



Low Energy Nanolayer Sensors

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Sensor
structure

Hydrogen
response

Mechanistic
investigations

Fire
detection

Thermal
reactivation

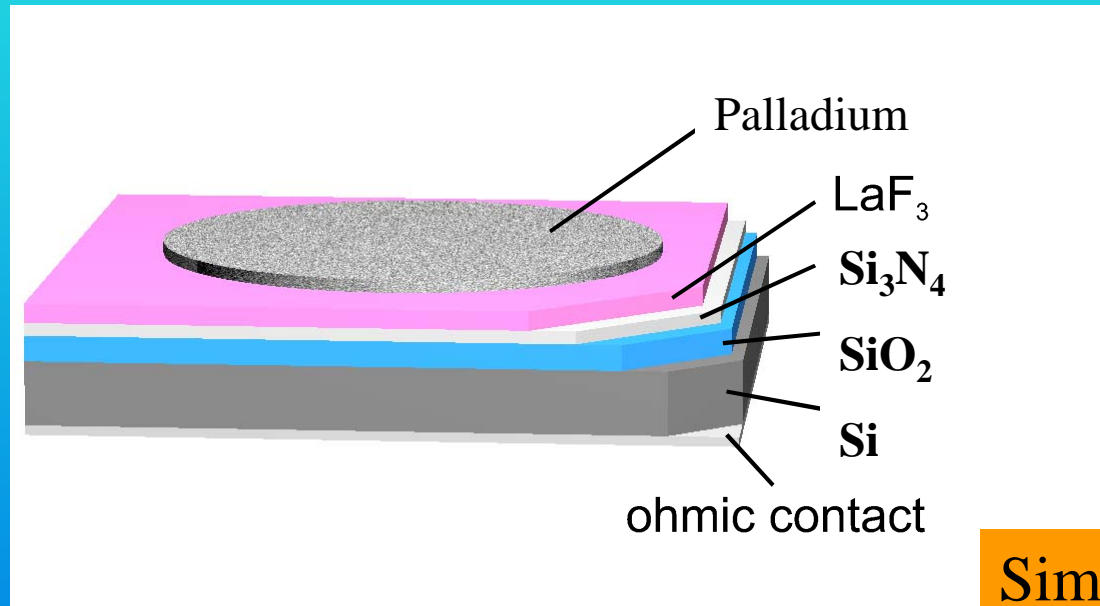
LOE
Explosion
alarm



- **Disadvantages of available hydrogen sensors:**

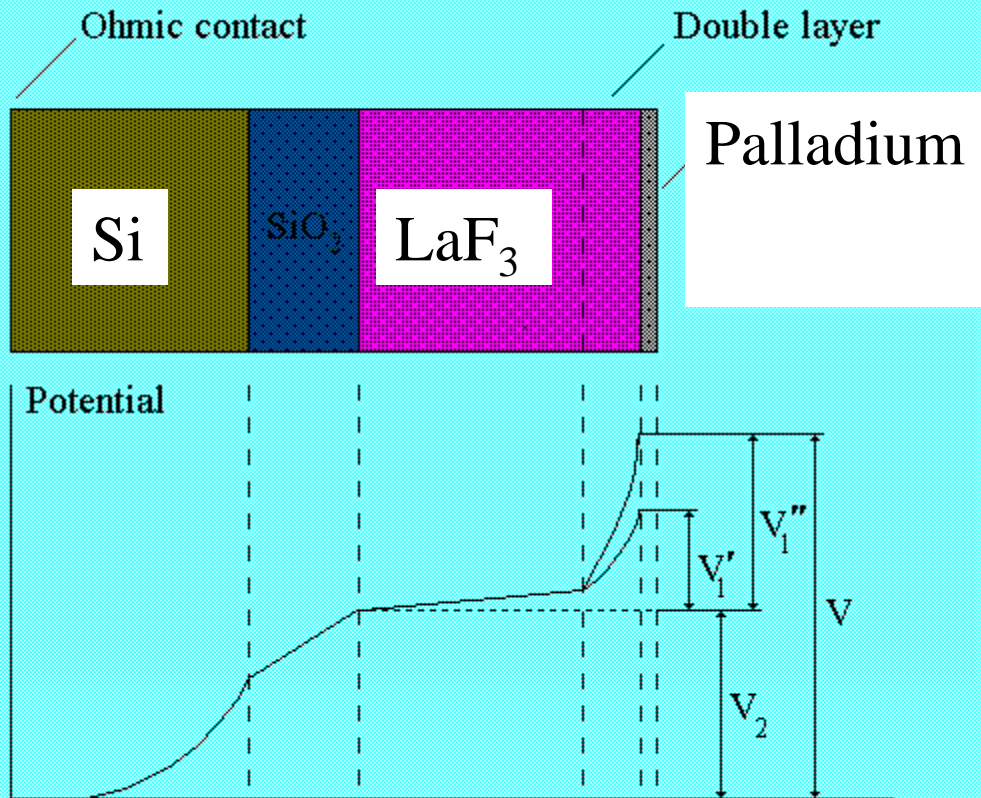
- energy consumption too high for battery powered systems due to elevated working temperature
- price too high for mass products
- poor selectivity

