3D-Patterning using a short pulse laser to manufacture thermal sensors with high sensitivity and robustness

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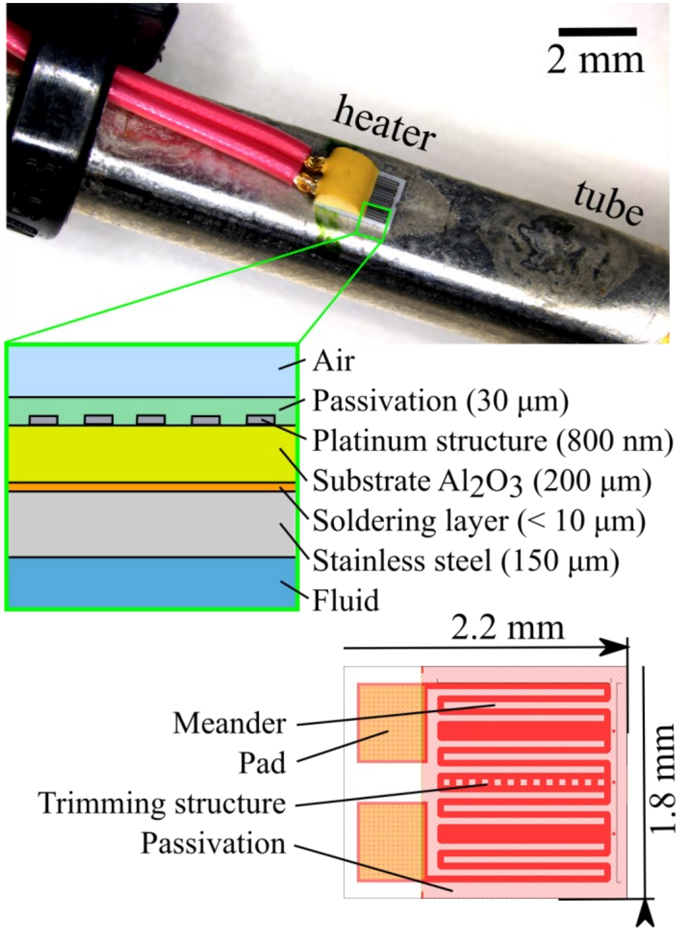
Innovative Sensor Technology
physical. chemical. biological.

Motivation

- **Thermal sensor for aggressive and corrosive fluids**

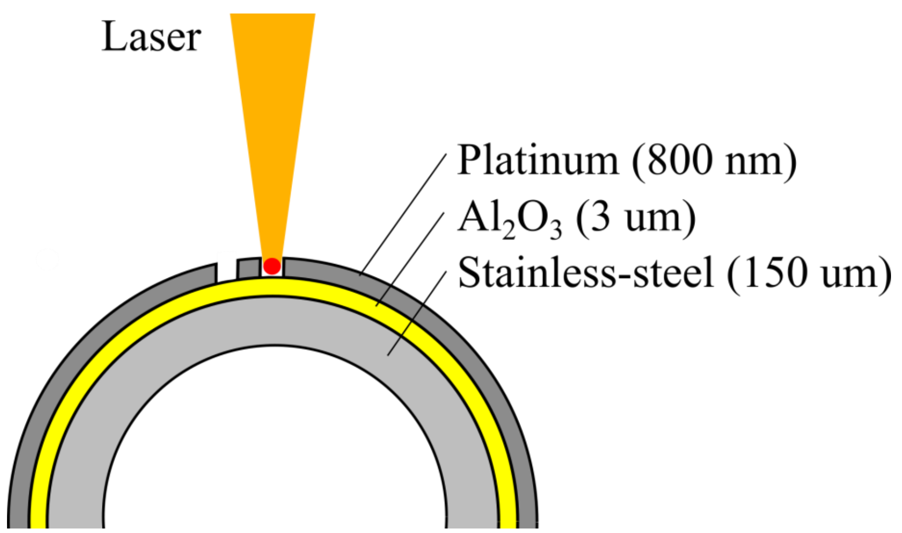
- **Standard structure**
  - Platinum thin film element soldered on a stainless steel tube
  - Loss of sensitivity due relatively larger distance between the sensitive structure and the fluid of interest



