

Progress Towards Producing Stable Gold Catalysts

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Introduction

Very significant advances in our knowledge of the scope and capability of catalysis by supported nanoparticulate gold have been made since this new phenomenon was discovered in the 1980s [1], and as a result many new opportunities for commercial applications are foreseen [2]. These are likely to be in pollution control [3], fuel cells [4], chemical processing [5] and sensor applications [6]. Use of gold catalysts is foreseen in the fuel cell itself and in purification of the hydrogen fuel [7]. In some of these application areas gold is now in competition with systems based on the PGMs, but gold's major advantage is its uniqueness, particularly with respect to its activity and selectivity at ambient temperatures and below and that some chemical transformations have only been performed using gold catalysts. The principal improvement required in the performance of gold catalysts before they find widespread use is increased durability in the gas phase. However significant progress is now being made and the purpose of this paper is to provide some indications of this.

Durability in the Liquid Phase

Gluconic acid is an important food and beverage additive, and it is also used as a cleansing agent and is made on the 60,000 tonnes per annum scale. Work at the Federal Agricultural Research Centre, Braunschweig, Germany has demonstrated that for the oxidation of glucose to gluconic acid high activity and selectivity can be maintained using a stirred tank reactor for up to 110 days [8], with gold catalysts prepared by deposition precipitation with urea and incipient wetness methods. 3.8 tonnes of gluconic acid can be obtained per gram of gold in 110 days [9]. The catalyst was thus shown to have excellent long term stability, proving that durability is not a problem for these gold catalysts in the liquid phase. Südzucker Akt. [10] have filed a patent covering use of gold catalysts for this conversion.

Chlorinated hydrocarbons are widely used and are major pollutants of groundwater. Recent research at Rice University, USA has revealed that bimetallic gold-palladium nanoparticles provide an active catalyst to break down trichloroethene (TCE), one of the most common and poisonous groundwater pollutants. TCE has been linked to liver damage, impaired pregnancy and cancer. The new catalyst works better than the carbon filters currently in use because it converts the TCE into non-toxic components instead of just trapping it in the filter [11]. It also performs better than iron and can be used repeatedly. Palladium catalysts have previously been shown to remove trichloroethene from water effectively at room temperature using hydrogen, which converts it into ethane and HCl. When small amounts of palladium atoms are coated onto gold nanoparticles, the palladium catalytic activity increased dramatically by two orders of magnitude (from 47 L/gPd/min to ~2300 L/gPd/min) and this was an exciting surprise [11]. The results show promise for the maintenance of activity in the liquid phase.

Durability in the Gas Phase

In the 20 years since Prof. Haruta's initial dramatic breakthrough on the low temperature oxidation of CO with oxide-supported nanoparticulate gold, there has been much effort on optimizing solution methods for preparing gold catalysts. The 3M company in Minnesota, USA have now found that very active gold nanocatalysts can be prepared via physical vapour deposition (PVD) using equipment originally designed for manufacturing electronic printed circuits[12] on a wide range of supports, including some that are water soluble. The method provides the advantages of low cost, superb reproducibility, removal of the need for washing and thermal treatment steps, and there are no toxicity hazards. It takes only 2 – 3 h to make 400 ml catalyst and there is minimal loss of gold. Such 0.7% Au/TiO₂/C catalysts are stable for two years if kept in a canister for use in respirators. Such a storage life is important for such life-critical applications.

Gold catalysts are highly active for the oxidation of many components in ambient air at low temperatures, particularly carbon monoxide and nitrogen-containing malodorous compounds such as trimethylamine. This ability offers scope for applications related to air quality improvement and control of odours, be they in buildings, transport or other related applications such as gas masks. This a very important issue and the scope here for commercial applications is very large: significant patents have been published [1,2]. It is particularly advantageous that gold's catalytic activity is often promoted by moisture. Prototype products that use gold catalysts for low temperature air quality control are now appearing in the public domain.

Significance

Durability has been established for gold catalysts for operation in both liquid and gas phase applications. Some of these applications use gold's unique ability to operate at ambient temperatures and gold catalysts will be used in pollution control and fuel cells, as well as chemical processing. Preventing poisoning and establishing durability in use at room temperature is new for catalysis as a whole, but use of mixed oxide supports increases durability and catalyst activity can be regenerated using photochemical irradiation.

References

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