Sensor structure

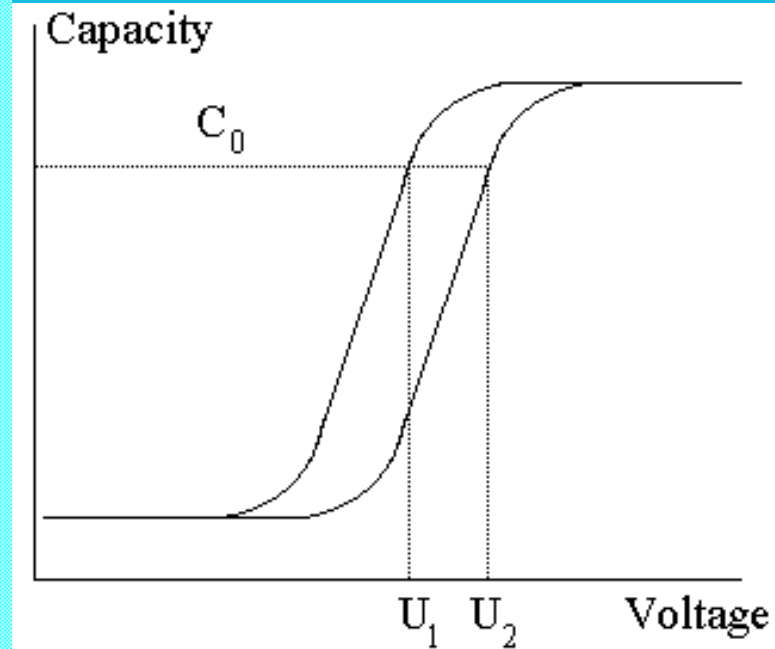


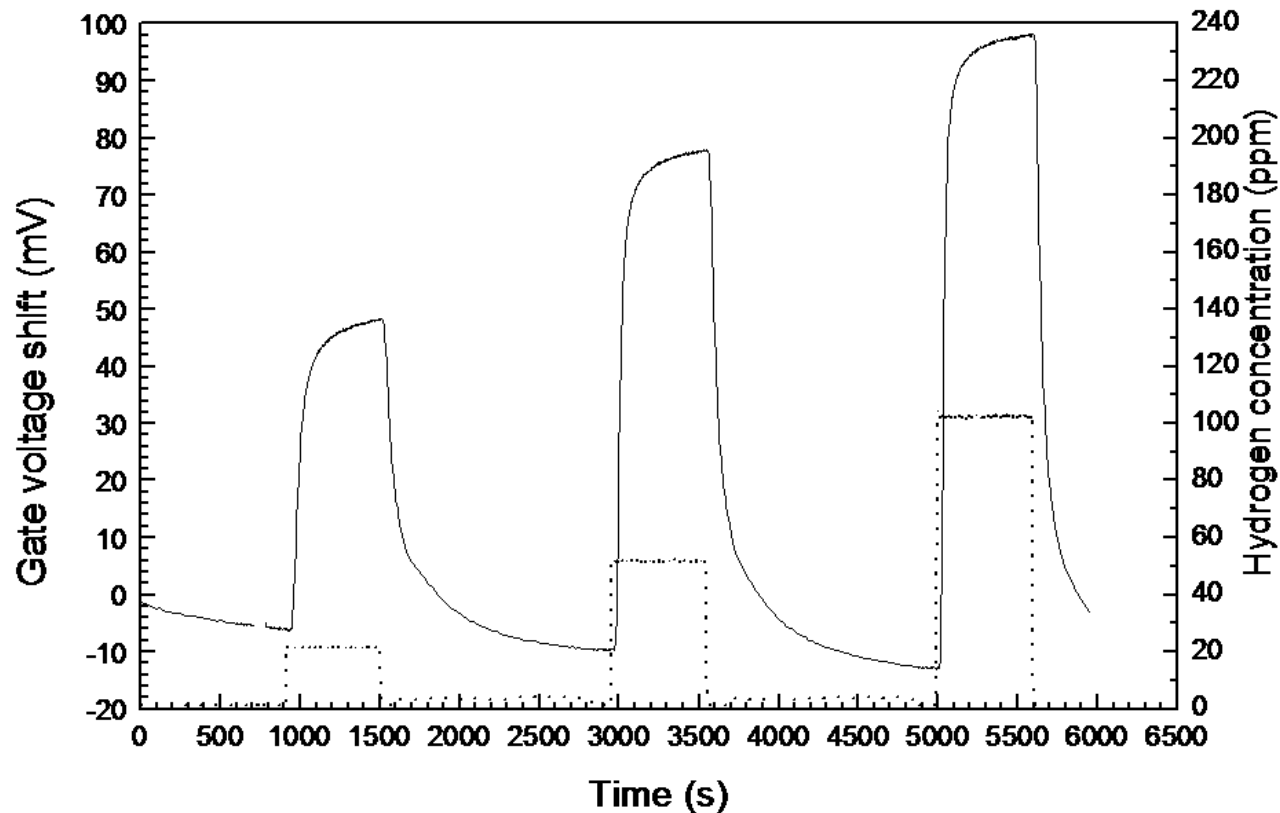
Similar to an
oxygen sensor
described earlier

Electrochemical mechanism ((different to Lundström type))