R.E. Bernhardsgrütter, et al., Sens. Actuators A: Phys., 321, 112419, https://doi.org/10.1016/j.sna.2020.112419, 2021

Motivation

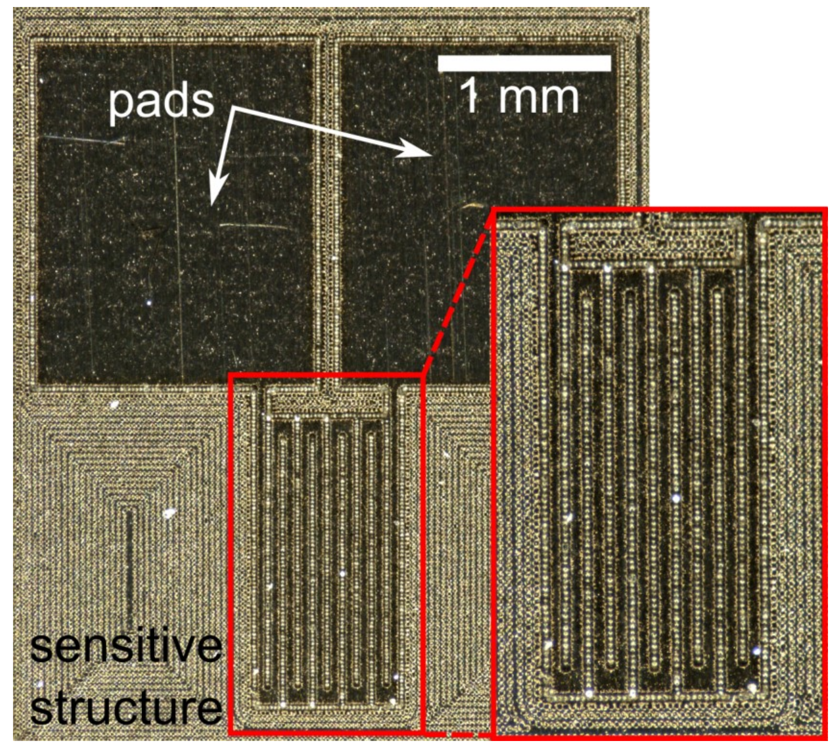
- **Approach**
  - Using a thinner insulation layer
  - Using laser ablation to pattern the sensitive structure



- **Advantages**
  - No lithography processes
  - Patterning and trimming can be unified
  - Non-flat structures can be patterned

