New Catalysts with Commercial Potential Based on Gold

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Introduction

Immediately after its discovery some 20 years ago, catalysis by supported nanoparticulate gold was explored by only a few groups of researchers and was viewed rather sceptically by the catalysis research community as a whole. However, interest during the present century has increased dramatically and there is evidence from the rapid expansion in the number of papers and patents published on the topic that there is strong academic and commercial interest [1]. Moreover the interest extends into all areas of catalysis, including gas and liquid phase heterogeneous and homogeneous catalysis. Alloys of gold with platinum group metals [PGMs] are giving even more promising results [2].

As a result, commercial applications are foreseen for gold catalysts in pollution control [3,4], fuel cells [5], chemical processing [6] and sensor applications [7]. In some of these application areas gold is now in competition with systems based on the PGMs, but its major advantage is its uniqueness, particularly with respect to its activity at ambient temperatures and below and that some chemical transformations have only been performed using gold catalysts. The room temperature activity gives new opportunities for air and water purification systems.

Commercial Processes

Gold plays an important role in the manufacture of vinyl acetate monomer using Pd-Au catalysts. There is a need for VAM for large scale uses in emulsion-based paints, wallpaper paste and wood glue. There are a number of well-established commercial processes for the manufacture of vinyl acetate monomer from ethene, acetic acid and oxygen using Au-Pd catalysts [8,9]:

$$CH_2 = CH_2 \quad + \quad CH_3CO_2H \quad + \quad ½\,O_2 \;\rightarrow\; CH_2 = CH.O_2CCH_3 \; + \; H_2O$$

The chemical technologies for these processes were developed in the 1960s, and have been operated commercially since the 1970s and today VAM is produced with high selectivity and high space time yield in many plants around the world. Worldwide VAM capacity is currently ca 5 million metric tonnes per year, and is expanding: 80% of which is produced via the ethene route. VAM catalyst consumption is several hundred tonnes per annum. Potassium acetate is widely used as a co-catalyst and BP have recently introduced a fluidized bed process [10]; the other processes use fixed beds. The catalyst is durable and typically lasts for between one and two years. The presence of Au leads to a 3-fold increase in space time yield compared with use of Pd alone (150 vs 50 g/l/h) and the presence of gold clearly has commercial importance [11]. The bulk alloy is $Pd_{0.8}Au_{0.2}$ but on the surface the composition is richer in gold, $Pd_{0.45}Au_{0.55}$ [12].

Recently a liquid-phase air-oxidation process has been developed by Nippon Shokubai in Japan for the one-step direct production of methyl glycolate from ethylene glycol and methanol using a gold catalyst.:

$$HOCH_2CH_2OH \quad + \quad MeOH \quad + O_2 \quad \rightarrow \quad HOCH_2COOMe \quad + 2\,H_2O$$

Methyl glycolate is used as a solvent for semi conductor manufacturing processes, as a building block for cosmetics and as a cleaner for boilers and metals.

A pilot plant demonstration, with a capacity of tons per month, successfully showed that this can be run as a clean and simple continuous process with the product obtained in high purity. The catalyst used for this reaction, as given in the associated published paper, was $Au\text{-}Pb/Al_2O_3$ and the conditions used were 90 ^{o}C and 0.1 – 5 MPa [13-15]

Progress in applications in the pollution control and fuel cell areas has been assisted by availability of 20 kg quantities of gold on titania, zinc oxide and alumina made by Project AuTEK at Mintek in South Africa [3], and by stable catalysts made on a substantial scale using physical vapour deposition by 3M [16,17]. Stability in liquid phase chemical processing has also been established for glucose to gluconic acid oxidation at the Federal Agricultural Research Centre (FAL) in Germany where very high activities and selectivities were maintained in a continuous reactor for 110 days[11].

Significance

Whereas traditionally gold was regarded as a poor catalyst, largely because its catalytic properties had only been examined in the bulk, supported nanoparticulate gold has now been shown to be very active in many reactions, some of which have significant commercial potential [1,3] .

References

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