CV-measurement

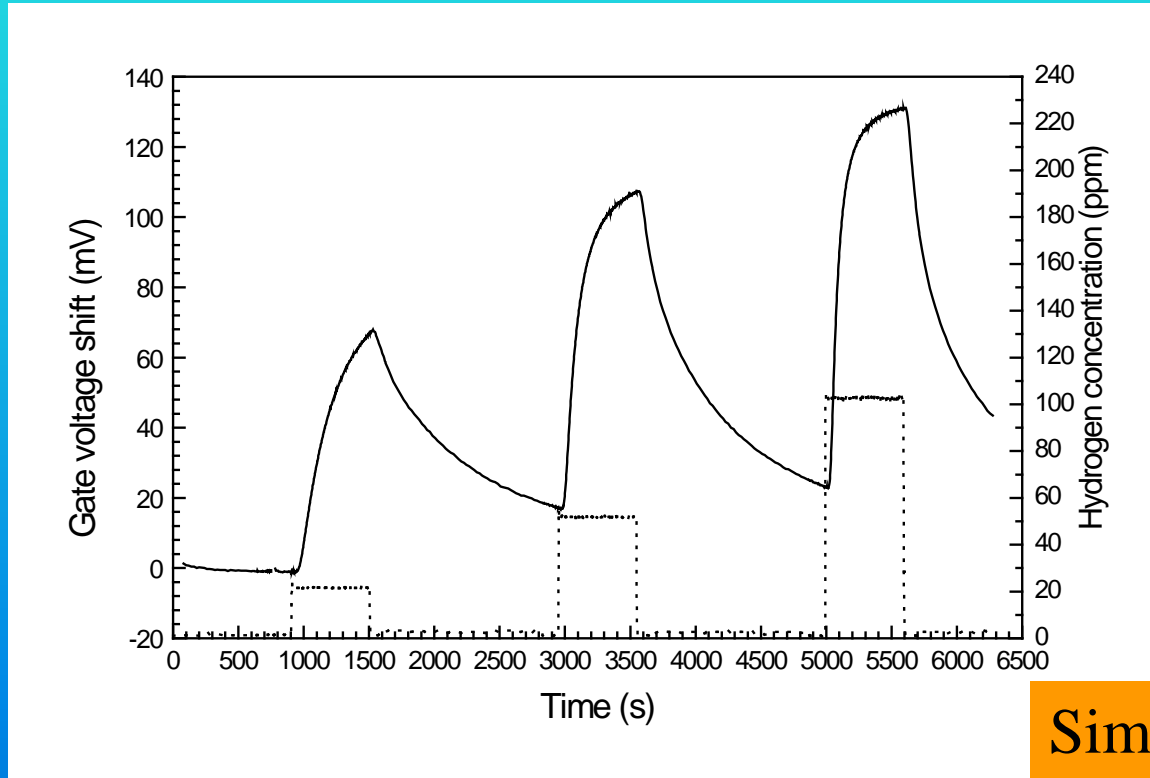




Response of the Pd/LaF₃/Si₃N₄/SiO₂/Si field effect structure (solid line and left scale) to different concentrations of hydrogen (dotted line and right scale) in synthetic air; room temperature; measurement 1 hour after preparation of the Pd layer