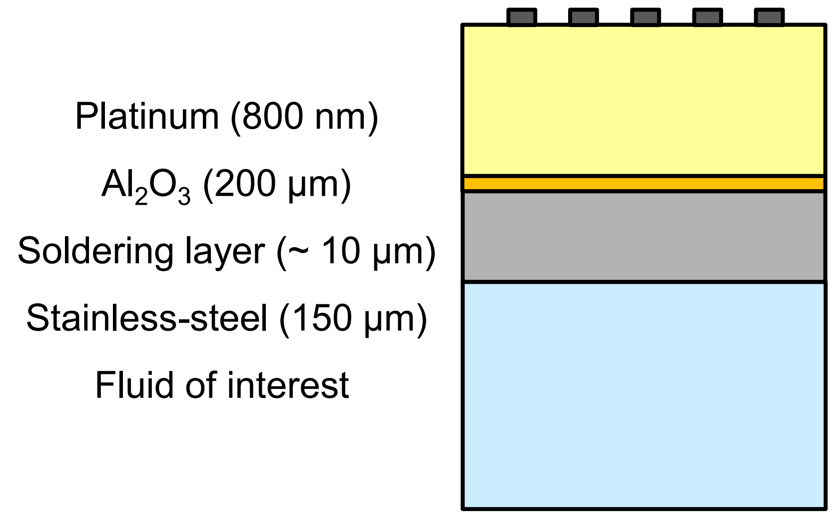
Prototype

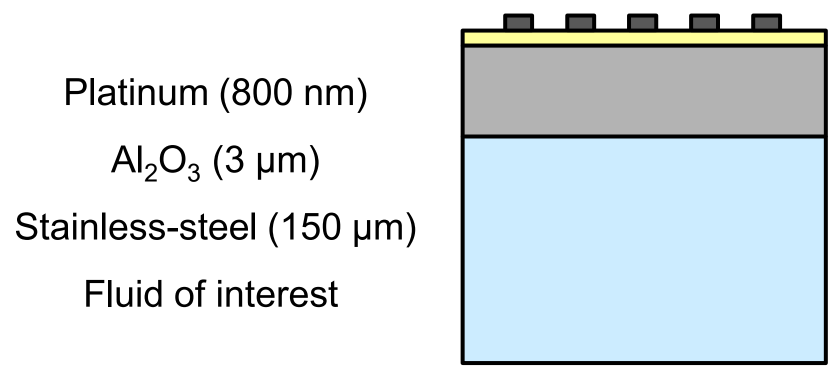
- **Nd:YAG laser**
  - Wavel length: 1064 nm
  - Pulse lenght: 100 ns
  - Spot size: 64 µm
- **Resistor: 55 Ω resistance at room temperatur**
- **Limitation:**
  - Resolution is around 50 µm
  - No selective ablation



Characterisation: 3ω-method

- **Behavior of thermal sensor is investigated by the 3ω-method**
  - Known measurement method for thermal conductivity and heat capacity.
  - Based on thermal wave
  - Sensitive for small changes in the sensor structure
    - Comparsion between state-of-the-art and prototype

