Effect of UV–visible Light Excitation Wavelength on the Photocatalytic Activity of TiO_2-doped with Noble Metals Towards CO_2 Hydrogenation

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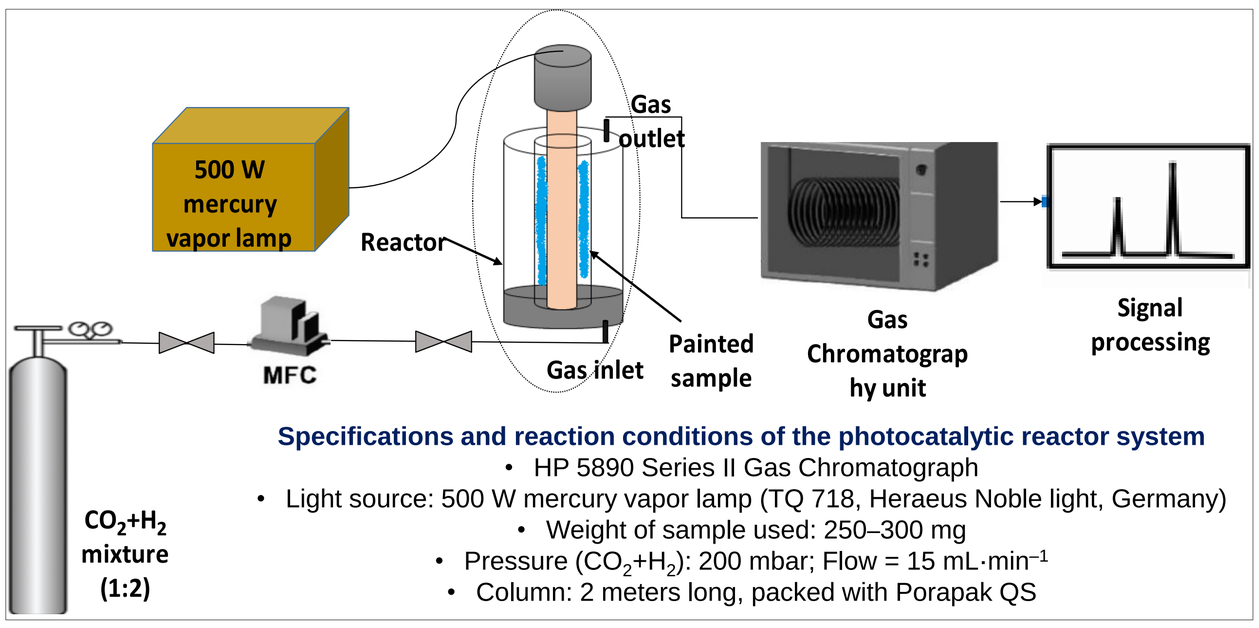
Introduction

- Energy consumption has been increasing with the world's population.
- Fossil fuels are the main source of energy.
- Combustion of fossil fuels generates greenhouse CO_2.
- Photocatalysis can be utilized under solar radiation and ambient conditions.
- Photocatalysts can satisfy requirements such as stability, non-toxicity, availability, low-cost, etc.
- Titanium dioxide (TiO_2) owing to its excellent photochemical stability and unique band structure has shown promising activity towards photocatalytic CO_2 reduction.
- The photocatalytic activity of TiO_2 can further be enhanced by the deposition of noble metals such as rhodium (Rh), ruthenium (Ru), and platinum (Pt).

Methodology



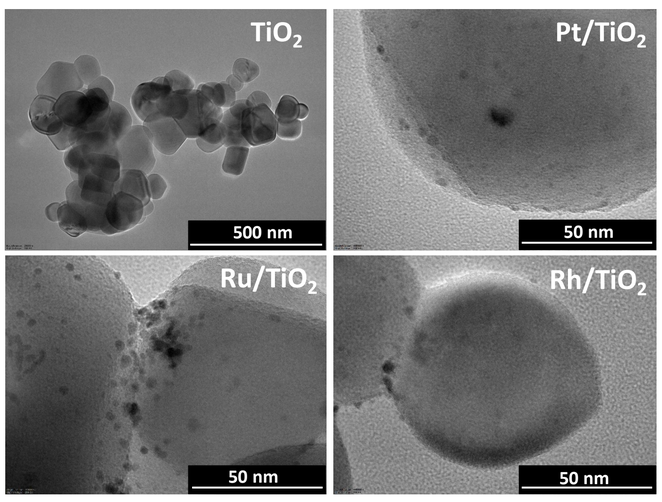
Specifications and reaction conditions of the photocatalytic reactor system

- HP 5890 Series II Gas Chromatograph
- Light source: 500 W mercury vapor lamp (TQ 718, Heraeus Noble light, Germany)
- Weight of sample used: 250–300 mg
- Pressure (CO_2+H_2): 200 mbar; Flow = 15 mL·min^{-1}
- Column: 2 meters long, packed with Porapak QS

Table 1. Catalyst loadings, specific surface areas (SSAs), band gaps and primary crystallite size values.