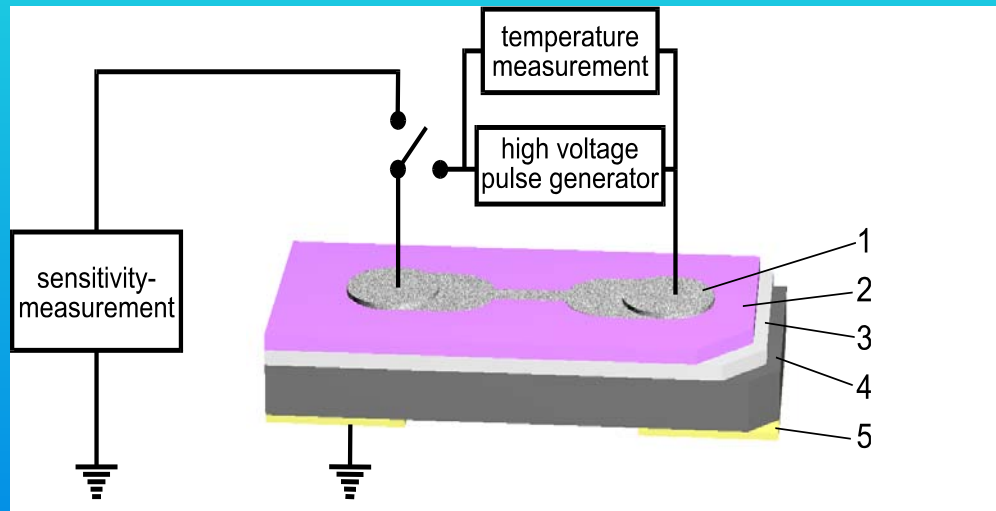


6 days after preparation



Similar to oxygen
sensor

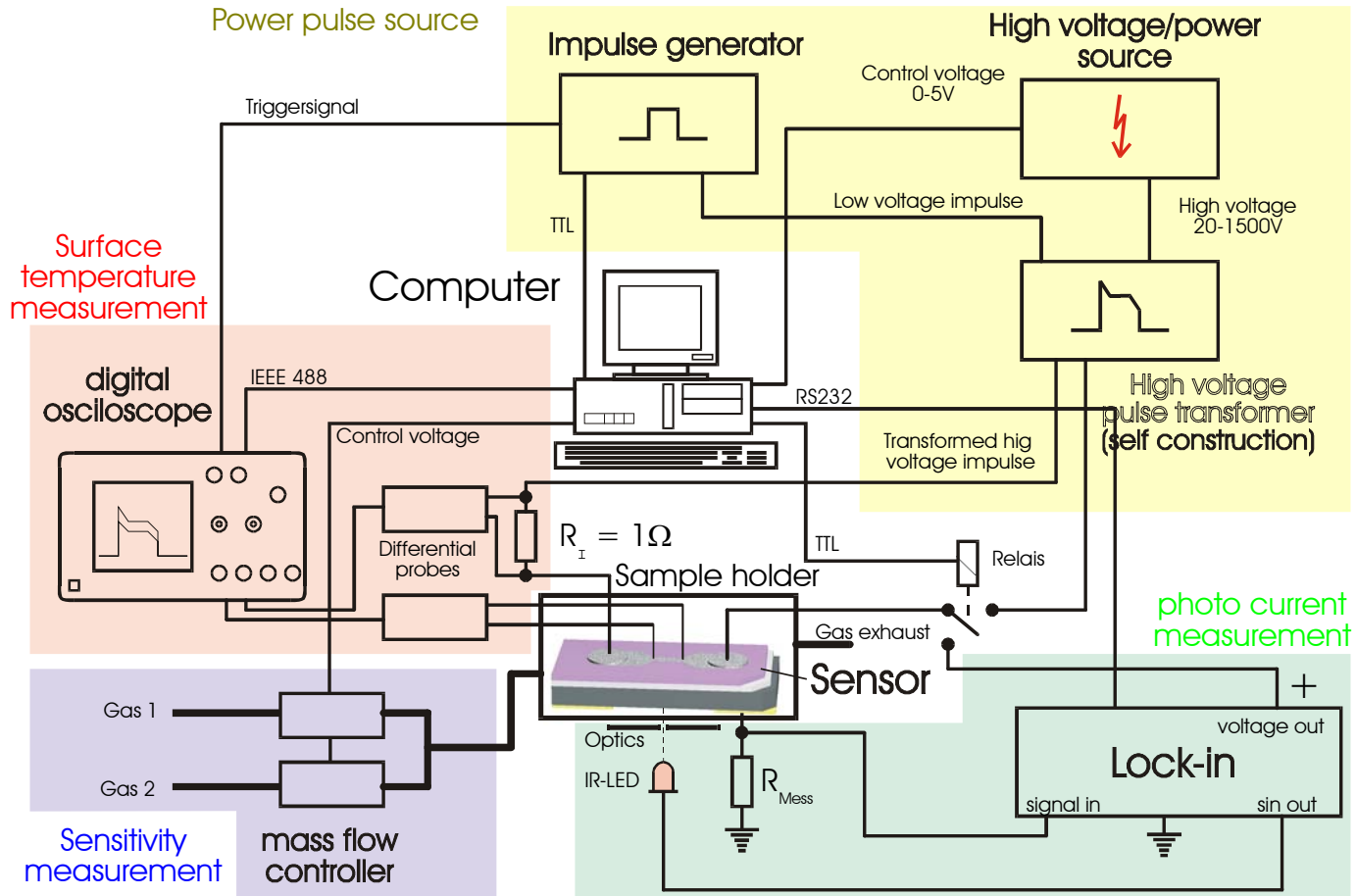
Heating and temperature measurement



No method for fast surface
temperature measurement

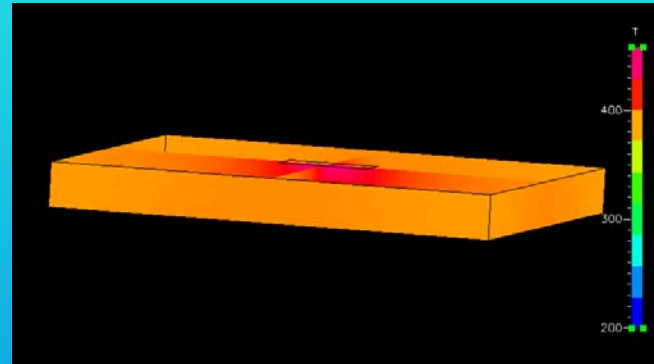
1 - Pt; 2 - LaF₃; 3 - SiO₂/Si₃N₄; 4 - n-Si; 5 - ohmic contact

