Hydrogen production in DBD reactor powered with nanosecond high voltage pulses

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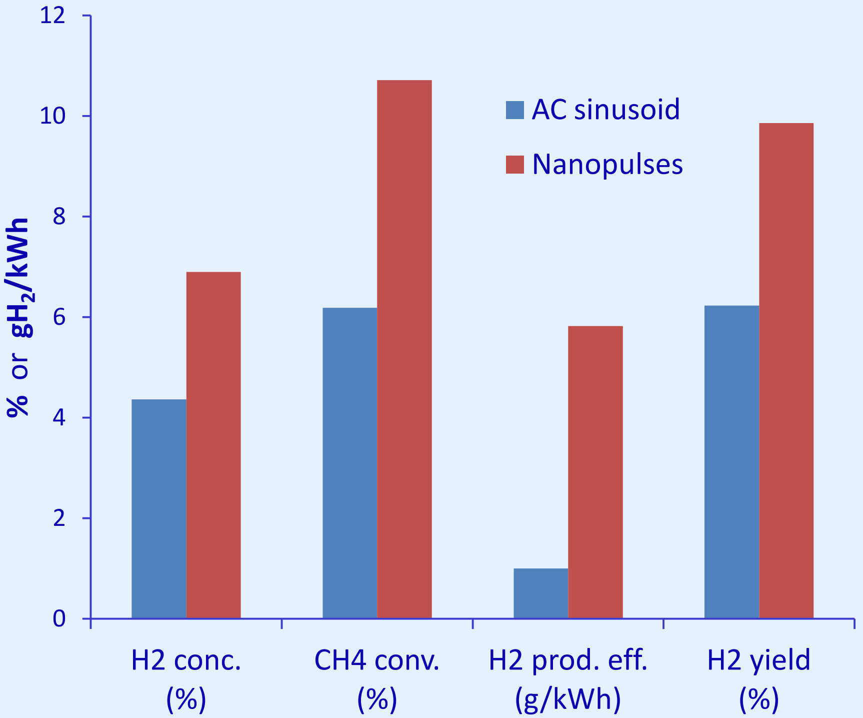
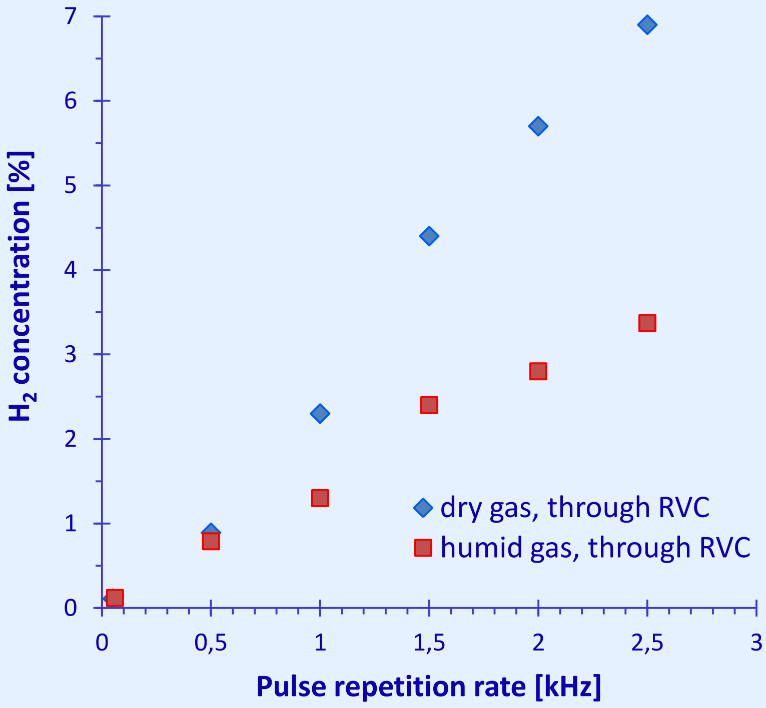
Previous experiments

Influence of power supply and H_2O

- Nanosecond voltage pulses much more efficient in H_2 production than AC

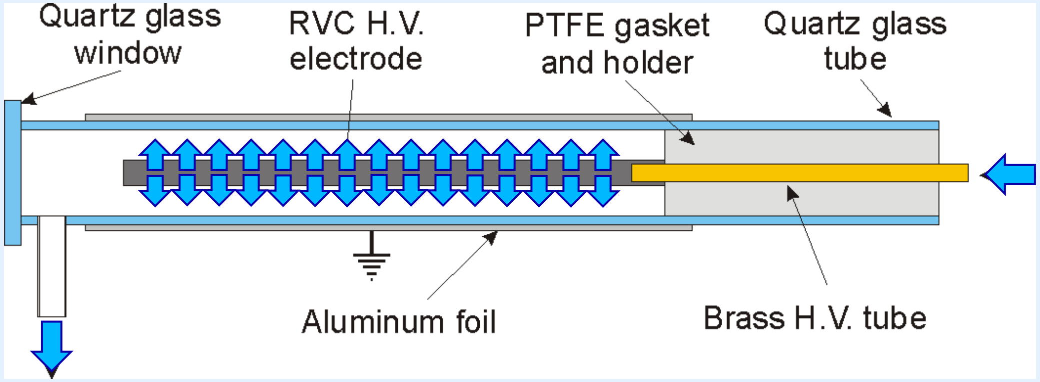


- H_2O inhibits H_2 production



DBD reactors

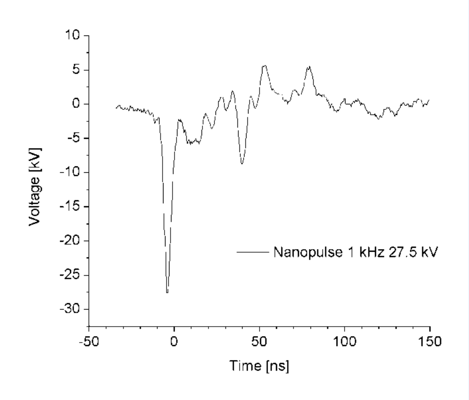
RVC electrode only



GC-TCD, FTIR

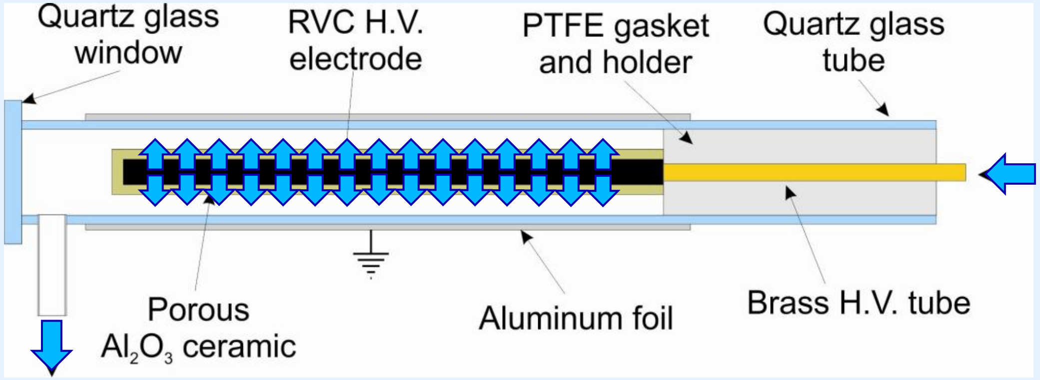
- Quartz glass tube: inner diameter 15 mm
- RVC (Reticulated Vitreous Carbon) electrode:
  - outer diameter 8 mm,
  - inner diameter 3 mm,
  - length 150 mm,
  - low porosity 80 ppi (pores per inch),
- Gas composition and flow rate:
  - $CH_4:CO_2:H_2S$ = 69%:30%:1%
  - 200 cm^3/min.

- Power supply:
  - Pulse generator NPG-15/2000 by Megaimpulse Ltd.
  - -29 kV, 50 Hz – 3 kHz



DBD reactors

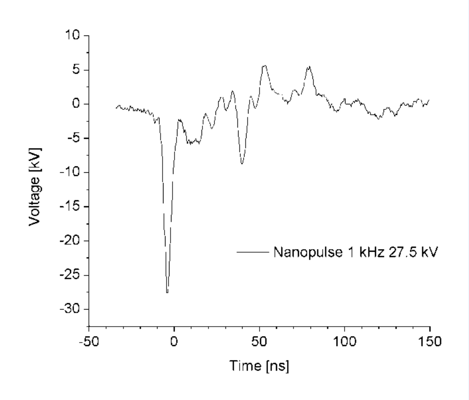
RVC electrode and porous ceramic tube



GC-TCD, FTIR

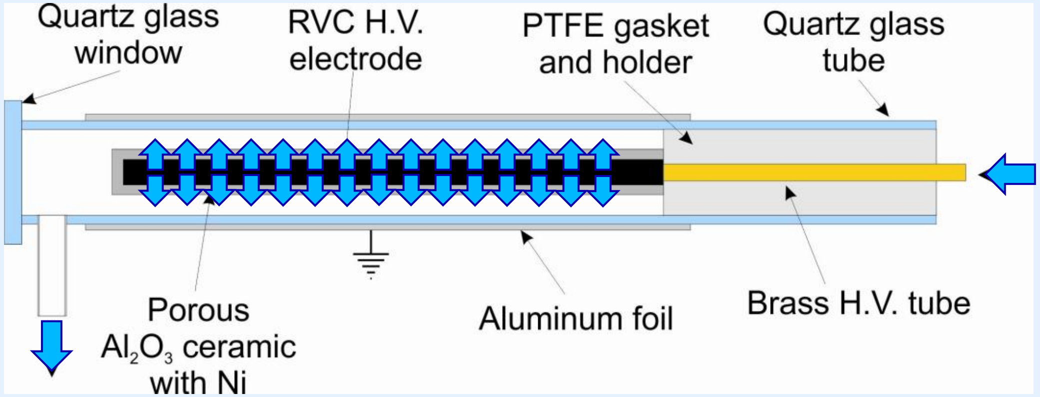
- Quartz glass tube: inner diameter 15 mm
- RVC (Reticulated Vitreous Carbon) electrode in porous ceramic tube:
  - outer diameter 12 mm,
  - inner diameter 8 mm,
  - length 150 mm
- Gas composition and flow rate:
  - $CH_4:CO_2:H_2S$ = 69%:30%:1%
  - 200 cm^3/min.

