264a Internal Combustion Engine to the Hydrogen Economy: New Catalysts and Reactor Designs

R. J Farrauto

It has been over 30 years since the first catalytic converters were installed into the exhausts of internal combustion engines in response to the Clean Air Act of 1970. This quickly led researchers to look for active and durable catalysts for the removal of carbon monoxide (CO) and unburned hydrocarbons (UHC) with the most likely candidates being Group VIII transition base metal oxides and precious metals. The latter were clearly more active but considerably more expensive and rare compared to the base metals.

Automobile manufacturers established a series of performance criteria simulating the expected duty cycle of the engine and, hence the catalysts. The catalyst had to function by promoting the oxidation of CO and UHC for 50,000 miles after experiencing exhaust temperatures in excess of 800oC in the presence of high steam concentration (i.e.>5%) and sulfur levels exceeding 100 ppm. Octane-enhancing lead (Pb) was already regulated to be removed from gasoline given its known poisoning effect on people and catalysts. The Research was intense as it was determined that precious metals supported on stabilized gamma alumina would be the primary catalyst of choice. After a few years, the particulates were replaced by ceramic monoliths as supports primarily due to attrition problems. A brief history of why base metal oxides failed for gasoline-fueled vehicles will be discussed along with the current state of the art for modern three way converters.

In 1994, when controlling diesel emissions became law for heavy-duty diesel trucks in the US, it was natural to apply gasoline catalyst technology. Ironically, non-precious metals and not precious metals were not found to be the most cost-effective solution. Diesel exhausts contain solid, liquids and gases and, thus an entirely new approach and materials were needed. A brief history of the development of non-precious metal-containing diesel catalysts and their superiority over precious metals for trucks will be presented. Precious metals, in combination with zeolites, did find a place for controlling diesel emissions for passenger vehicles.

Today, as we experience soaring fuel costs, unacceptably high greenhouse gas emissions and the geopolitical consequences of oil dependence, it is natural to ask the question; "Is there an alternative to the internal combustion engine and petroleum based-fuels for primary power generation?" Some forward thinking automobile manufacturers are saying yes to the future use of the fuel cell in the emerging hydrogen economy.

The long-term goal for the hydrogen economy is to power an automobile fuel cell with hydrogen produced from the sun, wind or other natural source of energy. The primary driving force is decreased dependence on liquid petroleum but with the positive consequence of eliminating primary pollutants and greenhouse gas emissions. Many technological advances are required especially in the durability of the fuel cell as well as safe and efficient storage of hydrogen on-board and an infrastructure of hydrogen fueling stations. Although progress is being made many believe this technology is 10-20 years in the future.

Residential and portable power fuel cells get little media attention but are clearly milestones along the path to the hydrogen economy. Applications for on-site hydrogen generators to be used for fueling stations and small-scale industrial uses, i.e. metal processing, hydrogenation reactions, cooling, etc., are also emerging. Although large-scale production of hydrogen is well known, it does not scale down economically for distributed applications. Consequently, new catalysts and processes for smaller scale generation of hydrogen are being developed worldwide. We are once again facing the challenge of deciding which Group VIII materials will be used; base metal or precious metals. It is generally accepted that precious metals will be necessary as electro-catalysts for the low temperature fuel cells (PEM = proton exchange membrane) but the argument for which catalysts will be used to generate the hydrogen is not yet resolved.

At Engelhard, we believe precious metals supported on monoliths, both ceramic and metal, will be the technology for future generations of fuel processors integrated to low temperature fuel cells. They are durable against start / stop experienced in daily operations, especially in Japan. The highly active catalyst washcoat deposited on the walls of monolithic structures, such as heat exchangers, permit reductions in reformer size by 10 times that of base metal systems. They offer greater structural stability, tolerance to some poisons, rapid response to transient operation and lower pressure drop. All of these properties add up to a robust, reliable and highly durable reformer system capable of meeting at least a 40,000-hour life requirement for residential fuel cell systems. When precious metal recycle is considered the solution offers economic viability.

Today's lecture will provide an overview of some of the critical catalyst and reactor design issues that are being addressed to move towards commercialization of a variety of fuel cell applications with special emphasis on the hydrogen infrastructure. The limitations of traditional base metal and the use of precious metal monolithic catalysts for hydrogen generation will also be discussed.