The generality of surface vanadium oxide phases in mixed oxide catalysts

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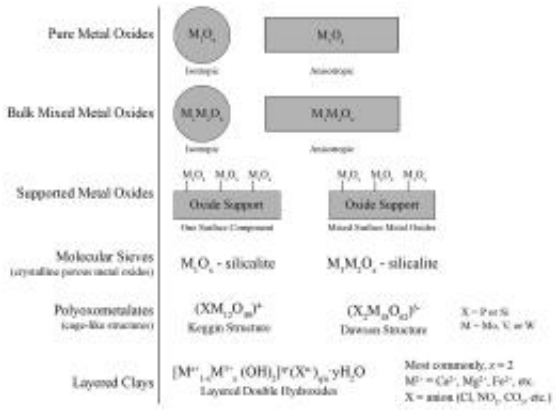

Different types of metal oxide materials employed as oxidation catalysts. (Chris Keturakis/Lehigh University)

In the spirit of the physicist's pursuit of a 'theory of everything,' Israel E. Wachs, the G. Whitney Snyder Professor of Chemical Engineering at Lehigh University, has published a paper entitled "The generality of surface vanadium oxide phases in mixed oxide catalysts."

It is common knowledge throughout the heterogeneous catalysis community that reactions take place at the surface of metal oxide catalysts, rather than in the bulk (inside) of the catalyst. Thus, the goal of fundamental catalysis research focuses on developing structure-activity relationships based on the surface metal oxide phases present, ultimately allowing for the rational design of improved heterogeneous catalysts

from the ground up.

This paper discusses research on vanadium oxide-containing catalysts performed in the past 30 years using a variety of techniques: IR and Raman vibrational spectroscopies, CH_3OH-temperature programmed surface reaction (TPSR) spectroscopy and steady-state oxidation reactions. The paper shows that surface VO_x phases, two-dimensional vanadium oxide overlayers, are a general phenomenon in vanadium-containing mixed oxide catalytic materials and that they also control the catalytic properties.

Mixed oxide catalysts consist of many different metal oxide arrangements, as depicted in the figure. Bulk oxides consist of either pure oxides (e.g., V_2O_5) or mixed oxides that can exist as either stoichiometric compounds (e.g., $FeVO_4$) or as solid solutions (e.g., $V_xTi_{1-x}O_2$). Supported metal oxides involve the impregnation of metal oxides onto high surface area supports (e.g., pure oxides, mixed oxides, zeolites, or molecular sieves). Polyoxometalate (POM) clusters are nanometer sized mixed oxide clusters consisting of a central XO4 unit (PO_4, SiO_4, etc.) that are surrounded by 12 or 18 $O{=}MO_5$ units (M = V, Mo, W, Cr, etc.).

Supported Metal Oxides

On pure oxide supports, isolated $O{=}VO_3$ species are almost exclusively present at low surface coverages (