- Power supply:
  - Pulse generator NPG-15/2000 by Megaimpulse Ltd.
  - -29 kV, 50 Hz – 3 kHz



DBD reactors

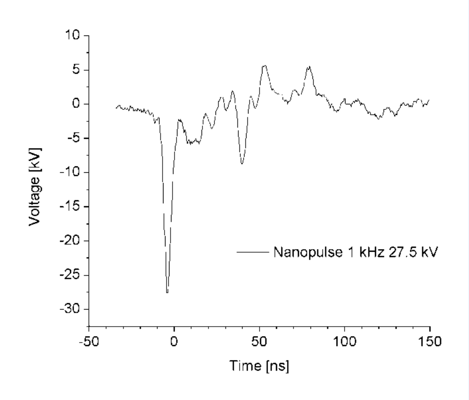
RVC electrode and porous ceramic tube and Ni



GC-TCD, FTIR

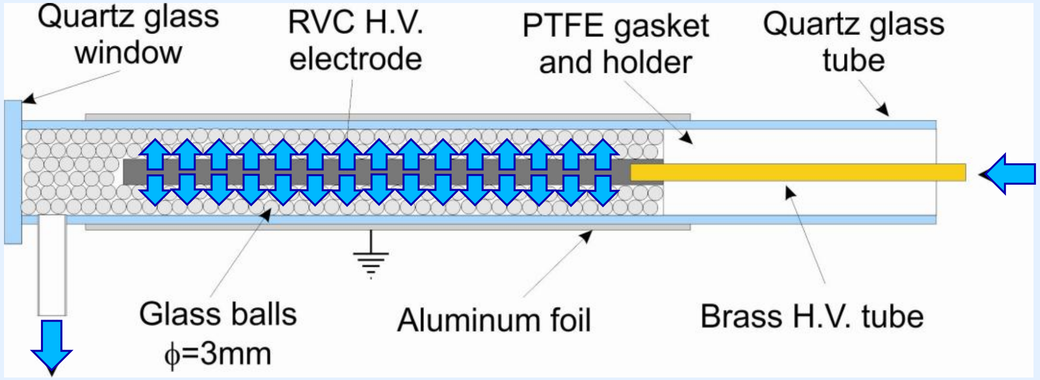
- Quartz glass tube: inner diameter 15 mm
- RVC (Reticulated Vitreous Carbon) electrode in porous ceramic tube:
  - outer diameter 12 mm,
  - inner diameter 8 mm,
  - length 150 mm,
  - saturated with Ni
- Gas composition and flow rate:
  - CH_4:CO_2:H_2S = 69%:30%:1%
  - 200 cm^3/min.

- Power supply:
  - Pulse generator NPG-15/2000 by Megaimpulse Ltd.
  - -29 kV, 50 Hz – 3 kHz



DBD reactors

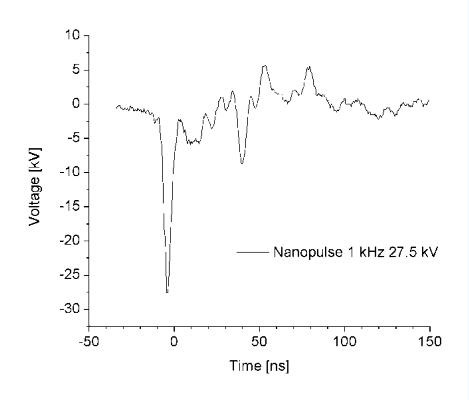
RVC electrode only



GC-TCD, FTIR

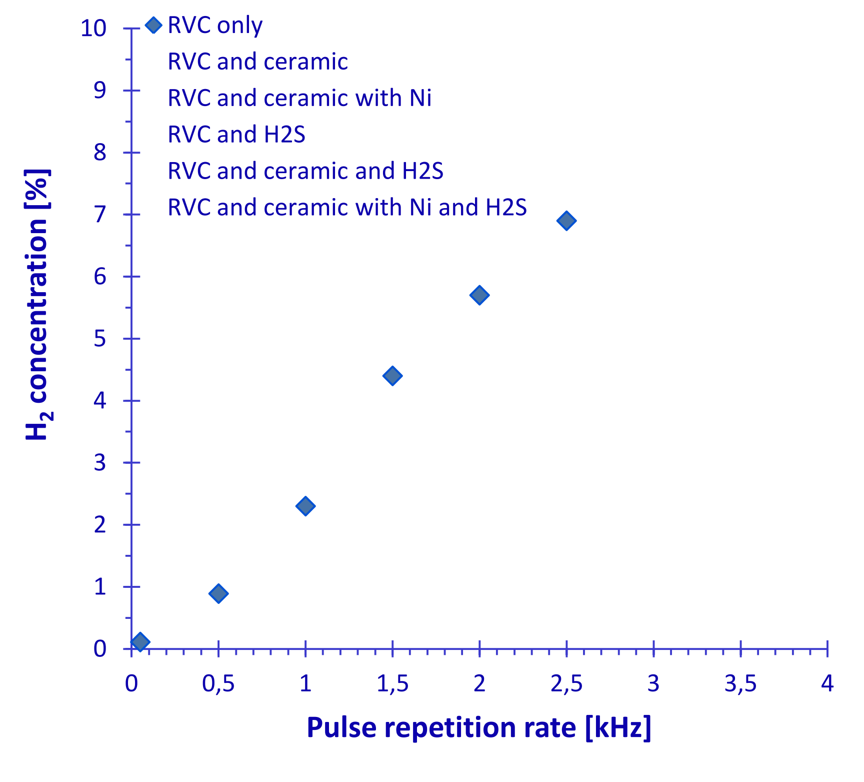
- Quartz glass tube: inner diameter 15 mm
- RVC electrode and glass beads Ø3 mm:
- Gas composition and flow rate:
  - CH_4:CO_2 = 70%:30%
  - 200 cm^3/min.

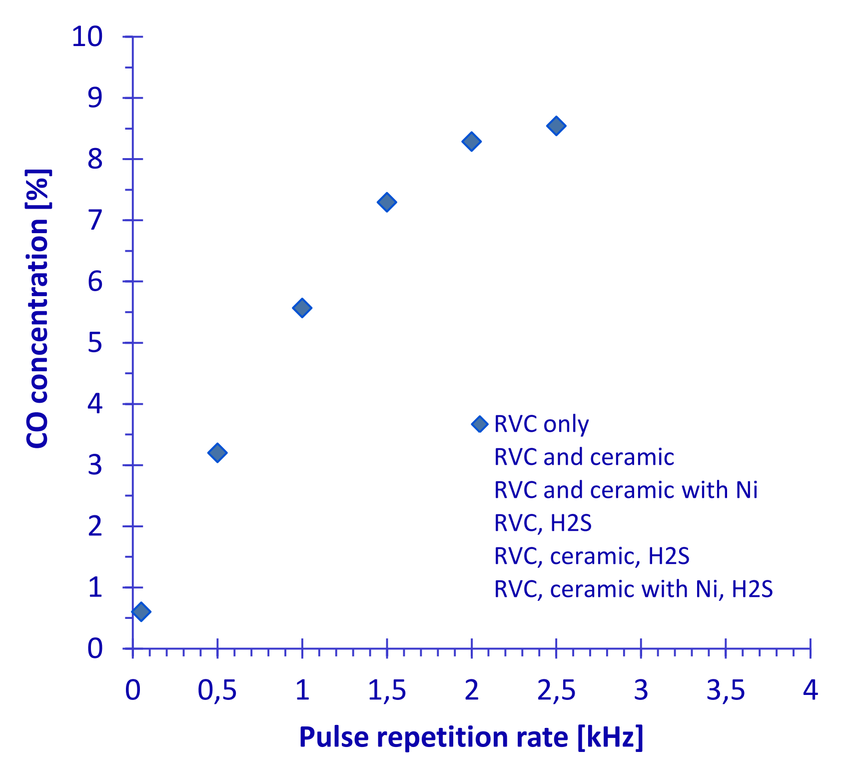
- Power supply:
  - Pulse generator NPG-15/2000 by Megaimpulse Ltd.
  - -29 kV, 50 Hz – 3 kHz



Results

H_2 and CO production





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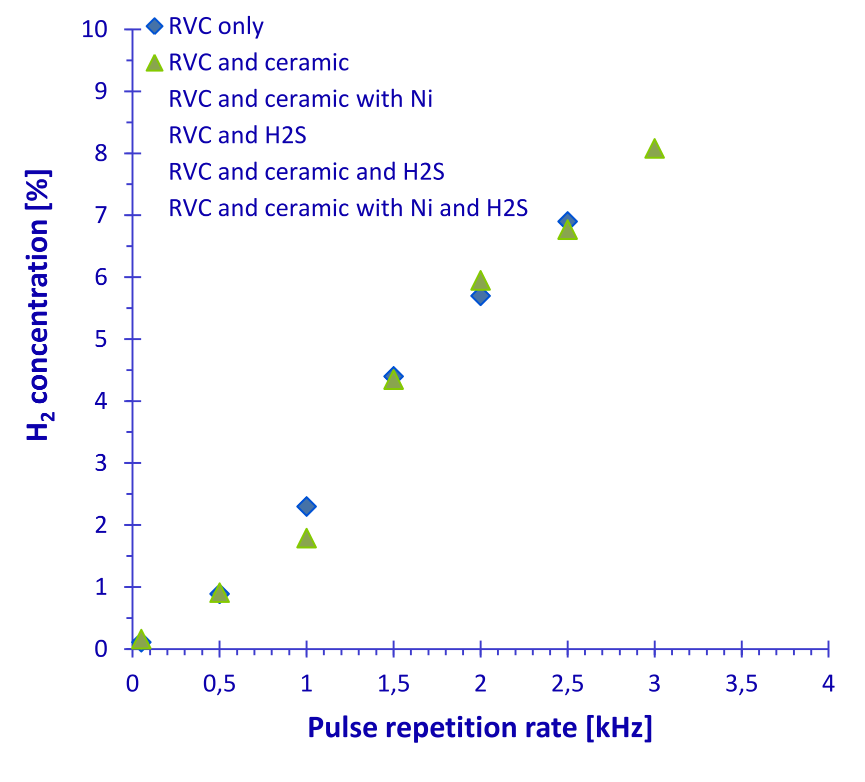
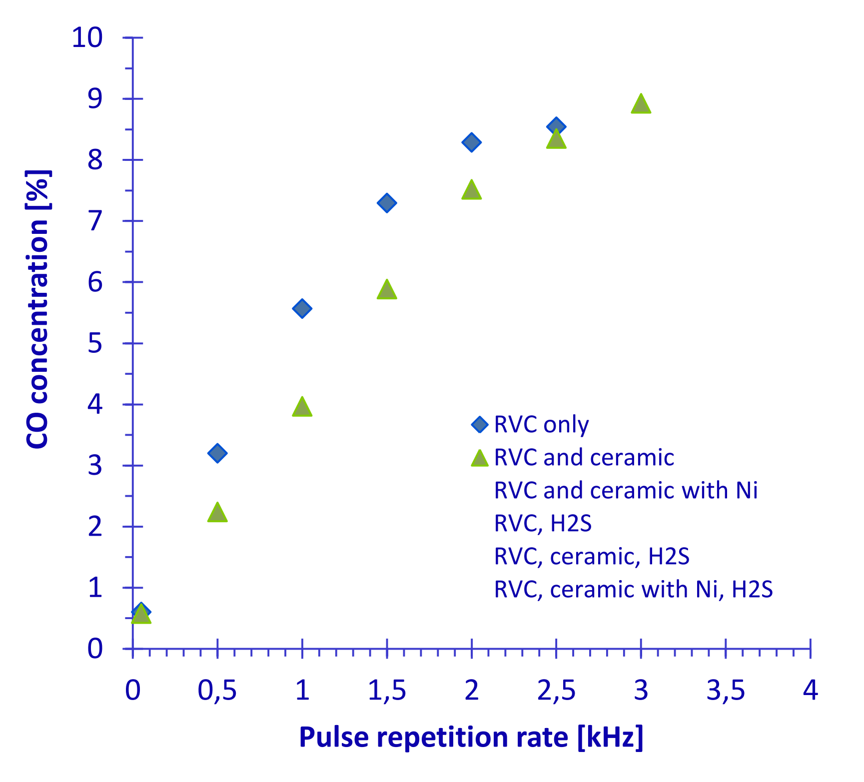


