UNIVERSITY OF MALAYA
The Leader in Research & Innovation

HYDROGEN ENERGY

Production of hydrogen and nanocarbon from methane over *n*-NiO/SiO_2 catalyst prepared by co-precipitation cum modified Stöber method

UPM Ashik
University of Malaya, Malaysia

UNIVERSITY OF MALAYA
The Leader in Research & Innovation

HYDROGEN ENERGY

Fossil Fuel and GHG emission

- Fossil fuels dominate energy consumption with a market share of 87%
- Emission of GHGs like CO_x, C_xH_y, NO_x, SO_x, etc.

- Atmospheric CO_2 level hits awful record highs
- Global warming, climate change and ocean acidification
- Alternatives - Wind, solar, bio and nuclear energy

Introduction

Jos G.J. Olivier GJ-M, Jeroen A.H.W. Peters. *Trends in Global CO_2 Emissions*. PBL; 2012

UNIVERSITY OF MALAYA
The Leader in Research & Innovation

GRDS

HYDROGEN ENERGY

Hydrogen

- **Hydrogen - a clean fuel - produces water only on its combustion**
- The simplest, the lightest and the most abundant element
- Greenest energy
- 3X energy than any other fuel on a mass basis
- Secondary energy carrier.

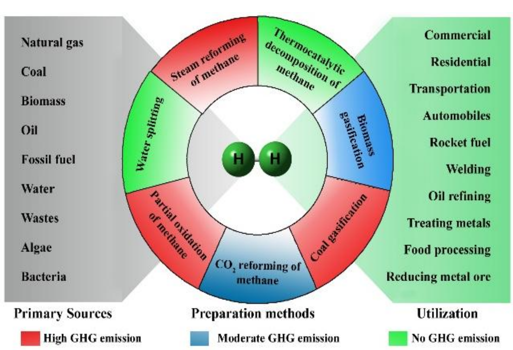
Introduction

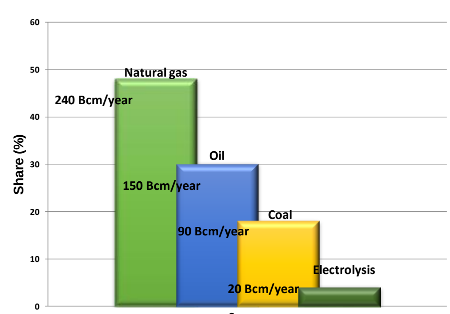
UNIVERSITY OF MALAYA
The Leader in Research & Innovation

GRDS

HYDROGEN ENERGY

Hydrogen production





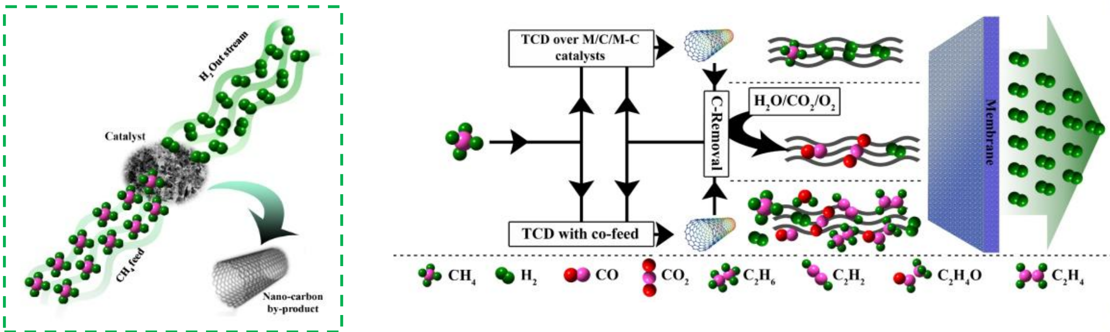
Introduction

Ashik, U. P. M., & Daud, W. M. A. W. (2015). *Nano-nickel catalyst reinforced with silicate for methane decomposition to produce hydrogen and nanocarbon: synthesis by co-precipitation cum modified Stober method*. RSC Advances, 5, 46735-46748.

