DOI 10.5162/SMSI2020/A6.4

A MEMS micromachined detector platform for kW power radiation in a wide spectral range

A. Laades[1], S. Görlandt[1], C. Heinze[1], F. Machalett[1] and T. Ortlepp[1]
*[1]**CiS** Forschungsinstitut für Mikrosensorik GmbH Erfurt*

Summary:
The focus of the development is on a silicon membrane based thermal detector for radiation extending from the infrared to the extreme ultraviolet (XUV) featuring very high powers in the range 100 W to 5 kW. The thermal radiation detector is equipped with a sensor platform chip consisting of an appropriate absorber and a silicon-based temperature sensor unit. This approach allows the radiation to be efficiently absorbed and converted into heat in the absorber leading to a local increase in temperature and a detectable temperature difference in the silicon unit.

Keywords: MEMS, Membrane, sensor responsivity, response time, microbolometer

Introduction

There is an increasing need for low cost radiation sensors for very high or total power radiation ranging from 100 W to 5 kW. These sensors find applications in e.g., fusion reactors [1], EUV lithography steppers of ultraviolett water treatments. MEMS (microelectromechanical sensors) micromachined CMOS compatible detectors with medium performance offer a viable solution to these needs.

In terms of the evaluated concepts for EUVL steppers requiring an area as a large as possible, The sensors developed in this work are based on a chip size of at least 7x7 mm² with a membrane size of at least 5x5 mm².

Sensor fabrication and measurements

We have developed a sensor platform based on a microbridge bolometer using standard processing steps, regularly used to manufacture piezoresistive pressure sensors. Their sensing unit consists of an anisotropically etched cavity in a silicon wafer to form the supporting membrane. A Wheatsone bridge configuration has been formed by ion implantation. The sensor was packaged and then characterized electrically and optically in terms of response behavior and responsivity.

Results

In Fig. 1 the packaged sensor and the bidge based readout circuit can be seen. The sensors were mounted on circuit boards using wire bonding and die attach technology, provided with additional heat-dissipating aluminum plates and attached to other circuit boards to connect the devices using SMA/BNC cables.

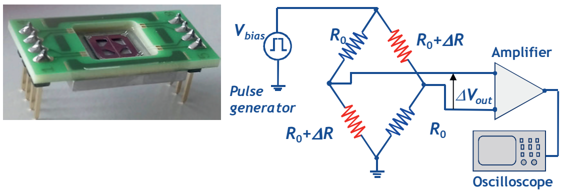

Fig. 1. Left: Sensor assembly. In the middle of the package the sensor with released membrane can be seen. Right: schematic drawing of the setup with Wheatsone bridge.

The suitability of the bridge based microbolometer as a thermal sensor was tested by means of electrical measurements by heating the bridge applying electrical power. Since the sensor does not have its own calibration heating resistor, the heating power was coupled-in via the bridge operating DC voltage.

The variation of the output offset voltage as a function of the bias voltage for one of the investigated devices is in displayed in Fig. 2(a). This shows that the sensor responds to the electrical power by generating a bridge output signal and varying non-linearly with the bias voltage.

The changing sign of the slope in the characteristic curve demonstrates the increasing bridge unbalance (offset) of the sensor with the DC bias voltage and thus quadratic increasing power loss. The characteristic curve was fitted with a third degree polynomial function and corrected by subtracting all loss components with the exception of the quadratic part. The latter corresponds to the electrical power that was actually used to thermally change the resistance. This procedure was exploited to determine the responsisitivity (defined as output voltage/input power in V/W), as shown in Fig. 2

DOI 10.5162/SMSI2020/A6.4

(b). The characteristic ΔV_{out} = f (V_{bias}) was recorded directly on various sensors without absorber, and with membrane thicknesses of 10 to 20 μm.

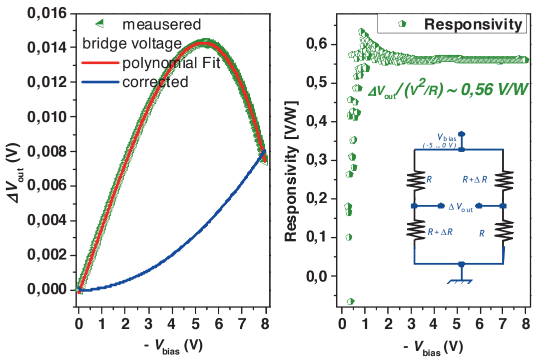

Fig. 2. Output voltage (left) and responsitivity (right) of the sensor as functions of the applied bias voltage.

