# Pd-functionalized MEMS resonator for hydrogen gas sensing

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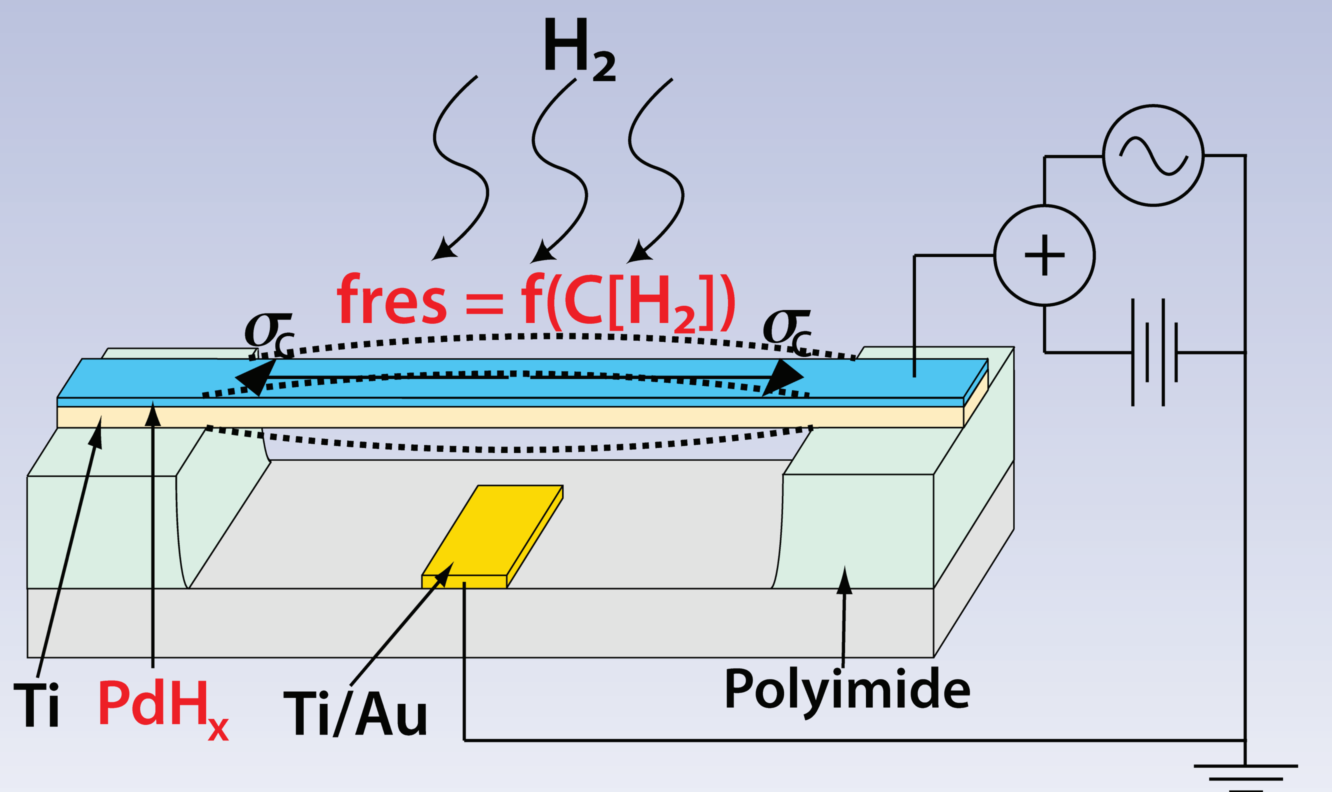
This work presents the fabrication and characterization of a novel hydrogen-detecting micro-resonator based on the expansion of palladium (Pd) as it is exposed to hydrogen (H2) gas. The working principle of the device has been confirmed and it shows a stronger response at a given H2 partial pressure than what theory predicts using bulk Pd material parameters. This may be explained by properties that are specific for Pd thin films in the nano-metre range. The results suggest that the presence of very dilute amounts of hydrogen gas could be detected and the dynamic range of the device could be greatly increased if the device is optimized further.