Scheme of measurement

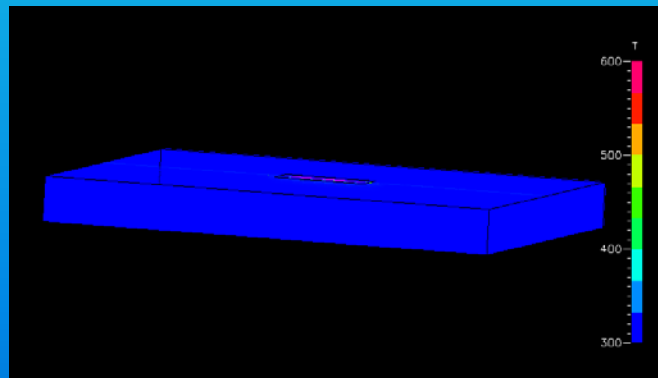




Calculations of temperature distribution

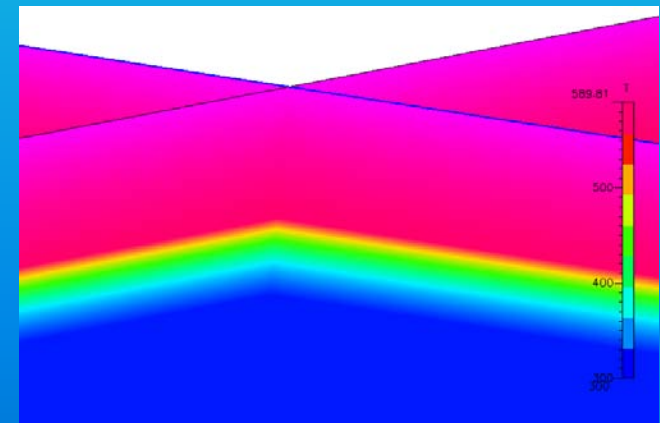


1 s
10 W
10Ws



10 μ s
100W
1mWs

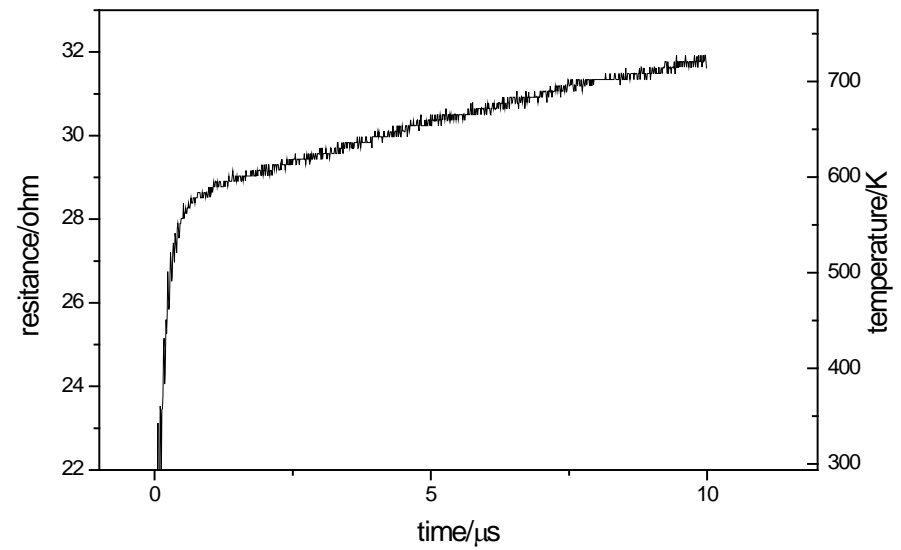
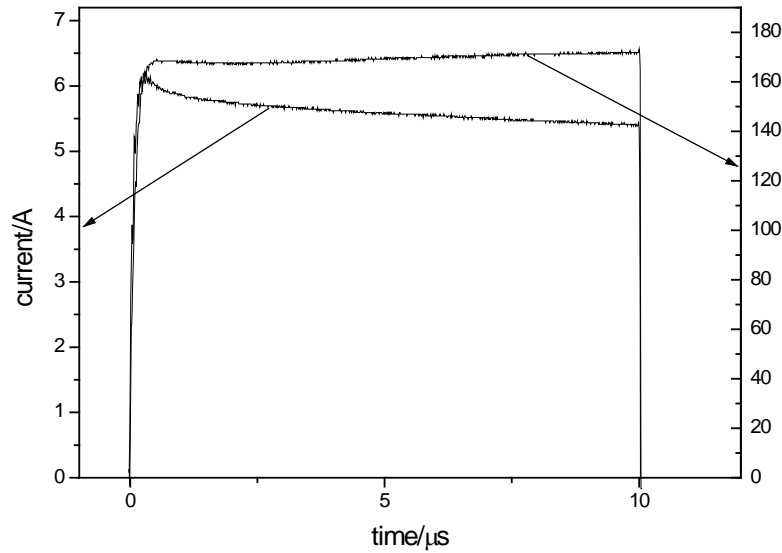
LaF₃
240 nm
SiO₂/Si₃N₄
80nm



100ns
1000W
100 μ WS

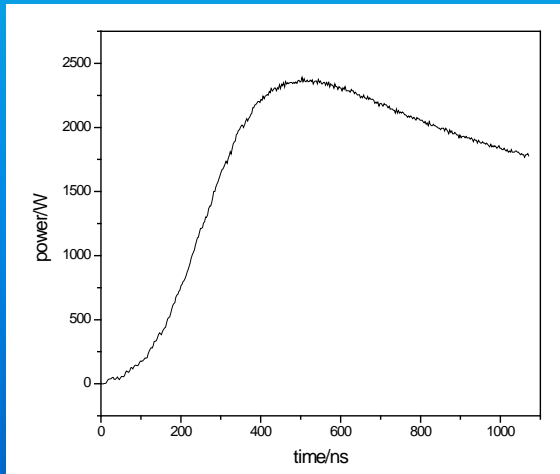
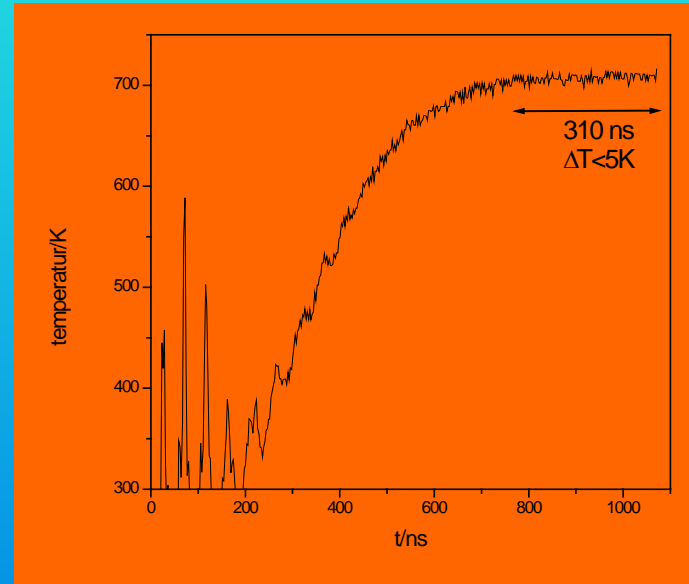
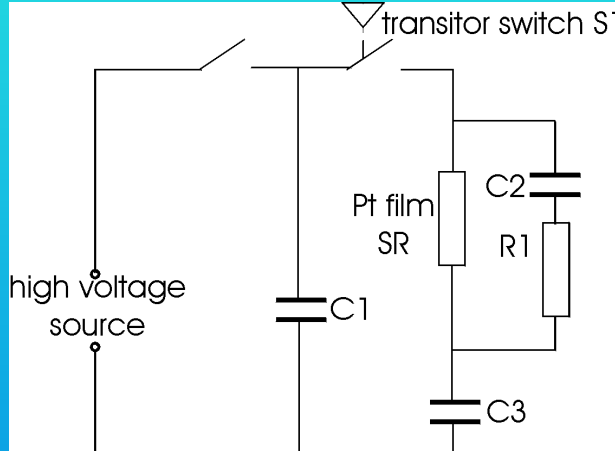