The (responsitivity) of the sensors tested using this method varies between 0.5 and 1 V/W.
Similarly, the sensor was further analyzed in terms of temporal response behavior electrically as well as optically. For this purpose, a precise voltage source was used to generate pulsed voltages. In Fig 3(a) the temporal response of the device to voltage pulses directly applied to the bridge are displayed. With a pulsed laser source, it is possible to analyze the response of the sensor to radiation absorbed in the membrane. A typical result for an excitation with a wavelength of 450 nm is displayed in Fig. 3 (b)

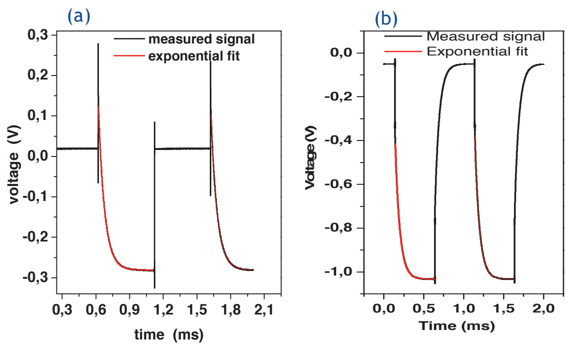

Fig. 3. Time response of electrically and optically excited senor .

The exponential part of the response behavior results from thermal coupling. The graph with optical excitation (f = 1 Hz) also shows photosensitive behavior, which is added to the actual measurement signal. The exponential part could be fitted by an exponential function according to the procedure applied in [2].
Accordingly, we could determine the time constant τ_{th}, thermal conductivity (G_{th}) and heat capacity (C_{th}) of the sensor platform. For the different sensors analyzed in this work τ_{th} ranges from 10 to 60 ms. G_{th} and C_{th} amount to 10^{-6} bis 10^{-7} W/K and von 10^{-7} J/K, respectively.

Finally we anlyzed the temporal response of the sensor by EUV excitaion using an XUV source.

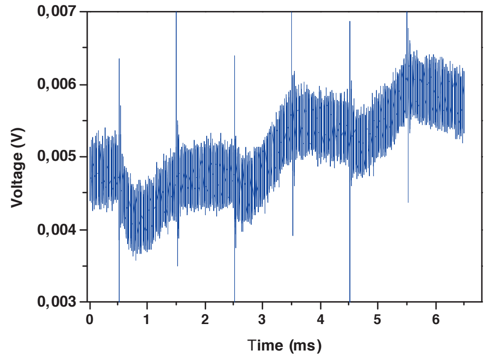

Fig. 4. Time response to XUV radiation.

The XUV source which was available features an output power of 100 μW maximum, such that the absorbed power was much less than that. Nevertheless an output signal upon XUV excitation could be recorded, though overwhelmed by the background noise. However, it can be predicted that for high powers from 100 W to 5 kW, the sensor solution is highly scalable and is well suited for detecting radiation in the EUV / XUV spectral range with high power.

Conclusion and outlook

It is demonstrated that using the cost effective MEMS technology, it is possible to fabricate thermal Sensors for a wide range of radiations. The developed bridge based bolometric sensors have a good response to photons in different spectral ranges (blue, green, XUV) with a thermal time constant in the range of 10 to 60 ms. The responsisitivity is approx. 1V/W. Thus, radiation with power over 100 W to 5 kW can be measured, which is the aim of the development. Since the approach is based on purely thermal excitation of absorber, the temperature sensor unit is less prone to XUV radiation damage.

References

[1] H. Meister H. Langer, S. Schmitt, "An alternative geometry for bolometer sensors for use at high operating temperatures", Fusion Eng. Des. **120**, (2017) 21

[5] X. Gu, G. Karunasiri, and G. Chen, "Determination of Thermal Parameters of Microbolometers Using a Single Electtical Measurement", App. Phys. Lett. **72**(1998) 15,