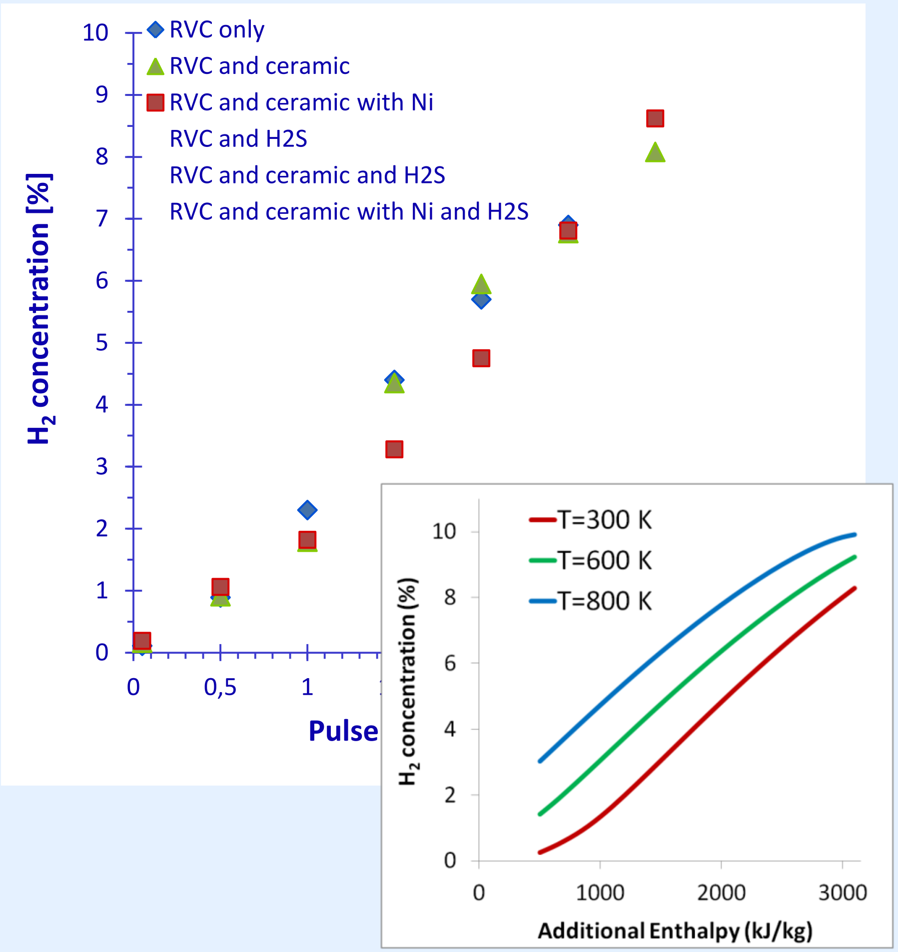


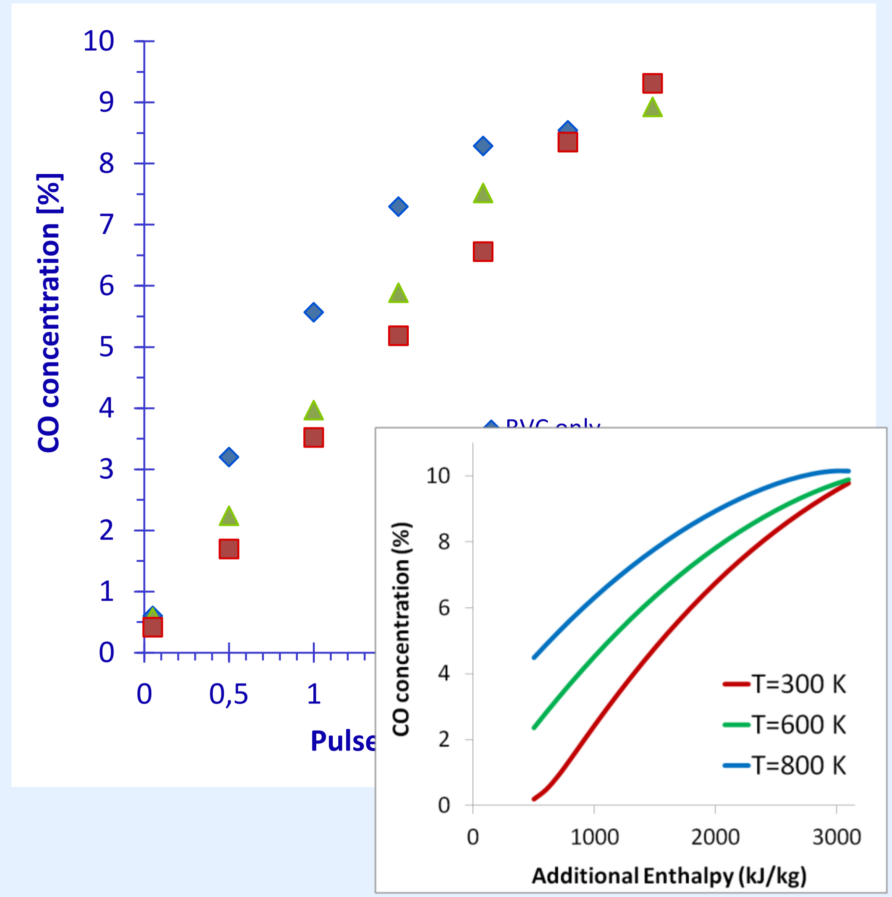
Results

H_2 and CO production – experimental and numerical

Thermodynamic Equilibrium Reactor, no ions, no electrons

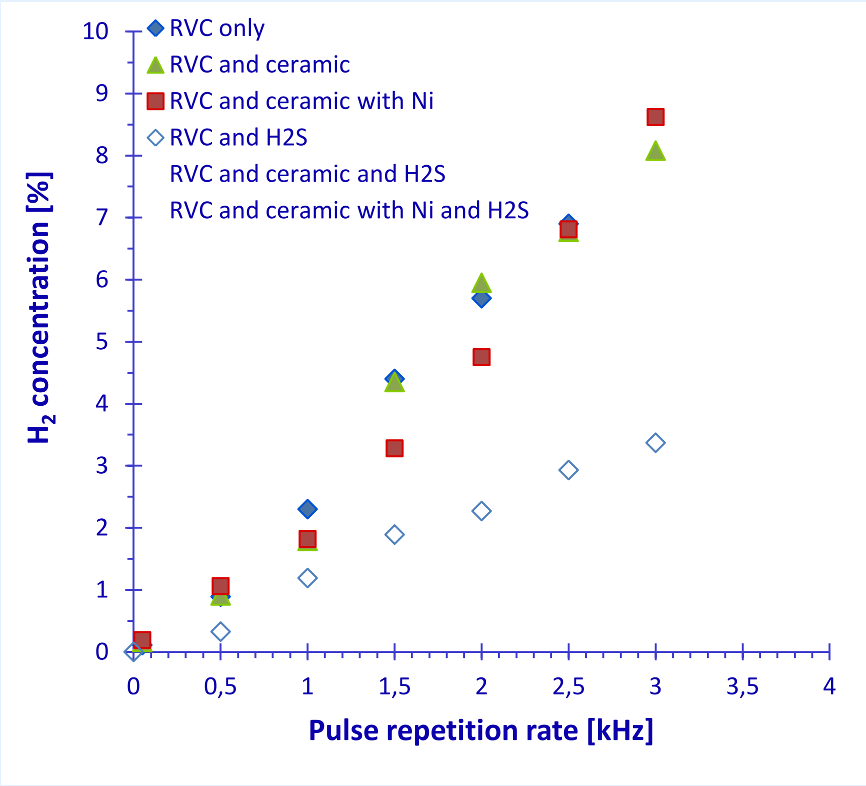
Close to thermodynamic equilibrium

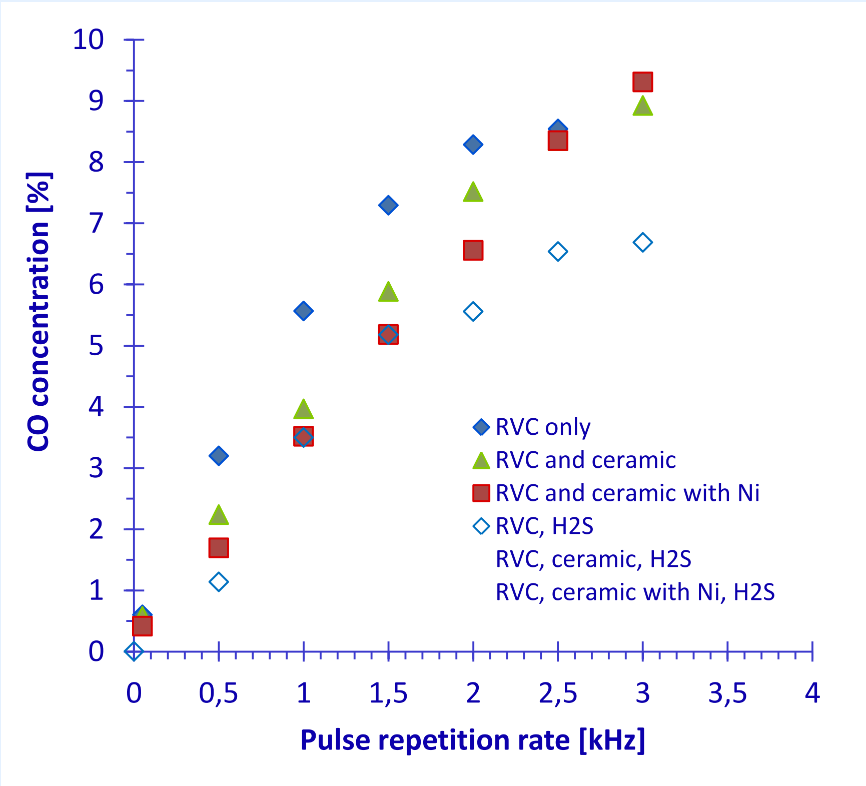




Results

H_2 and CO production – H_2S influence