Surface heating






Constant surface temperature



Parameters of the electrical heating pulse used in Fig. above

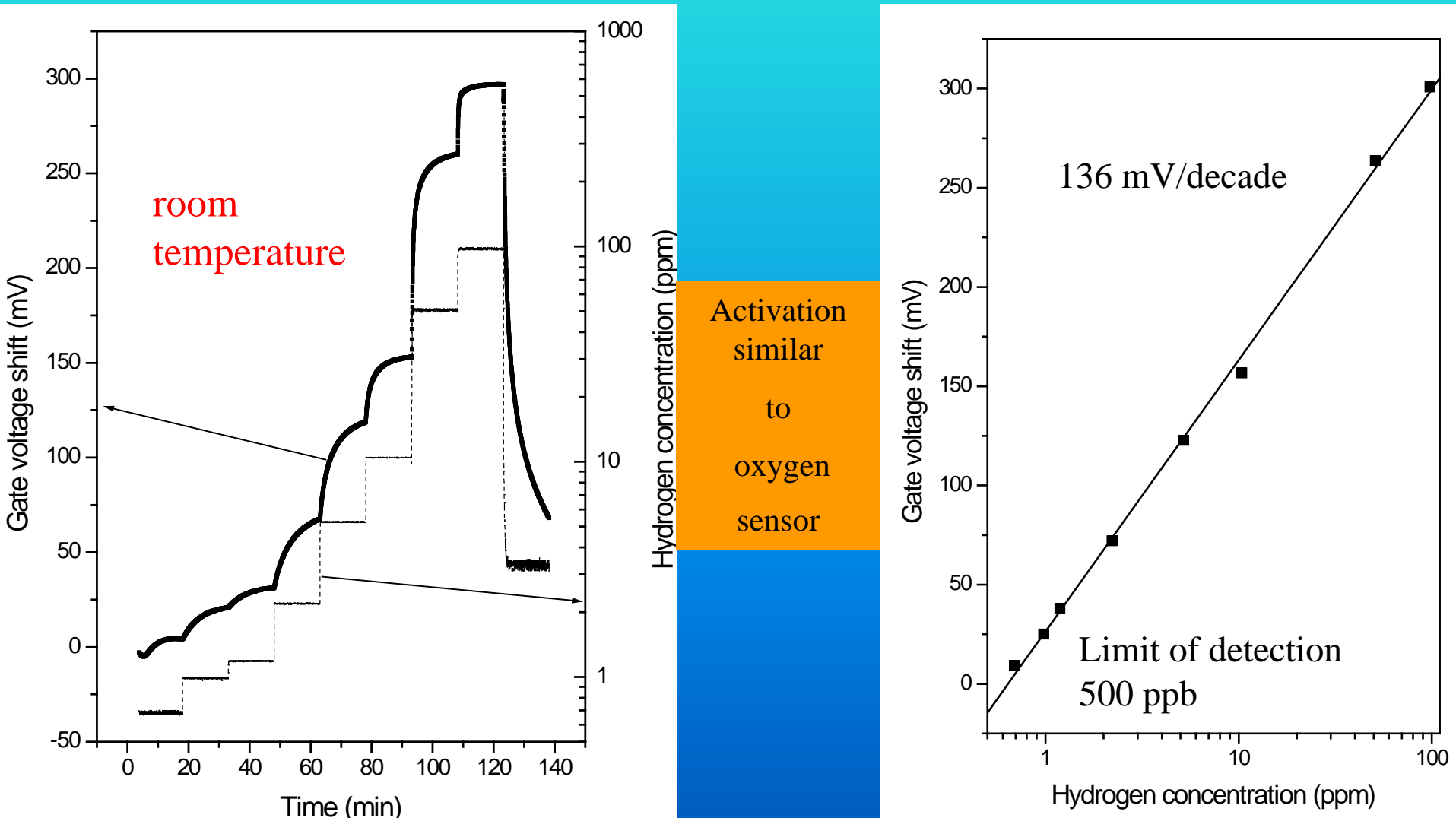
- Max. current 8,4A
- Cur. dens. $2,8 \cdot 10^7 \text{ Acm}^{-2}$
- Max. voltage 293 V
- Max. power 2365 W
- Total energy $1,82 \cdot 10^{-3} \text{ J}$
 ((average $2 \cdot 10^{-8} \text{ W}$))