UNIVERSITY OF MALAYA
The Leader in Research & Innovation

Thermocatalytic decomposition of methane

- $CH_4 \rightarrow C + 2H_2$
- The prime benefit of TCD is the elimination of GHG release



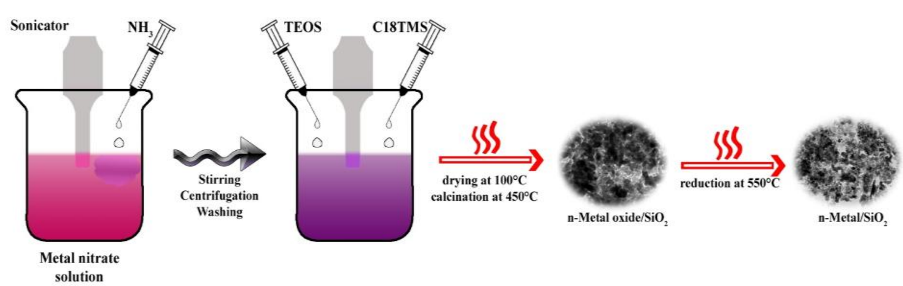
HYDROGEN ENERGY

Introduction

Ashik, U. P. M., Wan Daud, W. M. A., & Abbas, H. F. (2015). *Production of greenhouse gas free hydrogen by thermocatalytic decomposition of methane – A review*. Renewable and Sustainable Energy Reviews, 44(0), 221-256. doi: 10.1016/j.rser.2014.12.025

UNIVERSITY OF MALAYA
The Leader in Research & Innovation

Preparation of nano-NiO/SiO$_2$ catalyst

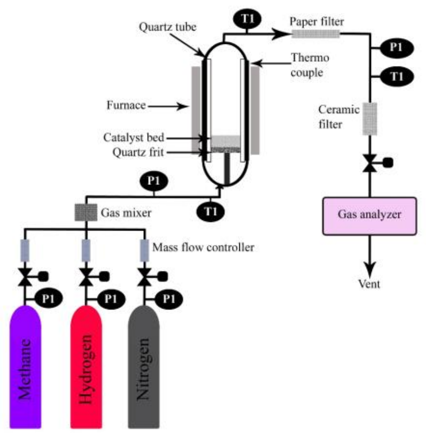


HYDROGEN ENERGY

Experimental

UNIVERSITY OF MALAYA
The Leader in Research & Innovation

Isothermal methane decomposition



- Fixed catalyst bed reactor
- Inner diameter = 3.03 cm,
- Wall thickness = 0.87 cm
- Height = 120 cm

- ***0.5 g of catalyst***
- ***Reduction at 550 °C***
- ***99.995% methane***

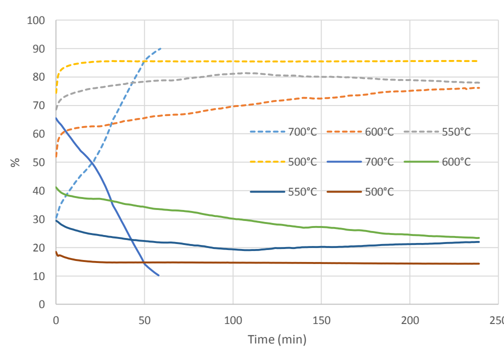
HYDROGEN ENERGY

Experimental

Ashik, U. P. M & Daud, W. M. A. W. (2015). *Probing the differential methane decomposition behaviors of n-Ni/SiO_2, n-Fe/SiO_2 and n-Co/SiO_2 catalysts prepared by co-precipitation cum modified Stöber method*, RSC Advances, 5, 67227-67241.

UNIVERSITY OF MALAYA
The Leader in Research & Innovation

Effect of temperature on catalytic methane decomposition



Percentage of methane (- - -) and hydrogen (—) as a function of time at different temperature. Flow rate was 0.64 L/min.

HYDROGEN ENERGY

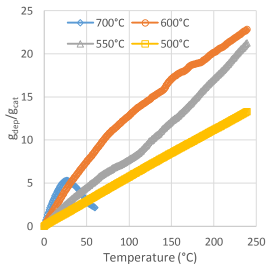
Result & discussion

UNIVERSITY OF MALAYA
The Leader in Research & Innovation

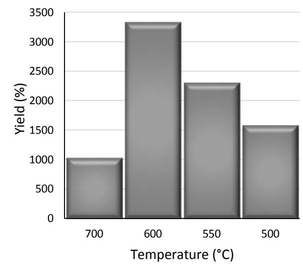
GRDS

HYDROGEN ENERGY

Effect of temperature on catalytic methane decomposition



Accumulated carbon at different temperature as a function of reaction time on stream



