Growth of copper particles in a Cu/ZnO methanol catalyst

M.C. Carroll a,*, B. Skrotzki a, M. Kurtz b, M. Muhler b, G. Eggeler a

a Institut für Werkstoffe, Lehrstuhl Werkstoffwissenschaft, Ruhr-Universität Bochum, D44780 Bochum, Germany
b Institut für Technische Chemie, Ruhr-Universität Bochum, 44780 Bochum, Germany

Received 12 November 2002; received in revised form 4 June 2003; accepted 12 June 2003

Abstract

The growth and coarsening of copper particles in a Cu/ZnO catalyst powder is evaluated through transmission electron microscopy and associated composition maps. The observed growth rate of discrete copper particles on the zinc oxide support structure follows a parabolic shape, with measured particle diameter $d \propto t^{1/2}$.

Keywords: Copper; Scanning/transmission electron microscopy (STEM); Coarsening; High-angle annular dark field imaging (HAADF); Catalysis

1. Introduction

An important industrial catalyst for the energy-efficient production of methanol (CH$_3$OH) is metallic copper dispersed on a support structure of zinc oxide (Cu/ZnO) [1]. As the catalytic process requires an effective surface area in order to induce the combination of synthesis gases in the production of a target molecule, changes in the surface area of the major elemental contributor to catalytic activity is necessarily an important factor in the useful life of the catalyst. As the synthesis feed gases CO/CO$_2$/H$_2$ flow over and hence come into direct contact with the porous catalyst structure, an adsorption and ensuing reaction occurs on the metallic copper surface that produces the methanol molecule. This target molecule undergoes a subsequent desorption from the surface and is collected in bulk further downstream in the production flow system. Studies involving the changes in effective copper surface area have thus far been evaluated in terms of catalytic efficiency by way of chromatography measurements of effluent gases (N$_2$O reactive frontal chromatography) [2]. No systematic studies have focused on the direct observation of copper morphology as a result of the exposure of the catalyst to elevated temperatures. It should be noted that copper surface area is not the lone factor in determining the catalytic performance of the Cu/ZnO system [3,4], but is nonetheless of direct interest in understanding the evolution of the catalyst under applied industrial conditions.

2. Experimental conditions

The experimental elevated temperature conditions for Cu/ZnO catalyst exposure were achieved...