## Working principle

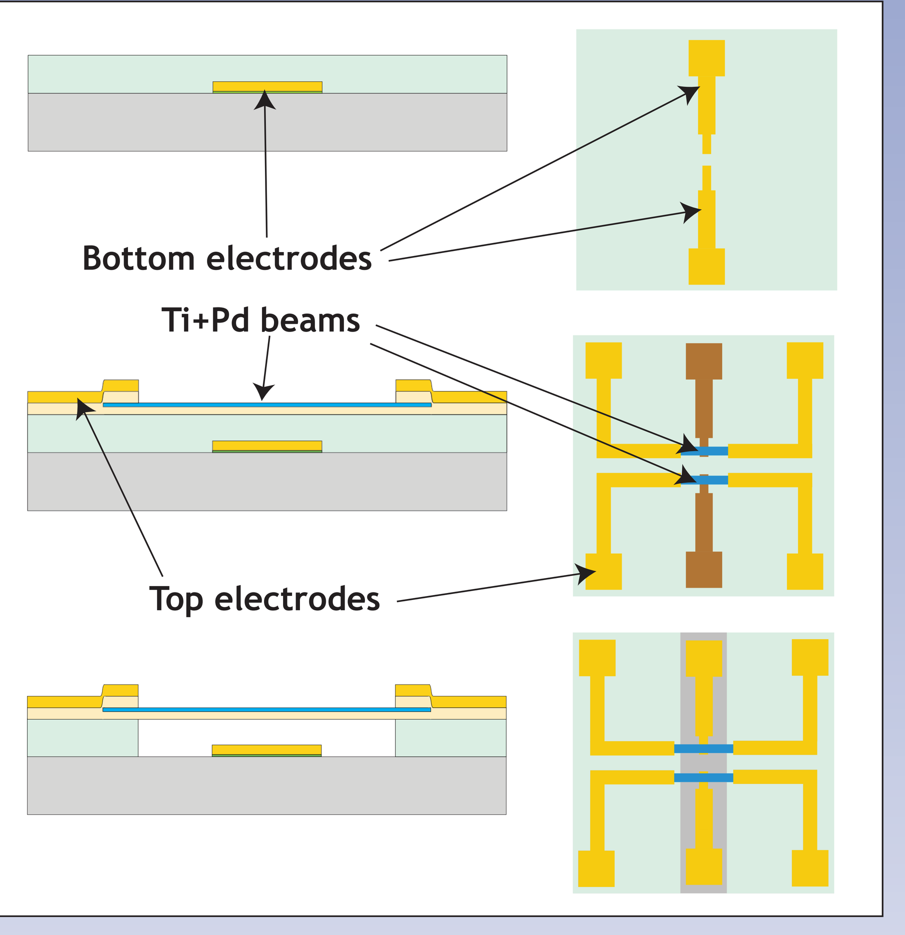
The working principle consists in the fact that a change of longitudinal stress in a double-clamped structure causes a change of resonance frequency. The beam is coated with Pd, which is longitudinally constricted by the clampings of the structure, hindering the strain that is normally observed during the phase transition to PdHx during H2 exposure.




Thus a compressive stress is induced, effectively softening the beam and thus lowering the resonance frequency.