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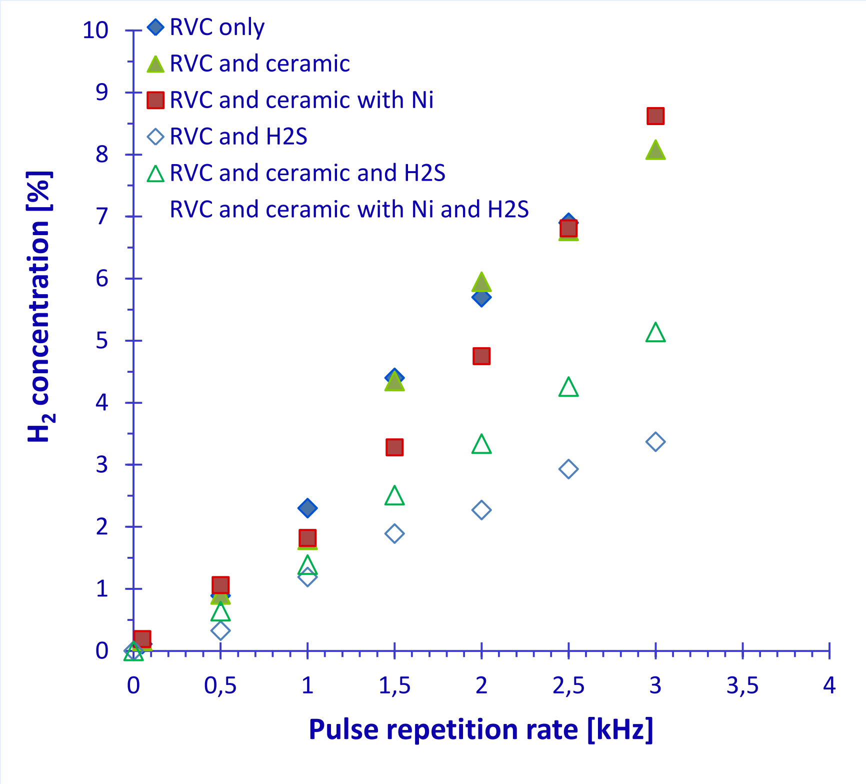
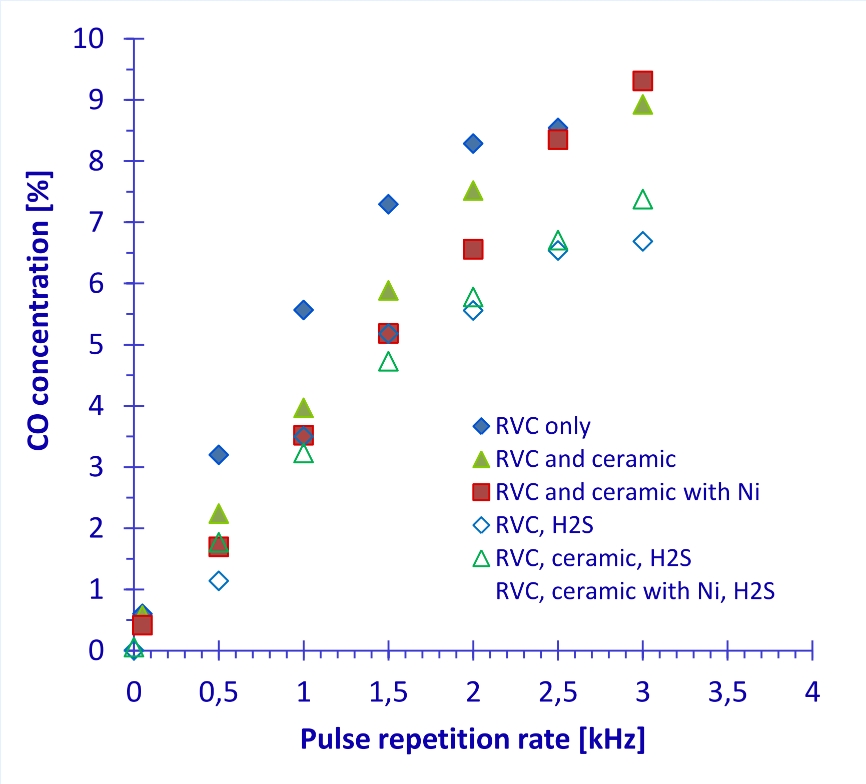
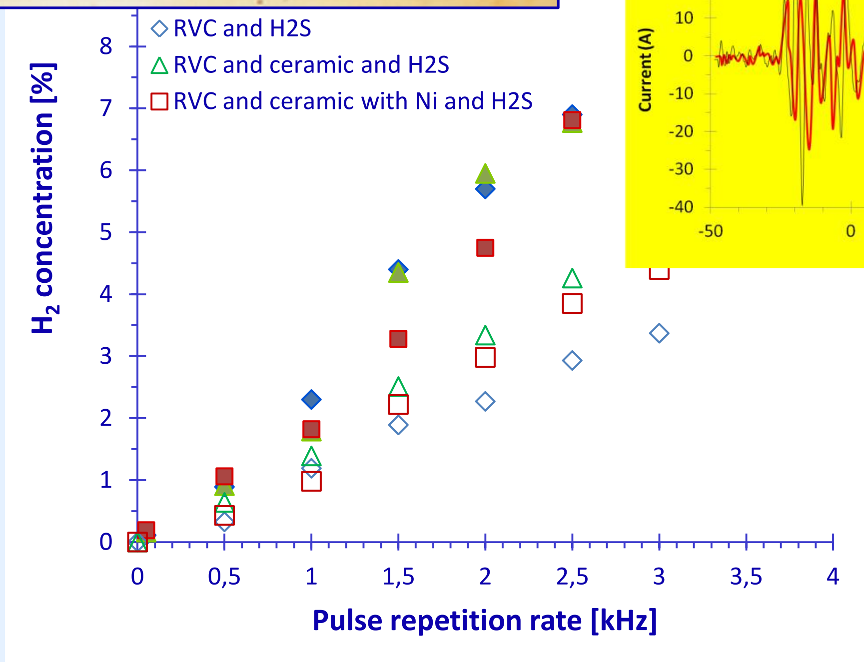


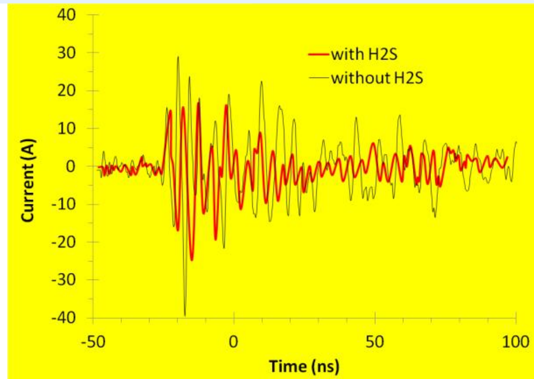


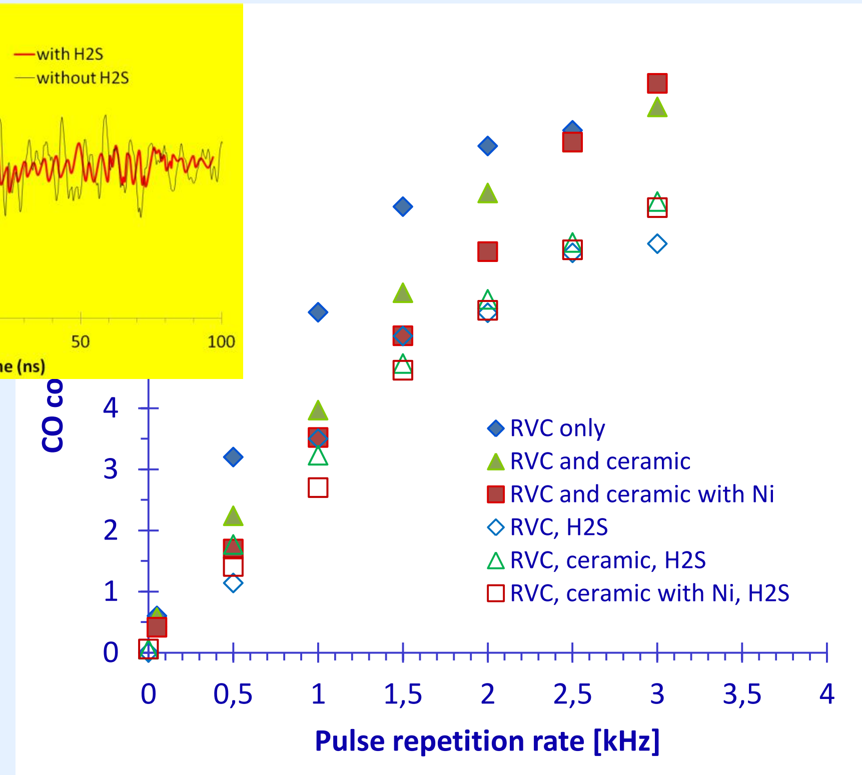
Results

H_2 and CO production – H_2S influence

Sulfur deposition on quartz glass → Electrical parameters changed → Lower CH_4 conversion



