An investigation on using photocatalysts in catalytic converter

Background

Currently, catalytic converters using noble metals (eg. platinum) are installed in motor vehicles to remove harmful exhaust products from the engine (eg. NO_x,CO,VOCs). However, it has many restrictions, such as high cost and not working at low temperatures (It won't start working until it reaches 260℃).

Aim

This investigation aims at discovering the possibility of using photocatalysts, a cheap and abundant resource, to replace noble metals in catalytic converters, as well as comparing the effectiveness of different photocatalysts. We have chosen TiO_2 and ZnO to be the photocatalysts for comparison.

Principle of photocatalysts

In a photocatalytic reaction, a photocatalyst (eg. TiO_2) absorbs photons from a light source and its electrons are excited from valence band to conduction band, generating an electron-hole pair. The electron-hole pair then generates hydroxyl radicals(•OH). The hydroxyl radicals have a high tendency to gain electrons and is highly oxidizing.The •OH can therefore carry out a redox reaction with other substances.

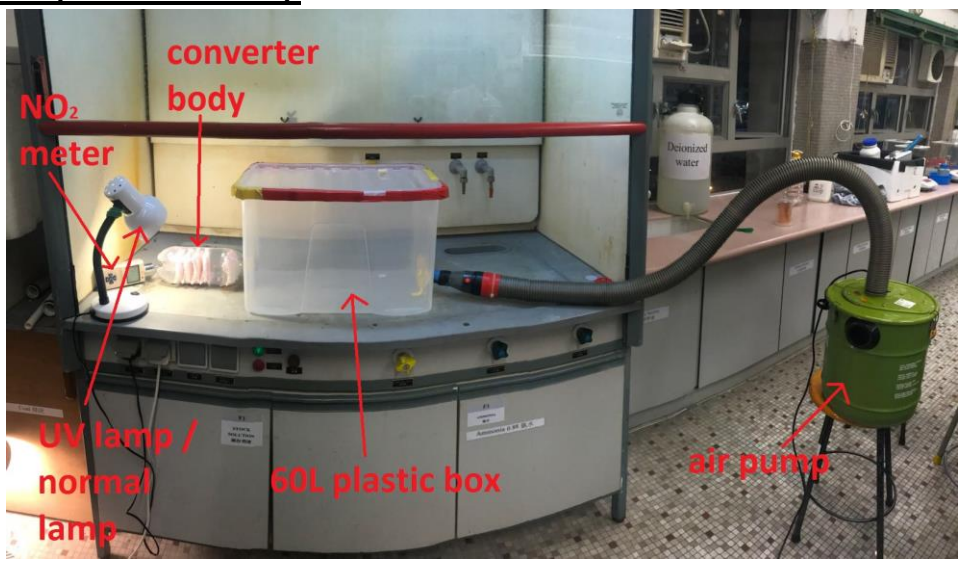
Purpose of the experiment

1. To test whether photocatalyst can reduce the NO_2 level at room temperature
2. To test whether UV is essential for the converter to work (UV light vs normal light)
3. To compare the effectiveness of different photocatalyst (TiO_2 vs ZnO)

Hypothesis

1. Both TiO_2 and ZnO can reduce the NO_2 level coming out of the converter only under UV illumination.
2. TiO_2 can remove NO_2 gas more effectively than ZnO.

Diagram of the experimental set-up

3. 

Results

	TiO_2	ZnO	Control
Normal Light (Average Concentration) (ppm)	**12.05**	**11.75**	**11.82**
UV Light (Average Concentration) (ppm)	**10.37**	**10.64**	**12.47**
% decrease under UV light (compared with control)	**16.84%**	**14.68%**	**/**

Interpretation of results

It is found that both the TiO_2 and ZnO set-up can reduce the concentration of NO_2 gas passing through it only under UV illumination but not normal light. The TiO_2 set-up has an efficiency of 16.84% whereas the ZnO set-up has an efficiency of 14.68%.

All of the experiments are carried out at room temperature, which shows that the TiO_2 set-up can remove NO_2 from exhaust gas even at low temperature, which traditional catalytic converters are not yet effective.

Discussion

A. Efficiency of different photocatalysts

The TiO_2 set-up has an efficiency of 16.84% whereas the ZnO set-up has an efficiency of 14.68% under UV illumination. The results prove that the TiO_2 set-up is more effective than the ZnO set-up by 2.16%.

B. Efficiency under low temperature

Traditional catalytic converter requires a high temperature (At least 260℃) to work, which is one of its limitations. This implies that when the engine has just been activated, the exhausted gas will not be treated as the converter hasn't been heated up and is not ready.

For the experiment, it is carried out at room temperature, which is far lower than the required temperature of a traditional catalytic converter. The result shows that the set-up is still efficient under a low temperature (room temperature).

This means that catalytic converter with photocatalyst doesn't need a warm-up time, and it can work at anytime after an engine is activated. Therefore, all the exhausted gas can be treated.

C. Cost

Cost of photocatalyst vs catalysts used in traditional catalytic converter (platinum & palladium & rhodium)

	ZnO	TiO_2	Traditional Catalytic Converter
cost(HK$/g)	0.560	0.960	/
Amount of catalyst used (g)	80	80	/
Cost (HK$/converter)	**45.7**	**76.8**	**670**

The total cost of the converters are not compared because the material used for the body of the converters are not comparable. Therefore, only the costs of the catalysts are compared.

The cost of noble metals (platinum & palladium & rhodium) in catalytic converters are estimated to be HK$670. For the TiO_2 set-up, the cost of TiO_2 is only HK$76.8 while the one of ZnO is HK$45.7. The cost of catalysts of TiO_2 converter and ZnO converter are only 11.5% and 6.8% of the cost of noble metal catalysts in traditional catalytic converter respectively.

Conclusion

To conclude, TiO_2 and ZnO can reduce the concentration of NO_2 gas through redox reaction. TiO_2 and ZnO are possible materials to be used in a catalytic converter which can overcome the problems of traditional catalytic converters ----- high cost and not working under low temperature. TiO_2 is also found to be more efficient than ZnO, and UV light is essential for the photocatalytic reaction to take place.Although the efficiency of the two set-ups are too low to be used as actual catalytic converters, further research on enhancing the efficiency can be done to make this device practical.