacting molecules, which eliminates local overheating and nonuniformity of feedstock distribution