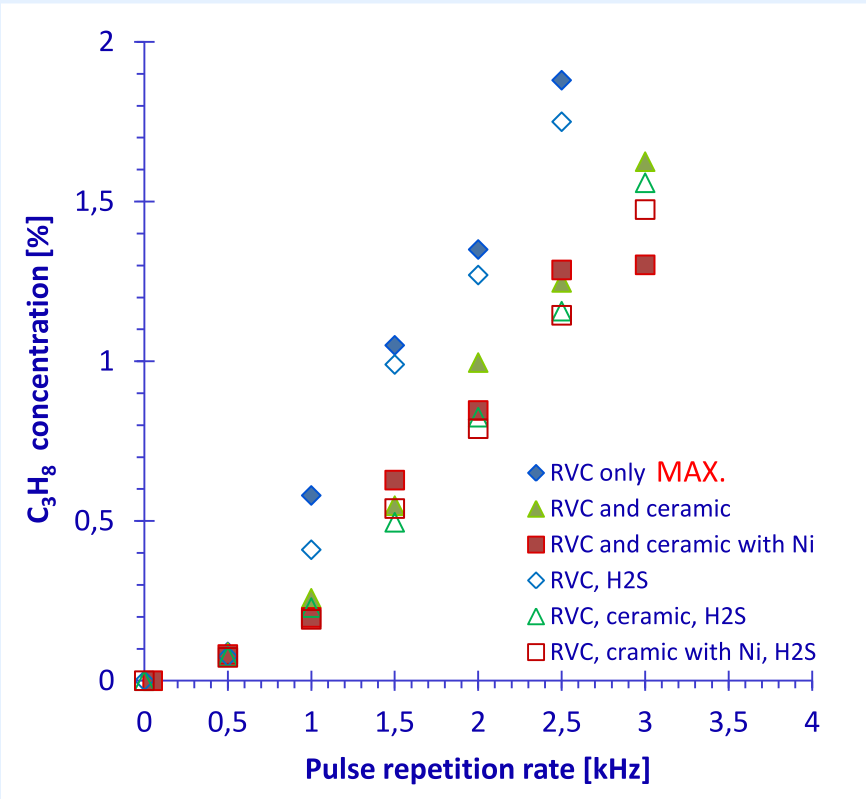


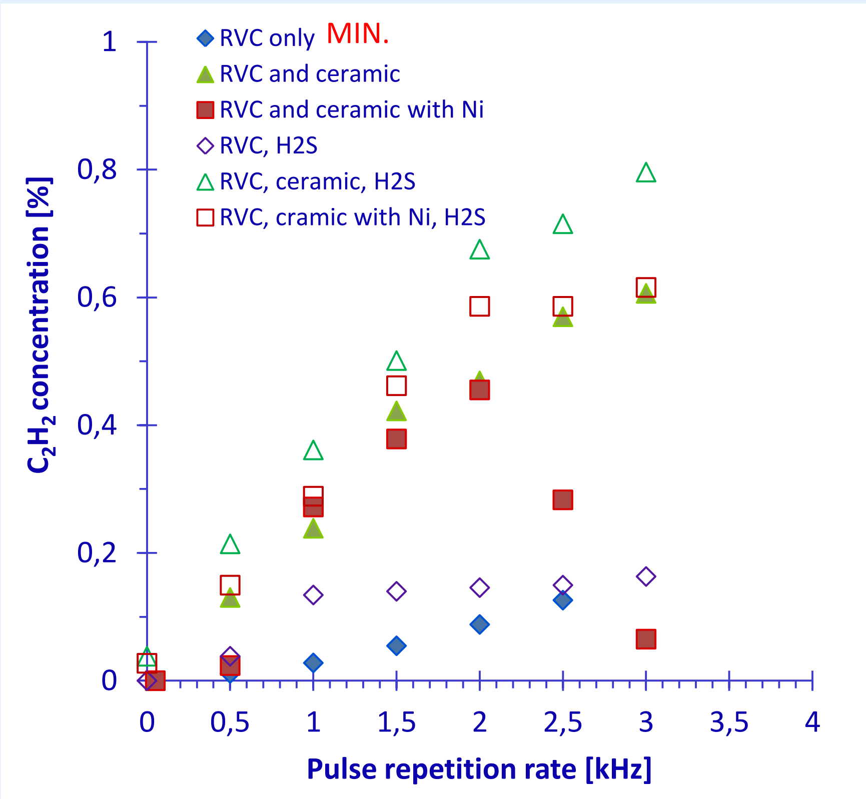


Results

C2 and C3 by-products

propane > acetylene > ethylene > ethane





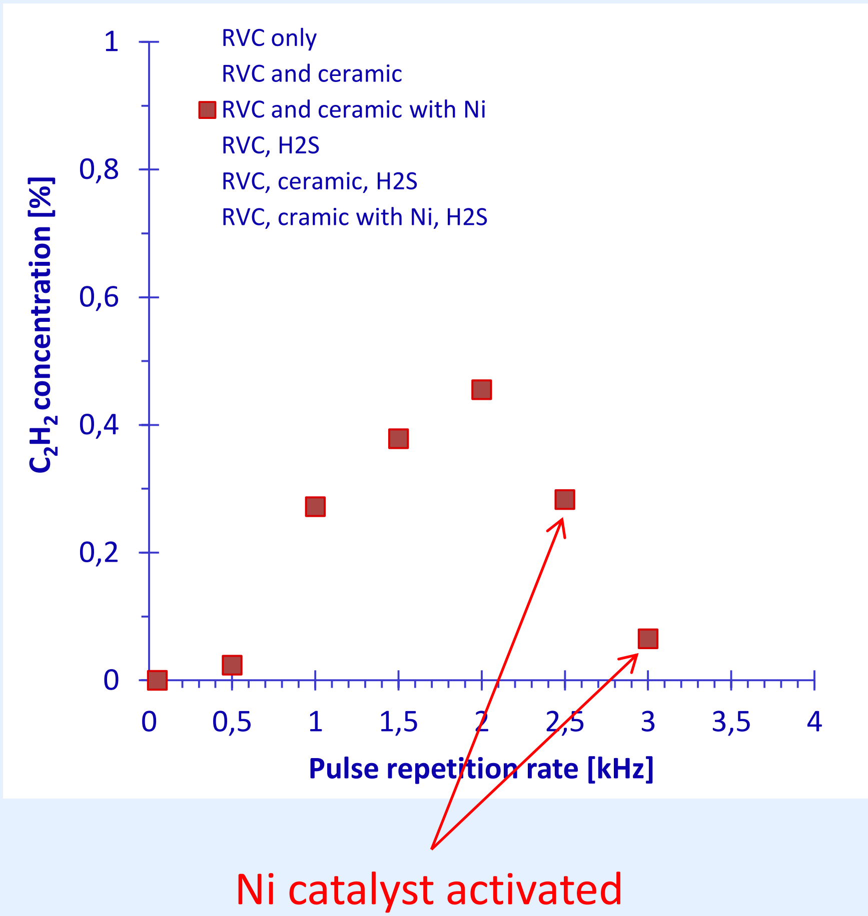
Small influence of H_2S

Results

C2 and C3 by-products

propane > acetylene > ethylene > ethane

- Ni catalyst activated due to heating the ceramic barrier



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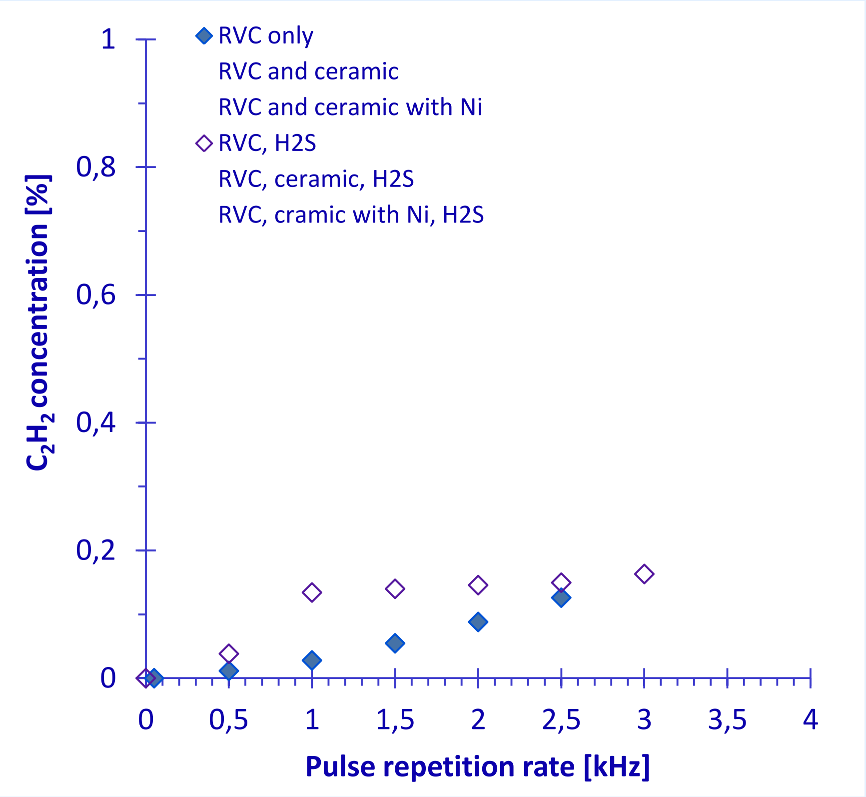
propane > acetylene > ethylene > ethane

- Ni catalyst activated due to heating the ceramic barrier
- H_2S increases C_2H_2 formation