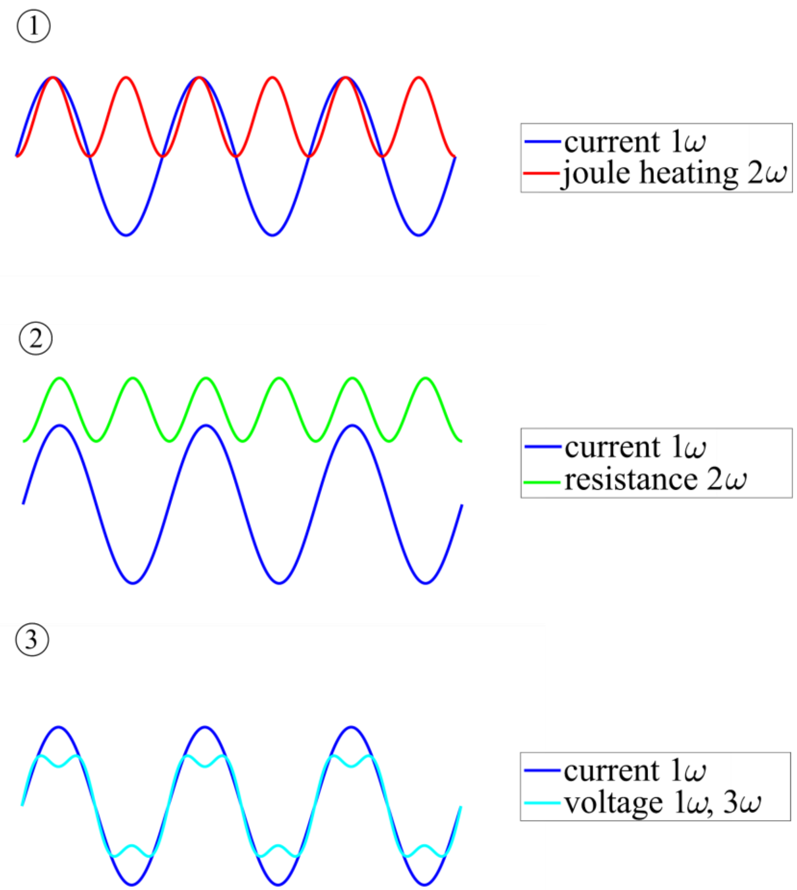




Characterisation: 3ω-method

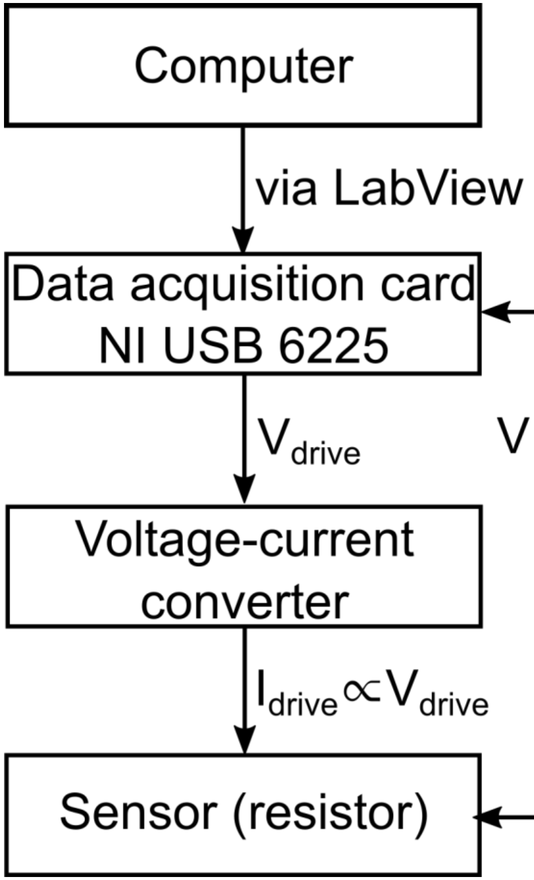
- **AC-driven resistance with defined TCR**

1. $I = I_0 \cos(\omega t)$
2. Heater resistance change with 2ω due to the defined TCR
3. Heater voltage is R · I and has a term with 3ω. The 3ω-term contains information about the thermal properties in the surrounding



Setup

- **Digital lock-in amplifier**
  - Typical measurement frequency: 0.1 Hz – 1000 Hz
  - Current amplitude: 30 mA
- **Advantages of a digital lock-in amplifier**
  - Phase sensitive
  - No physical reference is needed



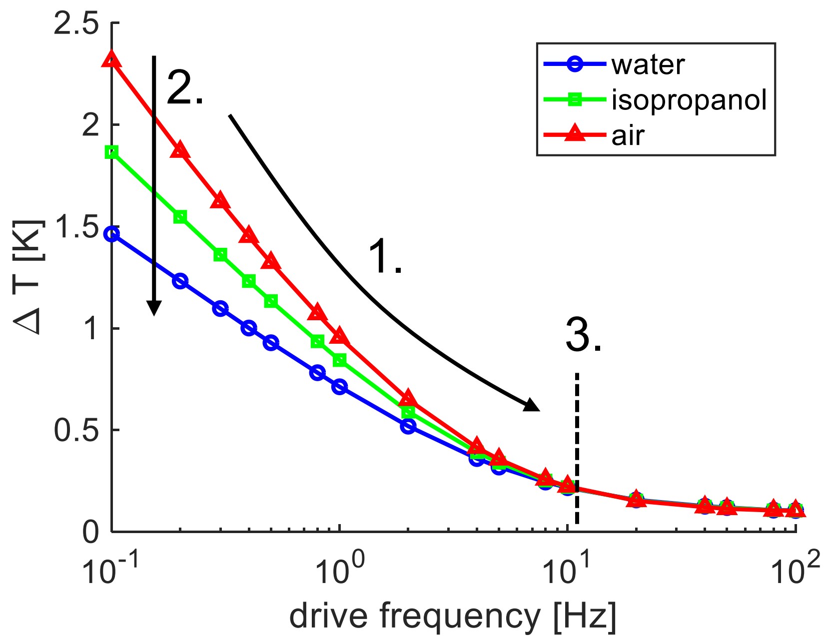
R.E. Bernhardsgrütter, et. al., J. Sens. Sens. Syst., 10, 5–12, https://doi.org/10.5194/jsss-10-5-2021, 2021