Sample	Rh, Ru and Pt (wt%)	SSAs ($m^2 \cdot g^{-1}$)	Band gap (eV)	Primary crystallite size (nm)
TiO_2	-	48.8	3.28	19.31
Pt/TiO_2	1	52.7	3.24	19.43
Ru/TiO_2	1	51.8	3.22	19.39
Rh/TiO_2	1	53.1	3.16	19.35

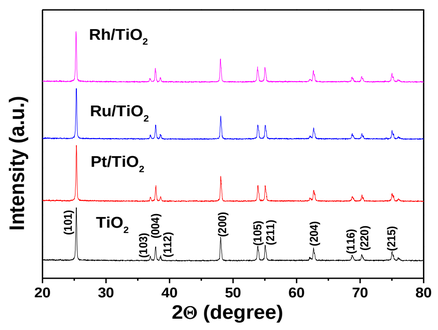
Morphology-TEM



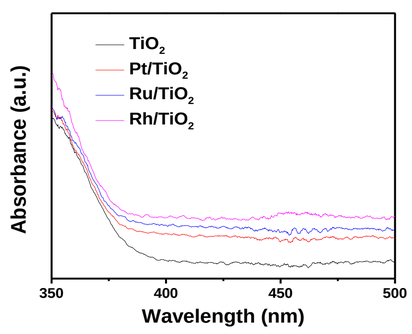
Characterization and photocatalytic activity

Transmission electron microscopy (TEM), X-ray diffraction (XRD), nitrogen adsorption, diffuse reflectance spectroscopy (DRS), and photoluminescence (PL) measurements were carried out to characterize the samples. The photocatalytic efficiency of the TiO_2, Rh/TiO_2, Ru/TiO_2, and Pt/TiO_2 composites were investigated *via* the photocatalytic reduction of CO_2 under UV and visible light irradiation.

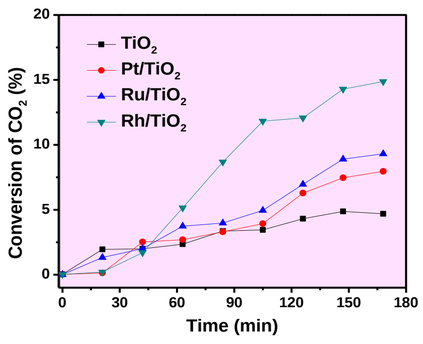
XRD



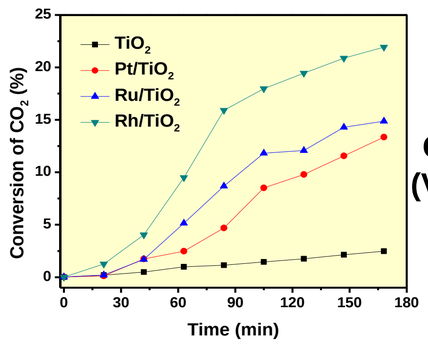
DRS



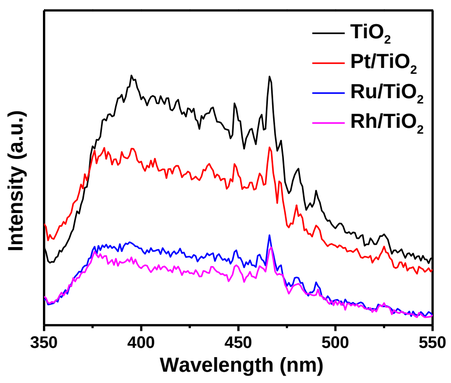
CO_2 Conversion (UV light)



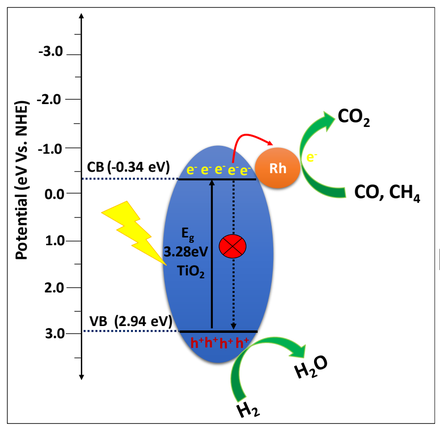
CO_2 Conversion (Visible light)



PL Spectra



Photocatalytic mechanism for CO_2 hydrogenation Over Rh/TiO_2



Samples	CO_2 conversion (%)		Formation of CO ($nmol \cdot g^{-1} \cdot sec^{-1}$)		Selectivity of CO (%)	
	UV	Visible	UV	Visible	UV	Visible
TiO_2	4.6	2.4	146.1	77.1	99.9	99.9
Pt/TiO_2	7.9	13.3	273.7	469.2	99.9	99.9
Ru/TiO_2	9.3	14.8	304.6	531.8	98.9	98.8
Rh/TiO_2	14.8	21.9	435.6	855.2	99.9	99.9

Conclusions

- Noble metals (Pt, Ru, Rh) were deposited on TiO_2 surfaces by a facile wet-impregnation method, which were tested under both UV and visible light irradiation.
- The light absorption properties were enhanced with the deposition of noble metals, and the electron–hole recombination was successfully inhibited based on the PL spectra.
- Rh/TiO_2 sample showed the highest photocatalytic activity towards CO_2 hydrogenation under both UV and visible light irradiations.
- A probable mechanism was proposed for the photocatalytic reduction of CO_2 on the as-optimized Rh/TiO_2 sample.

Acknowledgements

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