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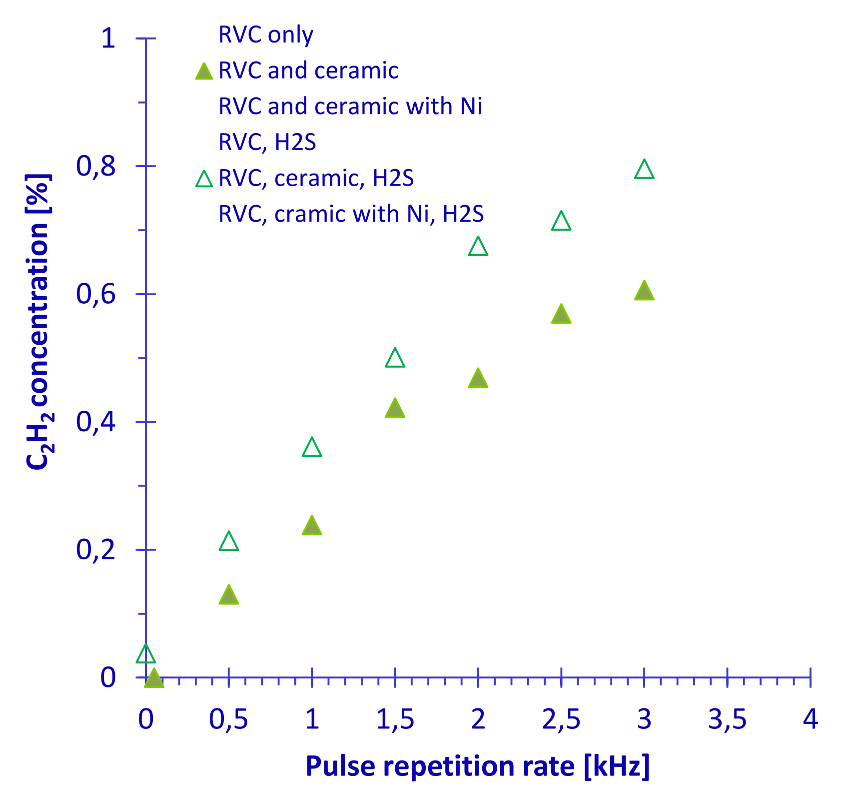
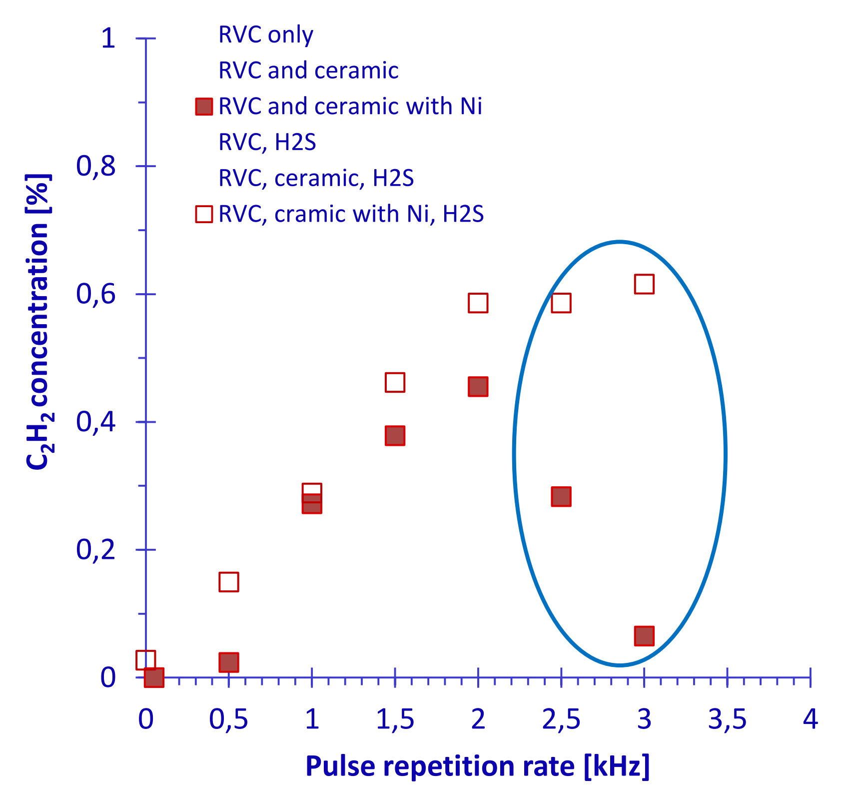


Results

C2 and C3 by-products

propane > acetylene > ethylene > ethane

- Ni catalyst activated due to heating the ceramic barrier
- H_2S increases C_2H_2 formation
- H_2S (or sulfur) poisons the Ni catalyst



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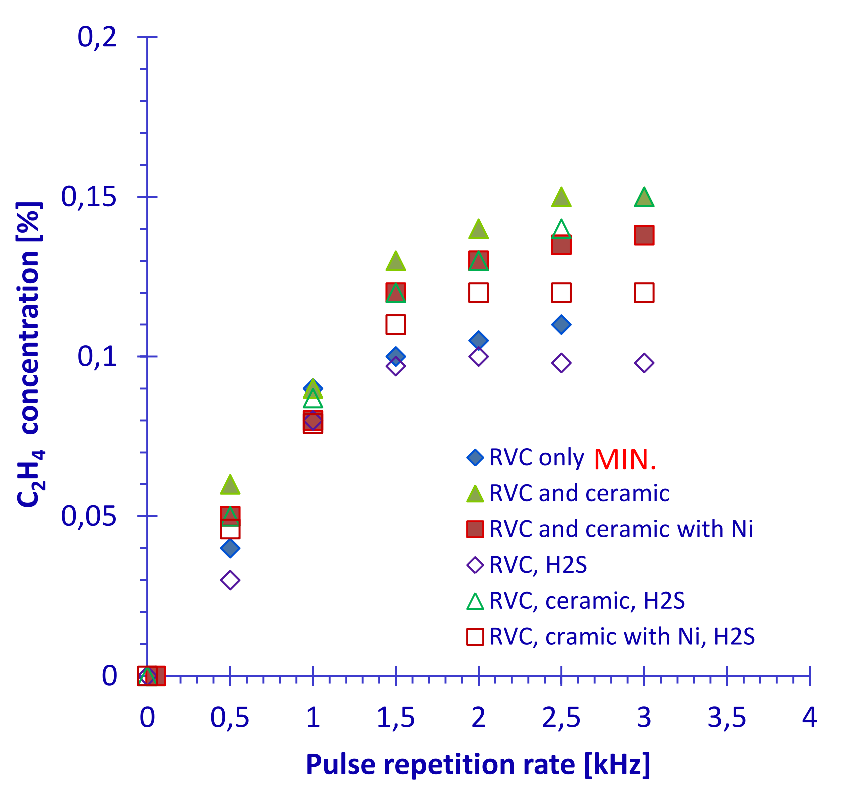
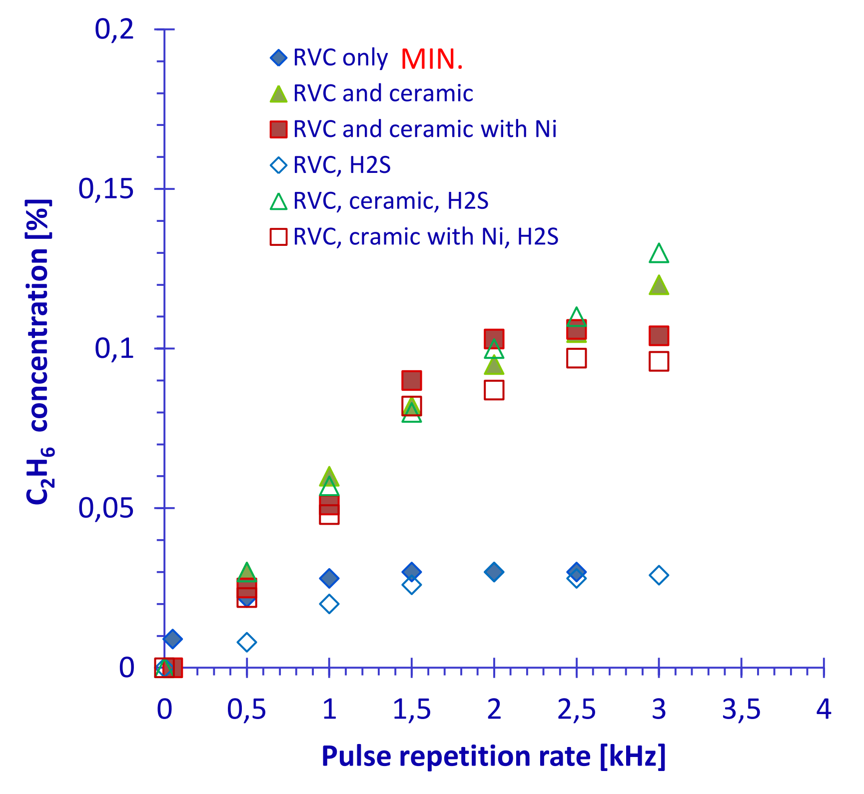




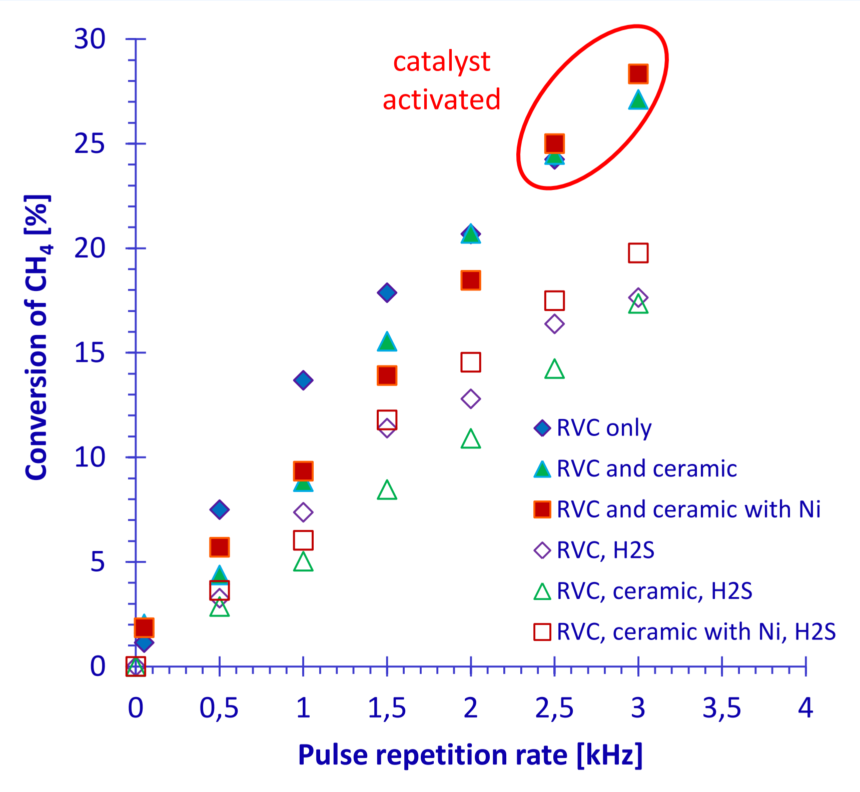
Small influence of H_2S

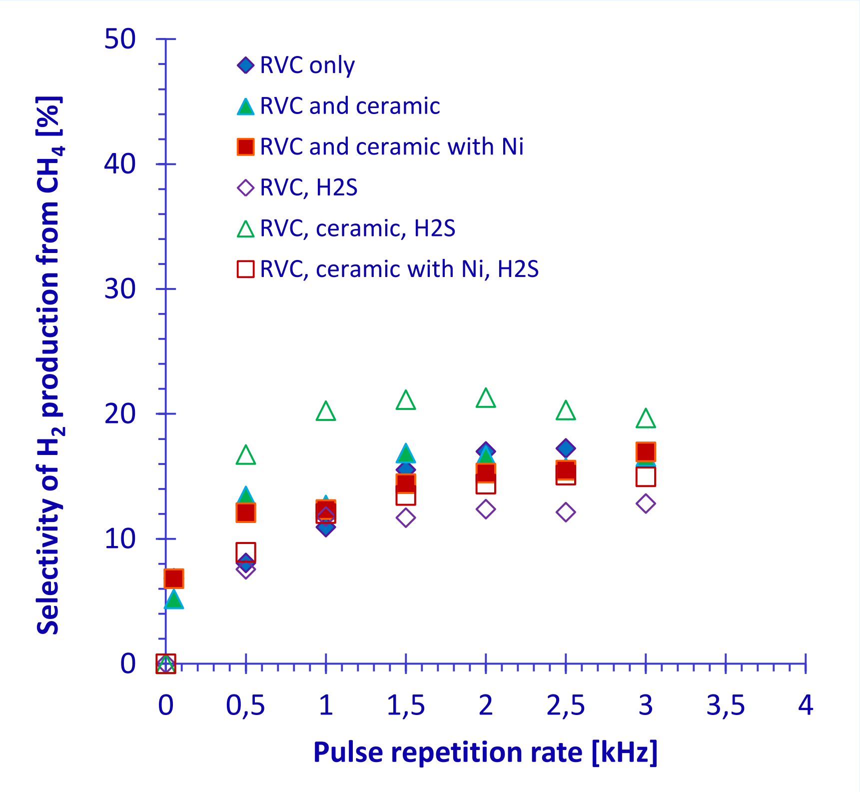
Small influence of H_2S

Results

CH_4 conversion and selectivity

Sulfur deposition on quartz glass → Electrical parameters changed → Lower CH_4 conversion