 $\Delta T_{Si} = 0,025 \text{ K}$

500 activations simulating 2 years 11



Hydrogen signal in air after thermal reactivation Low concentration range



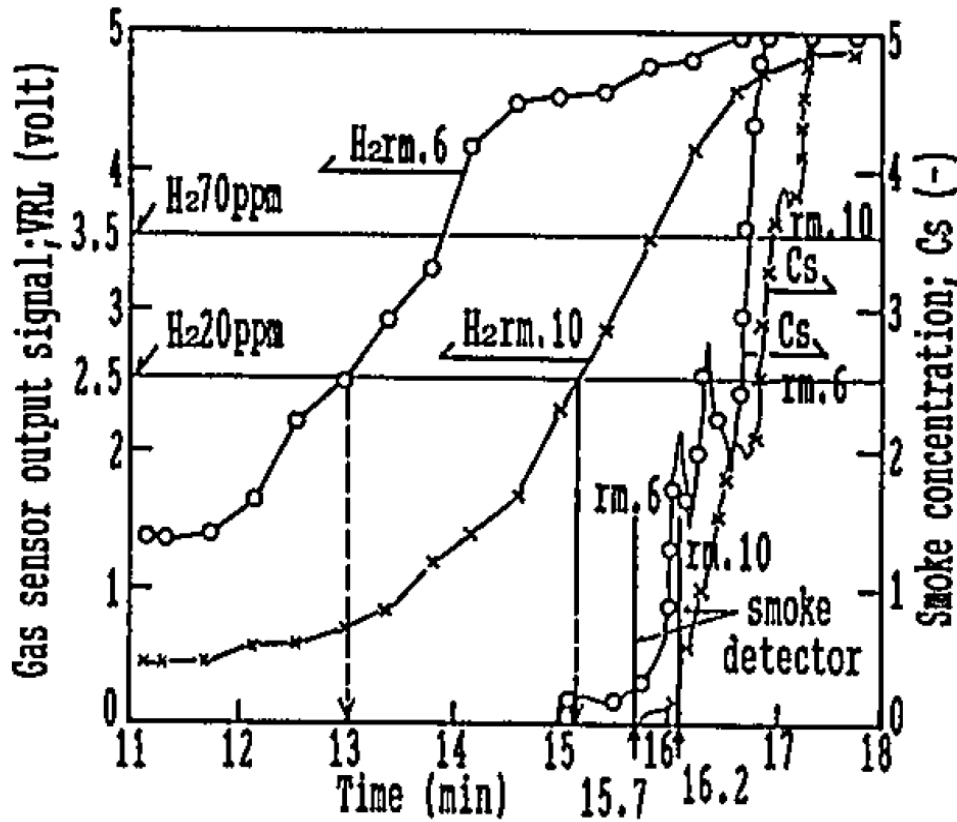
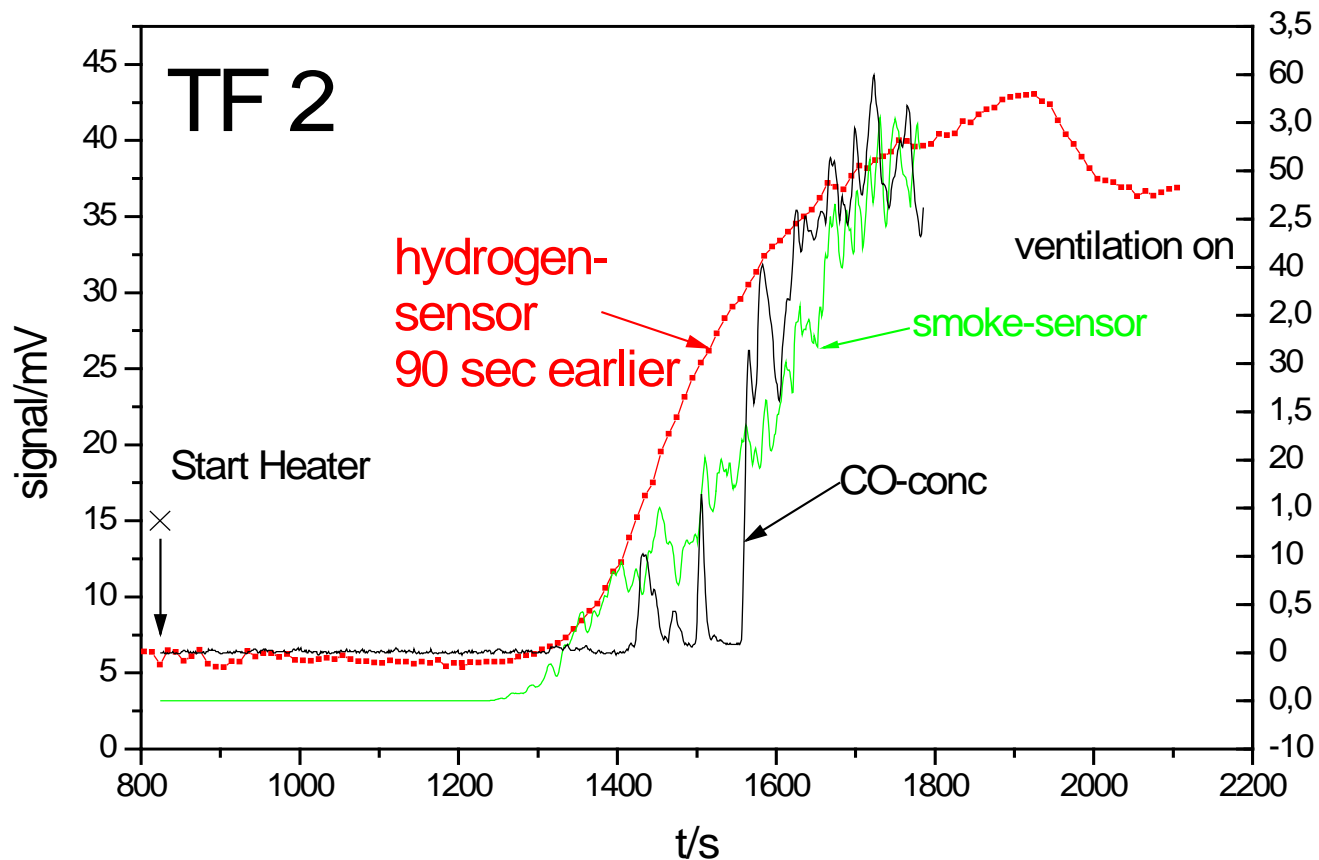


Fig. 5. Comparison between gas sensors, conventional smoke detectors and smoke concentration.

A Fire Experiment in a
 Wooden House.....
 T- Amamoto et al.,
 Sensors and Actuators,
 B1 (1990) 226-230



