Photocatalytic water splitting at Cold-Gas Sprayed (CGS) titanium dioxide surfaces

J. Freitag, H. Gutzmann*, R. Dillert, D. Bahnemann

Institut für Technische Chemie, Leibniz Universität Hannover, Callinstraße 3, D-30167 Hannover, Germany

*Helmut-Schmidt-Universität Hamburg, Universität der Bundeswehr, Germany

Contact: Freitag@iftc.uni-hannover.de

Introduction

- Photocatalytic water splitting using titanium dioxide (TiO₂) is a well known and promising method for hydrogen production from water to resolve the upcoming depletion of current fossil fuels.
- To reduce the recombination rate of photo-induced electrons and holes (e⁻/h⁺), which is one of the most limiting factors for efficient water splitting, several n-type TiO₂ powders were coated via Cold Gas Spraying (CGS) on metals such as titanium or steel.
- CGS is a relatively new method for surface treatment at low temperatures and high pressures, which, in contrast to other coating methods, does not need any linker.
- The aim of this study is to produce an inexpensive and cost efficient photoelectrochemical cell (PEC) to generate molecular hydrogen by water splitting with and without applying an external potential.

Methods

- The amount of evolved hydrogen was determined by Gas chromatography (Shimadzu GC-8A; Argon gas flux)
- Reaction conditions: 1000 W Xenon lamp (Osram); light intensity at 365 nm, 27.16 mWcm⁻², 1 M Sodium hydroxide (NaOH) solution with 5 % Methanol, 0.1 V bias if applied, 120 to 360 minutes
- Comparison to Sol-Gel TiO₂-layers on metals such as titanium

Results

- Hydrogen production has been observed for all CGS titanium/titanium dioxide-samples
- Best results: 1 M NaOH with 5 % Methanol and 0.1 V vs. Ag/AgCl
- Sol-Gel Samples show hydrogen evolution only with bias potential application

Outlook

- Other sacrificial reagents such as oxalic acid, ethylene glycole, ethanol and EDTA (ethylenediamine tetra acetic acid) will be investigated
- Mixtures of sacrificial reagents and even of waste water can be used for hydrogen production
- Other substrates such as steel for water splitting

Conclusions

- CGS-samples have good properties for water splitting, even for the water reduction itself.
- Water splitting without application of any potential could be observed

Volume of evolved hydrogen over time from a CGS TiO₂/titanium sample in 1 M NaOH with 5 % MeOH and 0.1 V bias. After 360 minutes of irradiation 0.609 mL hydrogen were produced.

Current-Voltage plot of a CGS TiO₂/titanium sample. Potential vs RHE in 1 M NaOH. The photocurrent starts at a very low potential in comparison to the Sol-Gel TiO₂-samples.

Volume of evolved hydrogen over reaction time from a Sol-Gel sample. 1 M NaOH with 5 % MeOH and 0.1 V bias. After 360 minutes of irradiation 0.609 mL hydrogen were produced.

Financial support from the Deutsche Forschungsgemeinschaft is gratefully acknowledged (BA 1137/8-1).