## Fabrication

Beams dimensions: 10-35 µm x 1.5-6 µm x 0.2 µm

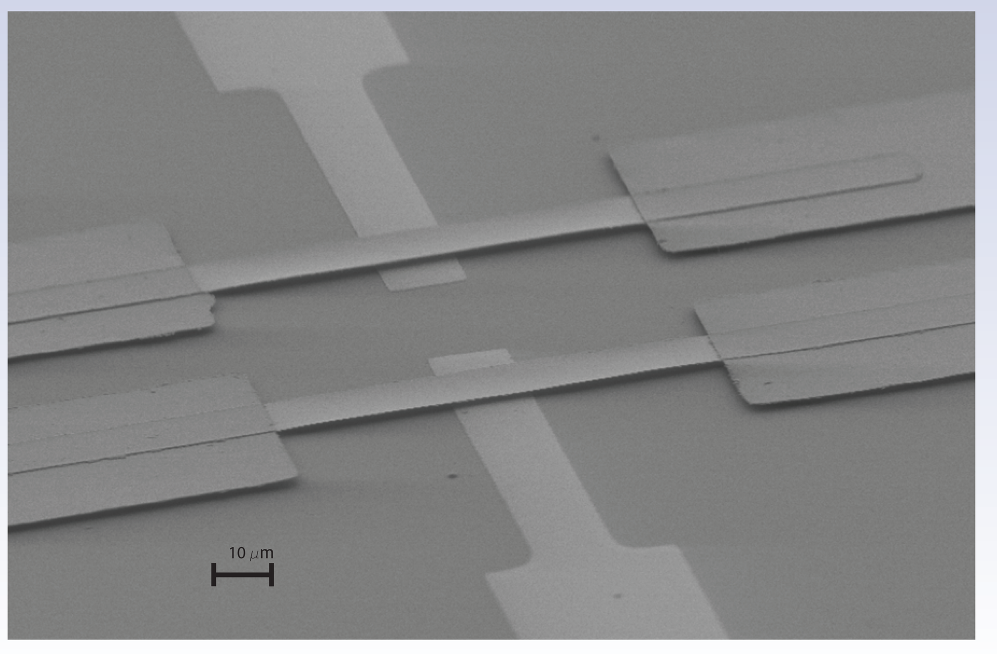



Bottom electrodes (Au) are defined on a pyrex wafer. The wafer is then coated with polyimide or parylene as a sacrificial layer.

Beams (Ti+Pd) and top electrodes (Ti+Au) are defined.

Beams are released in oxygen plasma.

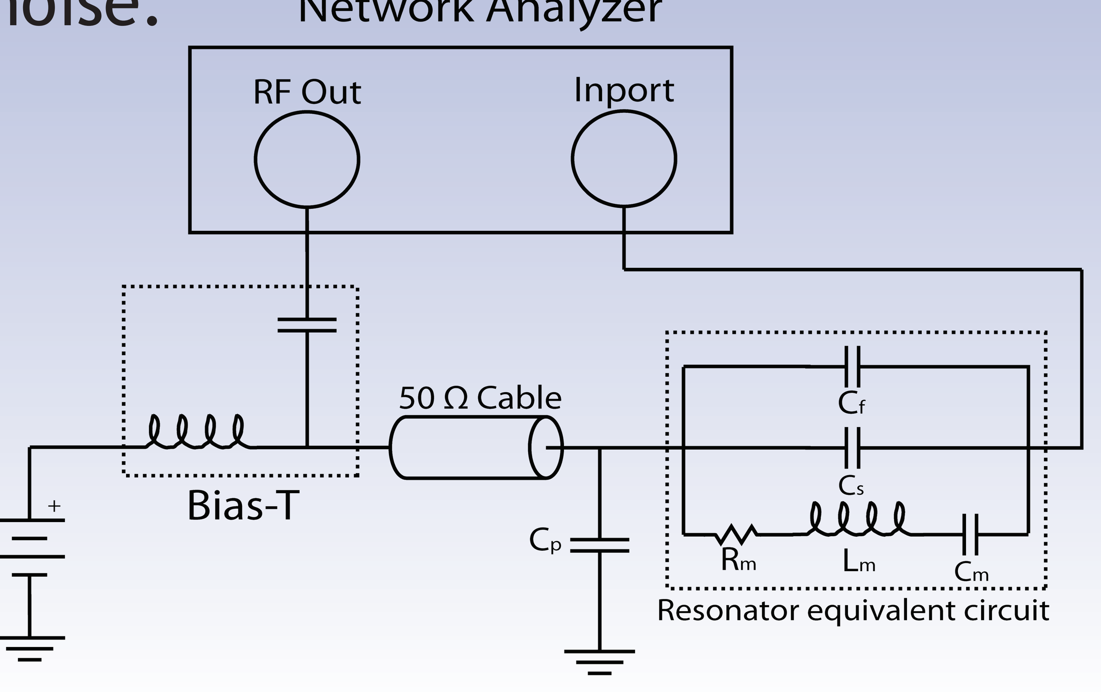
Calculated characteristics for dimensions
60 µm x 3 µm x 0.2 µm
**Resonant Frequence:** 1.45 MHz
**Spring Constant:** 0.21 N/m
**Pull-in voltage:** 69 V