Early state of Fire (smoldering) TF 2 wood on electrical heater





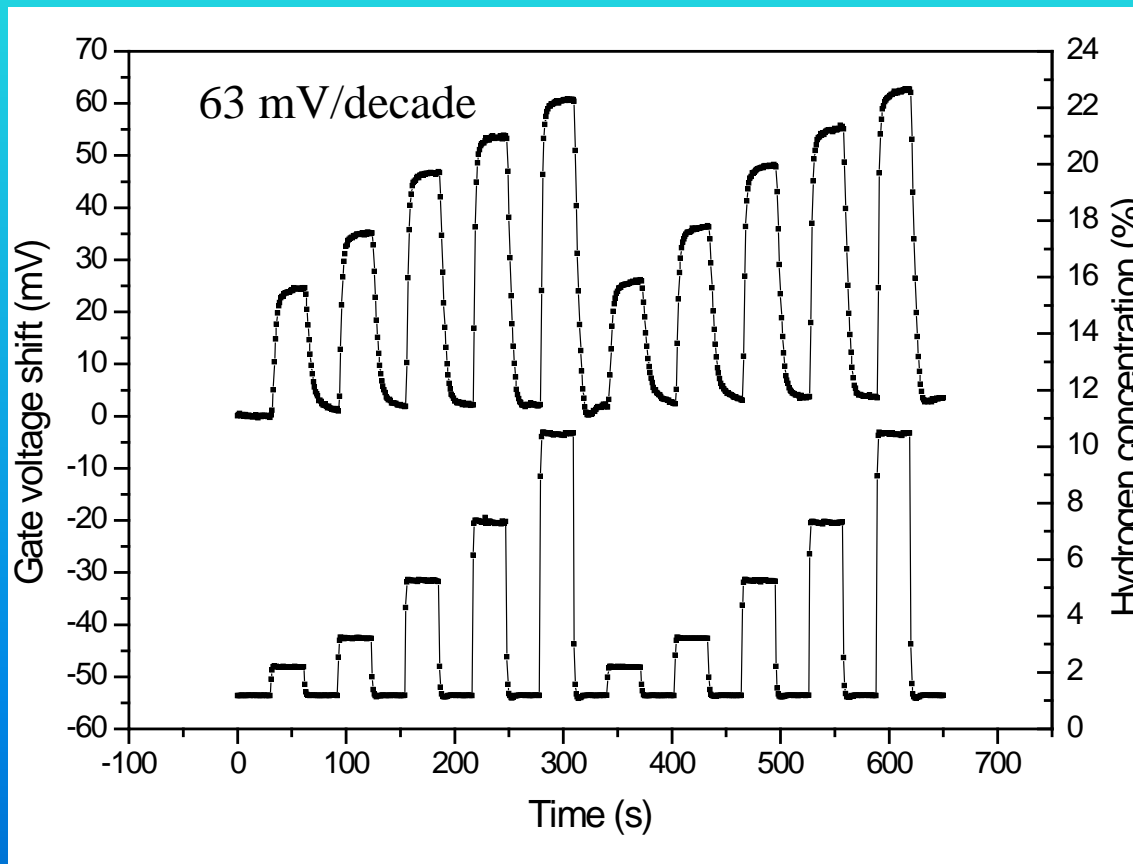
High concentration range

- LOE
- Limit of explosion 4% Hydrogen in air

Mass markets

- Fuel cells
- Hydrogen cars in garages

High concentration range

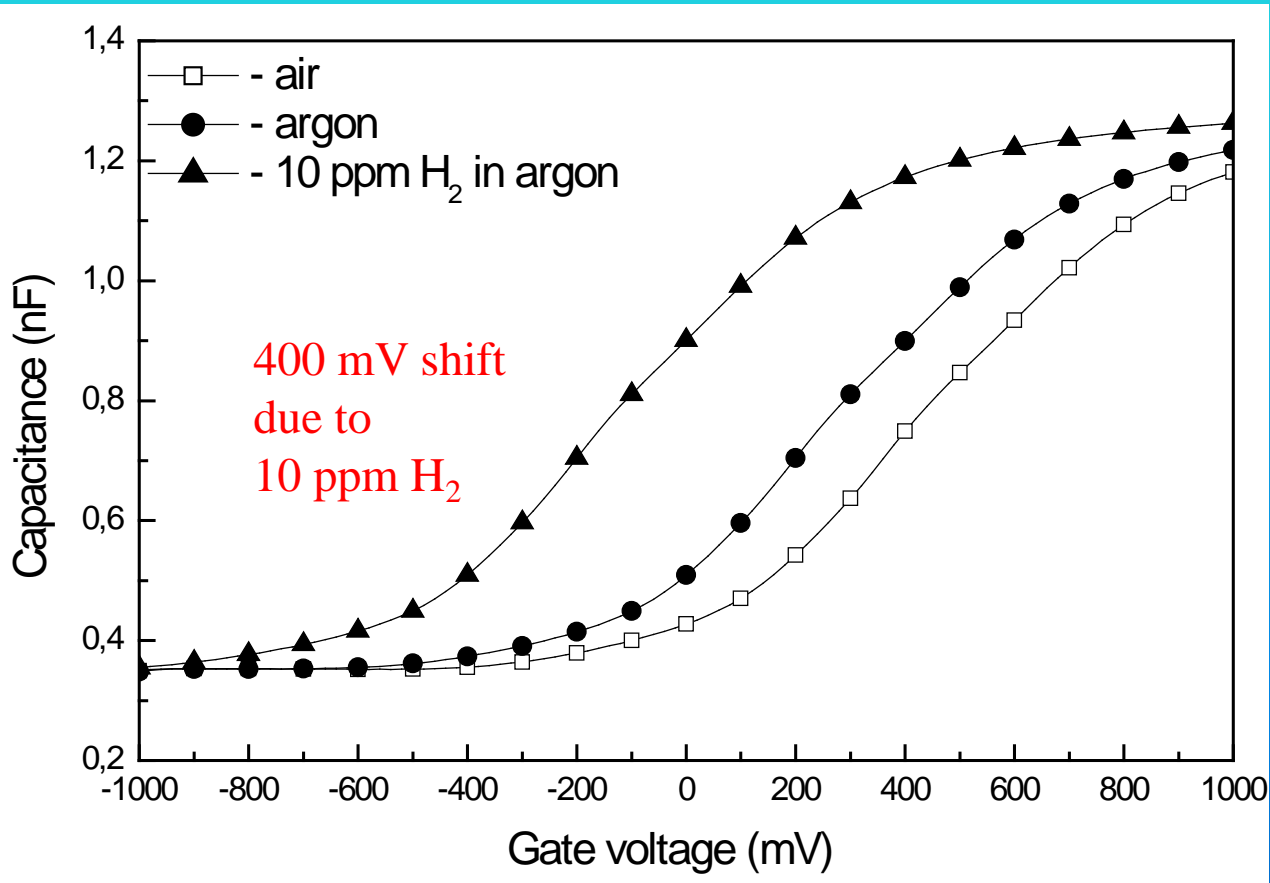


gate voltage at the base line concentration of 1% was set to 0 V



Mechanism

Hydrogen measurements in argon



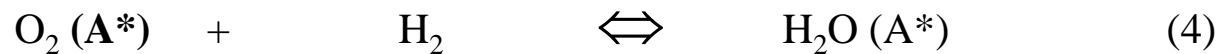


Mechanism

Oxygen sensor



Additional hydrogen action





Conclusions

- room temperature hydrogen sensor in ppm range and for high concentration
- thermal reactivation is possible
- Low energy consumption for heating impuls
- early fire detection
- alarm at lower explosion level
- Battery power application for long time
- Combination with energy harvesting technology possible