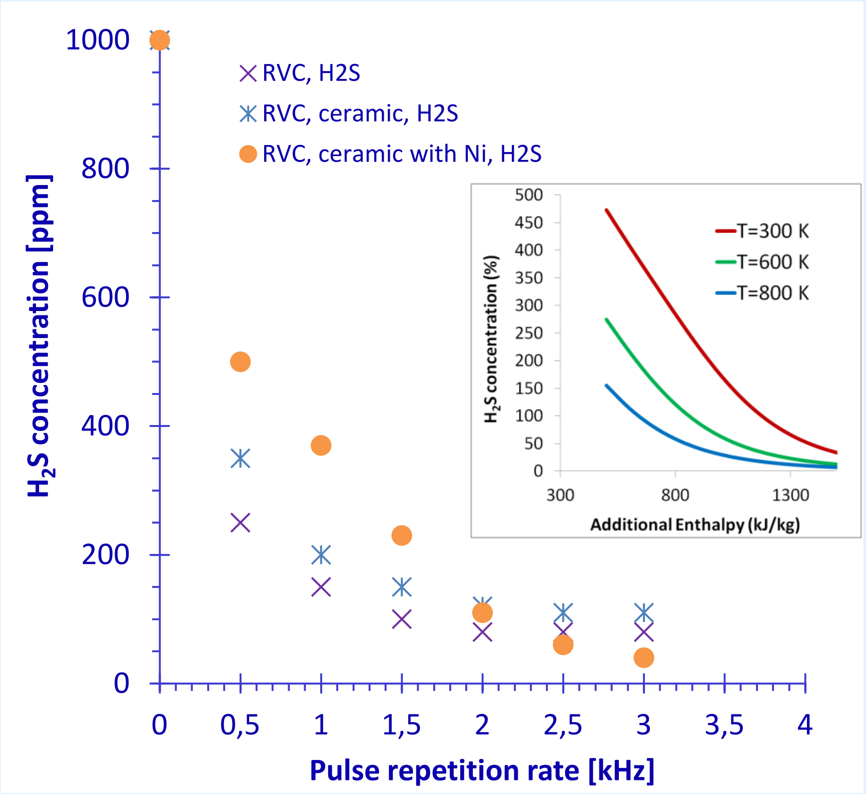




Results

H_2S

$H_2S = H_2 + S$

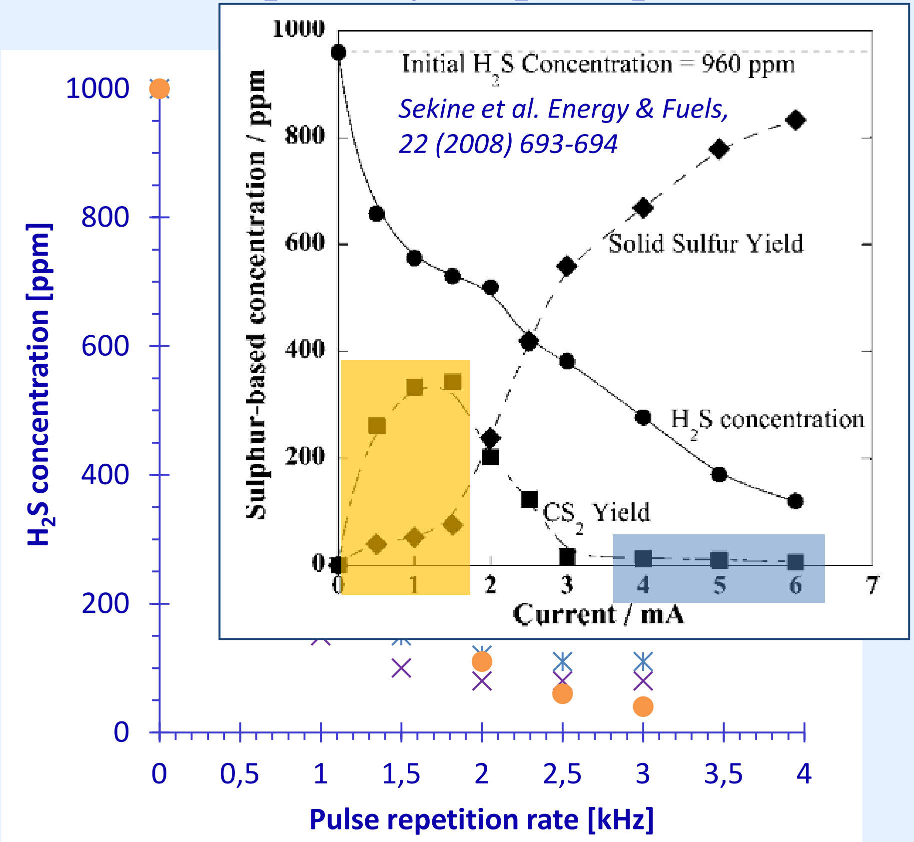


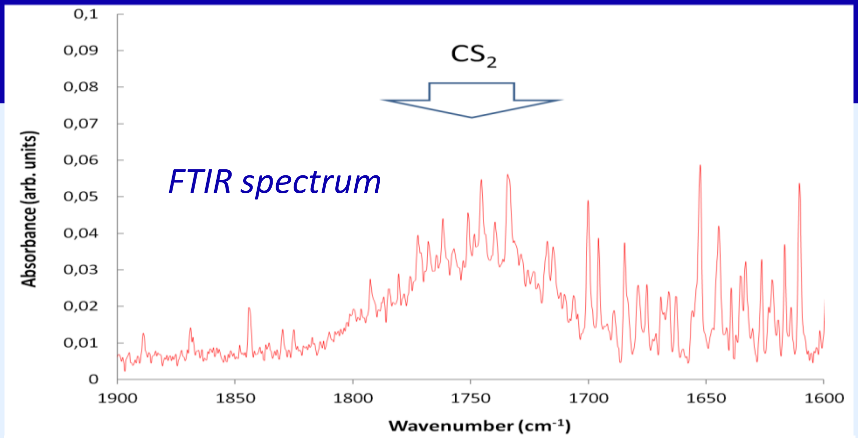
Results

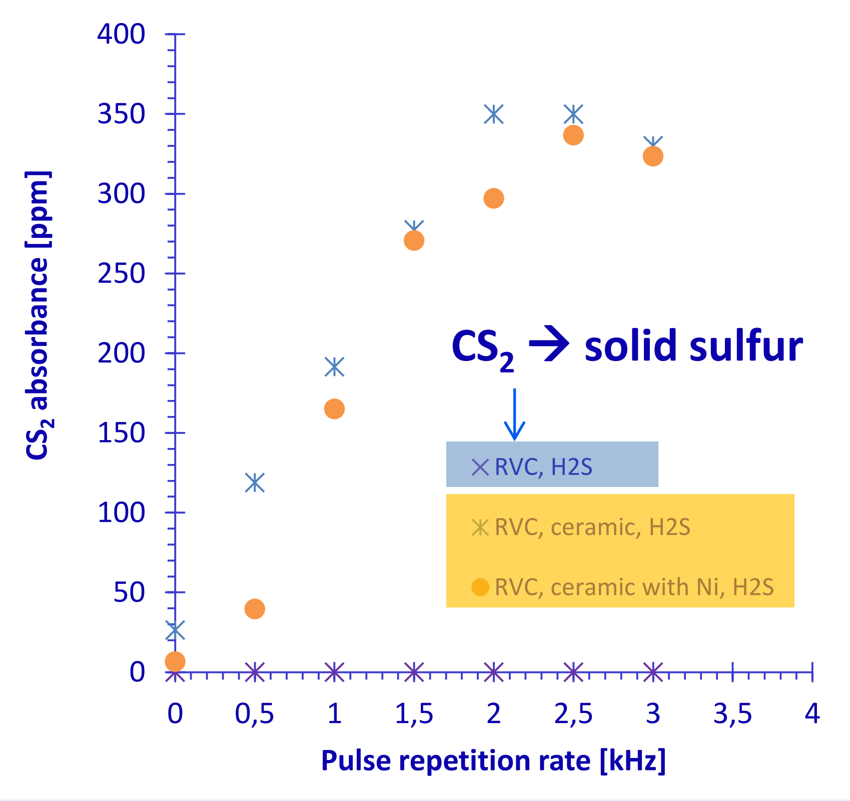
H_2S

$H_2S = H_2 + S$

$H_2S + CH_4 = CS_2 + 4H_2$

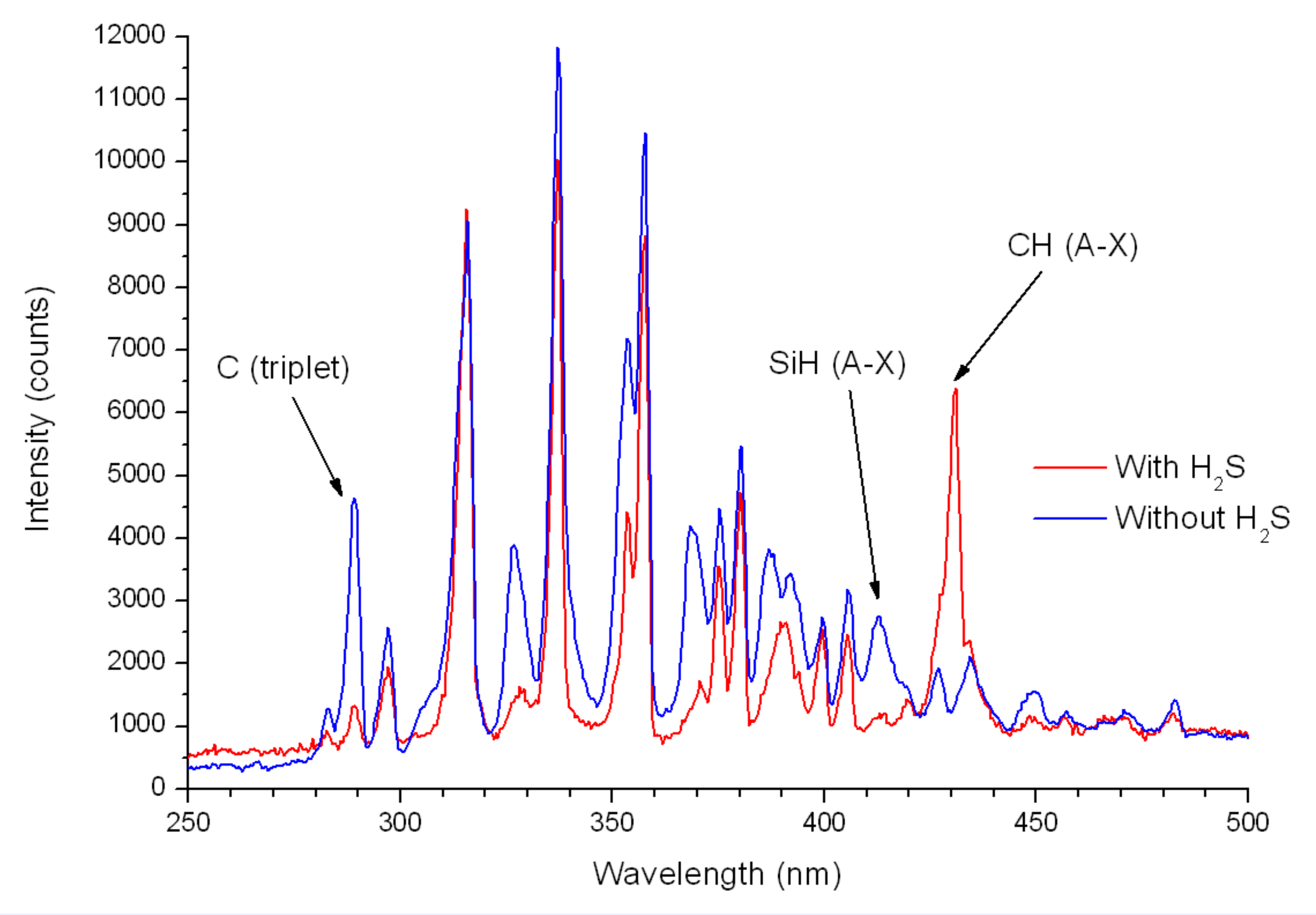






Results

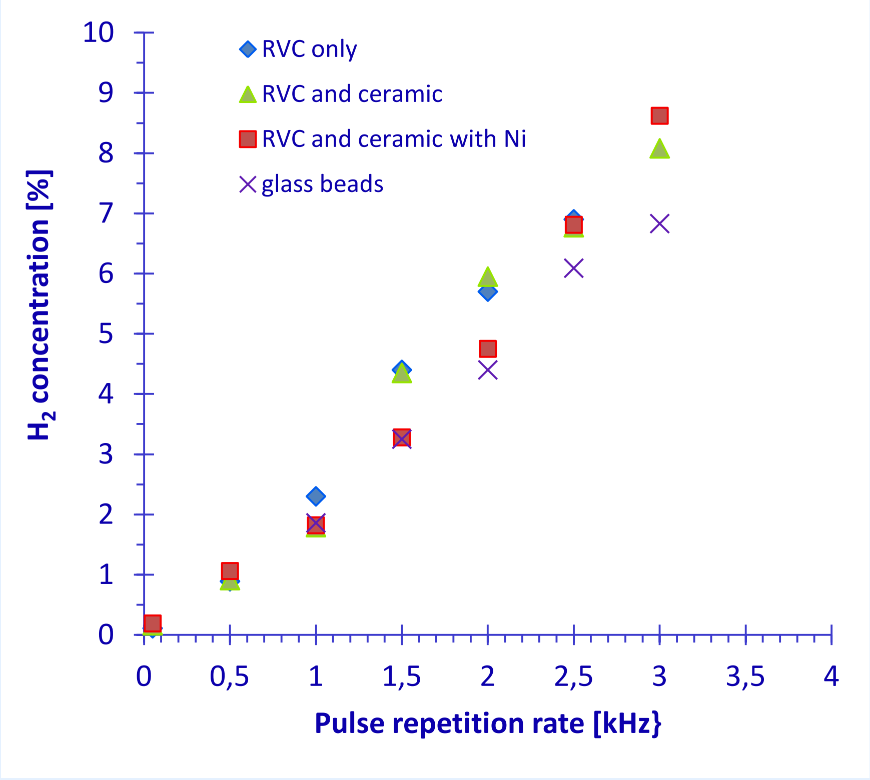
OES – influence of H_2S

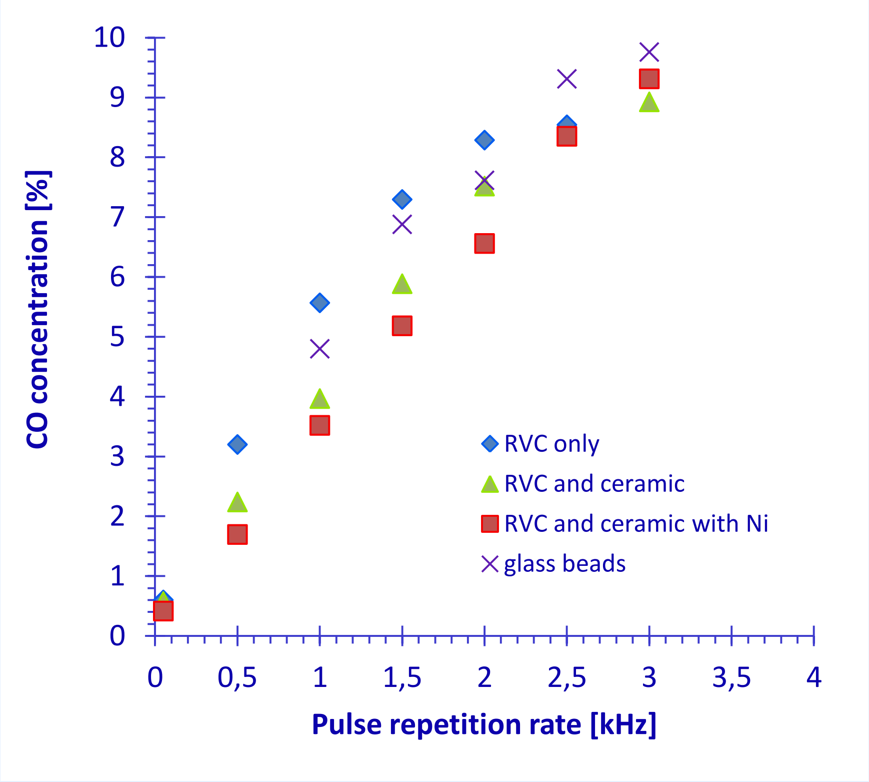


Results

Packed bed DBD reactor

Reactor with RVC and glass beads = Reactor with RVC only





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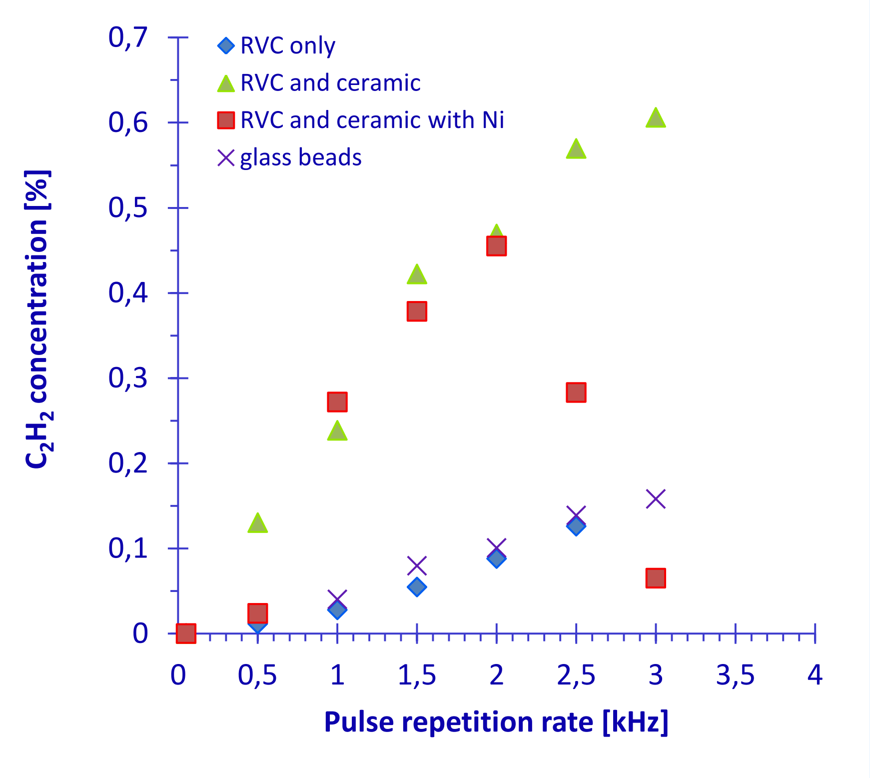

Conclusions

- **Influence of reactor geometry:**
  - higher H_2 production in the DBD with RVC only due to the higher discharge energy,
  - different by-products profile:
    - C2 hydrocarbons ↘ when discharge energy ↗,
    - C3 hydrocarbons ↗ when discharge energy ↗,
- **Influence of Ni catalyst:**
  - activated at higher pulse repetition rate,
  - decreases C_2H_2 production,
- **Influence of H_2S:**
  - is converted into soil sulfur directly and via CS_2,
  - changes discharge parameters due to deposited sulfur,
  - decreases CH_4 conversion and H_2 production,
  - poisons Ni catalyst (no activation observed).

Thank you for your attention!