## Measurement setup

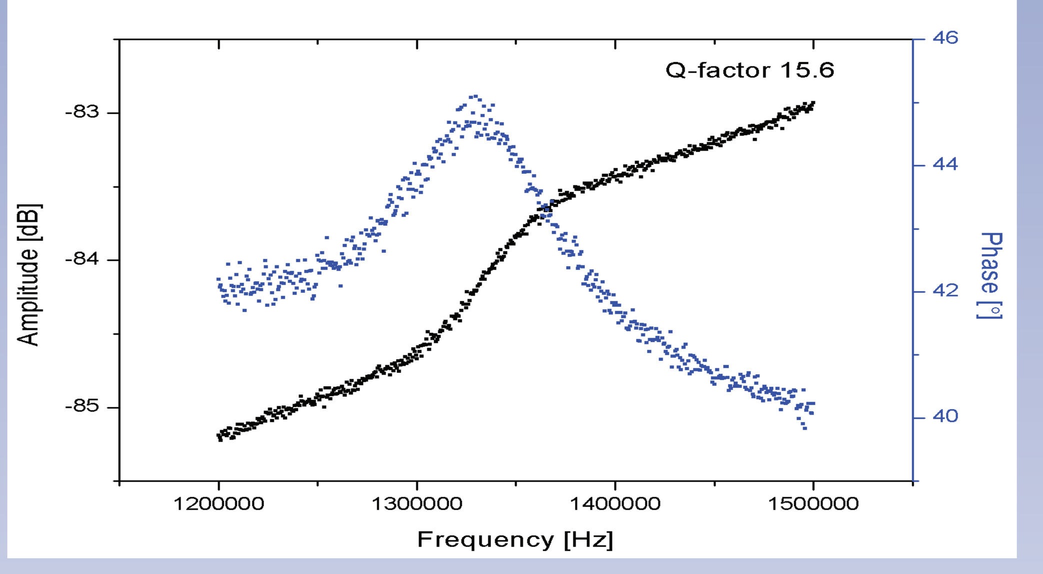
The network analyzer sends a RF-signal which is added to a DC bias using a bias tee. The transmission of the device is measured as the signal frequency is varied. Device actuation and measurement of amplitude and phase are thus simultaneous. Also a differential approach, using a power splitter, is implemented in order to lower background noise.

Settings:
Vdc = 30 V
Vac,rms = 5 V

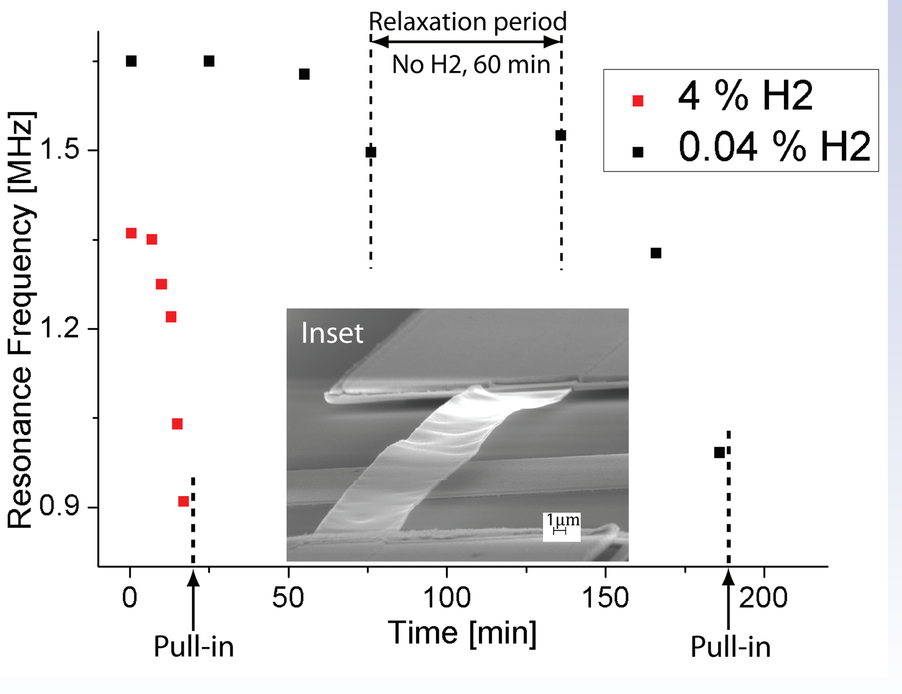



## Characterization

**Transmitted response at resonance (60 µm x 3 µm x 0.2 µm)**




**Hydrogen exposure experiments**




## Conclusions

- It was possible to verify the working principle and acquire a response to H2.
- The Pd film responds more powerfully to a certain partial pressure of H2 gas than what could be expected from bulk Pd, suggesting a higher hydrogen content in the film. This is coherent with the findings by Huang et al. (2005).
- The sensitivity of the device is high but its robustness is unsatisfying.

## References

X.M.H. Huang, M. Mandolis, S.C. Jun, and J. Hone, App. Phys. Lett., 86(14) (2005)

S. Okuyama, Y. Mitobe, K. Okuyama, K. Matsushita, Jpn. J. Appl. Phys. 39 (2000)