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New Platinum-Based Lean NOx Conversion Strategy

The introduction of increasingly stringent environmental legislation brings benefits to our quality of life, and presents challenges to catalytic chemists, who are required to develop novel solutions to enable the new legislation to be met. Within the automotive area, new legislative limits to exhaust pollutants mean that it will soon be necessary for the catalytic convertors on diesel vehicles to additionally remove significant concentrations of nitrogen oxides, NOx, from the exhaust feed, besides the oxidation functions for carbon monoxide, CO, and hydrocarbon which they already perform.

Diesel engines are extremely fuel-efficient. This is achieved by ensuring that combustion occurs under highly oxidising conditions, and results in a strongly oxidising gas feed which needs to be treated using a catalytic convertor. Under such highly oxidising conditions the oxidation of the unburnt hydrocarbons to CO_2 and H_2O and of the CO to CO_2 is relatively straightforward. However, reducing NOx to N_2 under such conditions is very difficult.

The major breakthrough in automotive NOx control under very oxidising conditions was reported simultaneously by the Held group in Germany (1) and by the Iwamoto group in Japan (2). These workers independently showed that significant quantities of NOx could be reduced to N_2 under highly oxidising conditions using a catalyst of copper incorporated into ZSM-5 zeolite. Others have characterised the mechanistic aspects of the reaction over Cu/ZSM-5 (for example (3)), and have shown that the major role of the copper is to oxidise NO to NO_2. This subsequently reacts with hydrocarbon-derived species activated by the surface of the zeolite.

The copper catalyst can only be used at relatively high temperature (350–550°C), and it is not particularly stable. The conversion of NO to NO_2 over copper is poor at the low temperature end of this range, so its performance here is nowhere near as good as that of platinum. At high temperature the NO to NO_2 reaction becomes limited by thermodynamics and both copper and platinum catalysts then become equivalent in their NO oxidation performance.

Now, Iwamoto has used the mechanistic information/approach to develop a highly efficient NOx conversion catalyst system capable of operating at low temperatures (4). The strategy uses two separate catalysts – one to oxidise the NO into NO_2 and the other to reduce this NO_2 into N_2. Iwamoto has shown that platinum incorporated into ZSM-5 zeolite is a highly efficient NO oxidation catalyst and this catalyst is used to perform the first step in the conversion process. The second step is carried out using indium incorporated into ZSM-5 zeolite. Since there is only a small amount of unburnt hydrocarbon in the exhaust stream of a diesel vehicle, additional hydrocarbon needs to be injected to provide the reductant to achieve significant NOx conversions.

Position of Hydrocarbon Injection

Platinum is an excellent oxidation catalyst, which means that if the hydrocarbon were injected in front of the platinum catalyst, substantial quantities would be converted over the platinum, thereby lowering the hydrocarbon concentration reaching the indium catalyst. Iwamoto proposes that this additional hydrocarbon injection should instead occur between the two catalysts: that is, after the platinum catalyst and before the indium catalyst, thus ensuring that the indium reduction catalyst sees enough hydrocarbon to effect the reduction of the NO_2 generated over the platinum catalyst.

This approach is the latest in the long line of platinum-based strategies developed to remove NOx under highly oxidising conditions. Within industry and academia, platinum-based work is continuing to advance the technology further to ensure that future environmental legislation can be met.

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