Carbon yield at each temperature

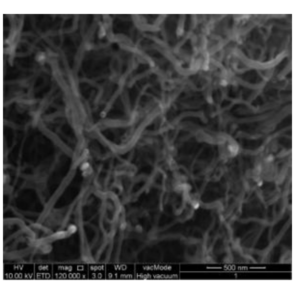
Result & discussion

UNIVERSITY OF MALAYA
The Leader in Research & Innovation

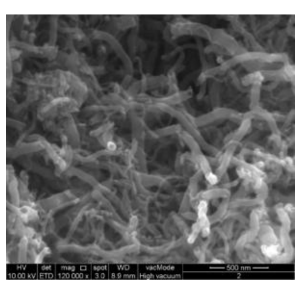
GRDS

HYDROGEN ENERGY

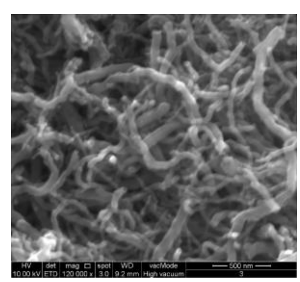
Effect of temperature on catalytic methane decomposition



700 °C



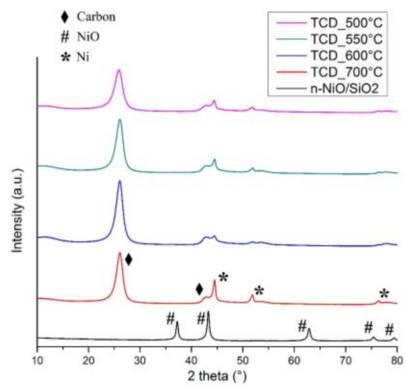
600 °C



500 °C

Result & discussion

Effect of temperature on catalytic methane decomposition



HYDROGEN ENERGY

Result & discussion

UNIVERSITY OF MALAYA
The Leader in Research & Innovation

Effect of temperature on catalytic methane decomposition

XRD evaluation report of *n*-NiO/SiO_2 nanostructures before and after activity analysis

Sample	2θ (°)	Ni (111) (nm)	Ni (200) (nm)	Ni (220) (nm)	Avg. crystal size (nm)	Interplanar distances, d (Å)	Structure formed
n-NiO/SiO_2	37.25, 43.27, 62.81	31.13	26.85	23.77	27.25	2.41373, 2.09085, 1.47935	Cubic
TCD-700	44.52, 51.86, 76.43	31.88	25.77	41.32	32.99	2.03481. 1.76299, 1.24611	Cubic
TCD-600	44.45, 51.81, 76.56	70.14	45.11	25.84	47.03	2.03779, 1.76435, 1.24430	Cubic
TCD-500	44.50, 51.83, 76.28	26.97	72.11	51.58	50.22	2.03600, 1.76380, 1.24818	Cubic

HYDROGEN ENERGY

Result & discussion

UNIVERSITY OF MALAYA
The Leader in Research & Innovation

HYDROGEN ENERGY

Effect of temperature on catalytic methane decomposition

Porosity and surface characteristics of *n*-NiO/SiO_2 catalyst before and after activity test from N_2 adsorption-desorption analysis

Catalyst	Single point SA[a] (m²/g)	BET SA (m²/g)	Micropore area[b] (m²/g)	Mesopore + external area[c] (m²/g)	Mean particle size (nm)
n-NiO/SiO_2	91.50	93.18	5.17	88.01	32.19
TCD-700	48.18	48.81	7.76	41.05	61.45
TCD-600	68.66	70.10	9.95	60.15	42.79
TCD-500	73.18	74.90	15.05	59.84	40.04

Result & discussion

UNIVERSITY OF MALAYA
The Leader in Research & Innovation

HYDROGEN ENERGY

Conclusions

- Co-precipitation cum modified Stöber method was used to prepare catalyst.
- TEOS was used as silicate precursor and C18TMS as porogen.
- The highest carbon accumulation was observed at 600 °C, and lowest at 700 °C.
- However, the lowest deactivation was occurred at 500 °C.

Result & discussion

UNIVERSITY OF MALAYA
The Leader in Research & Innovation

HYDROGEN ENERGY

Gratefully acknowledge the financial support from postgraduate Research Fund (UM.C/HIR/MOHE/ENG/11), University of Malaya, Malaysia.

UNIVERSITY OF MALAYA
The Leader in Research & Innovation

&

Thank you!