Results

1. **The amplitude shows a monotonic decreasing behavior**

2. **Signal decreases if the thermal parameter increases**

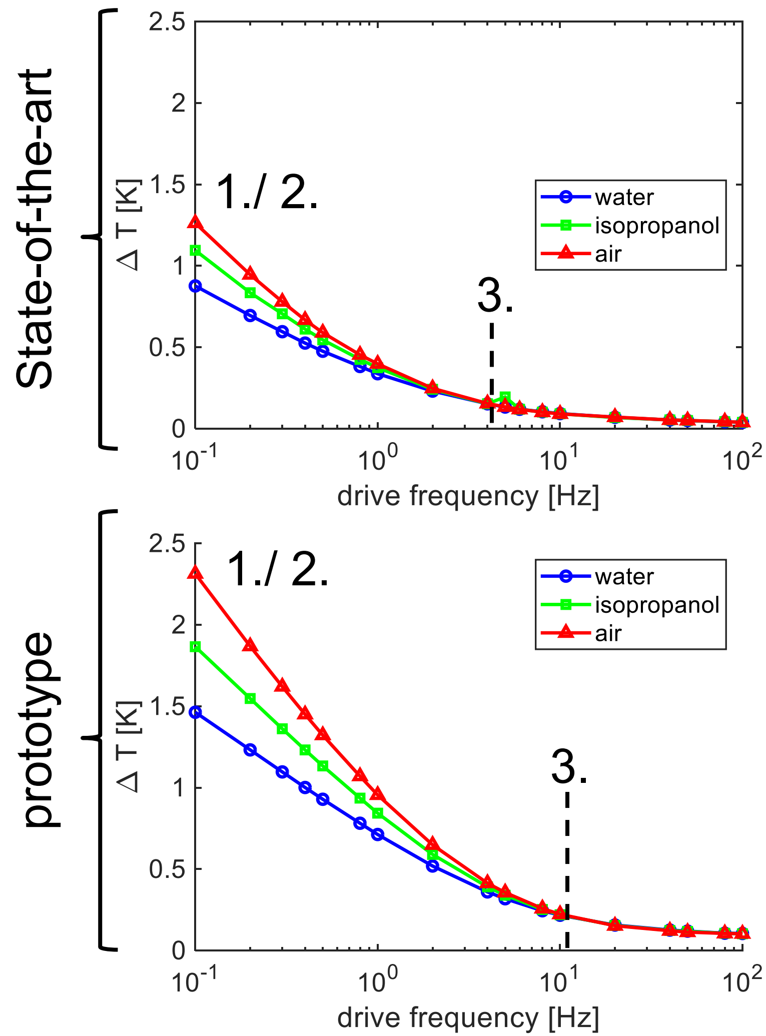
3. **The fluid dependence is visible up to a frequence of around 10 Hz.**



Results – Comparison

- **Comparison**
  1. Amplitude is increased
  2. Fluid sensitivity is increased
  3. Fluid dependence is visible for higher frequencies
     - Penetration depth

$$\delta = \sqrt{\frac{k}{2\omega\rho c_p}} \propto \sqrt{\frac{1}{\omega}}$$



Conclusion/ Next steps

- **Laser ablation can be a technology to do thinfilm platinium patterning**
  - However, a 100ns-pulse laser might be not the best choice.
- **A promising approach is presented to enhance the thermal contact by direct application of the Al_2O_3 and the platinum on a stainless-steel tube**
  - The performance could be enhanced by a factor of 2.
- **Next steps:**
  - Using a ultra short pulse laser to pattern the platinum thinfilm

Thank you for your attention

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