APPLICATION OF PZT THIN FILM TECHNOLOGY FOR ANGULAR RESOLVED FLAME DETECTION

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INTRODUCTION

Hot gases emit a specific spectral pattern in the infrared range at about 4.3 µm, which can be sensed with an infrared (IR) flame detector. State-of-the-art detectors are designed as single-point detectors to detect a flame inside a certain field of view but the position of the flame was not resolvable. The new detector has to provide additional spatial information about the observed scene for an angular location of the flame with only a few pixels.

THIN FILM TECHNOLOGY

The PZT thin film is co-sputtered from metal targets in an oxygen atmosphere onto platinized silicon wafers. The PZT film is subsequently patterned in to 3 x 3 arrays. The films have a high degree of (111) orientation and the Zr/(Zr+Ti) ratio of the film is 0.25.

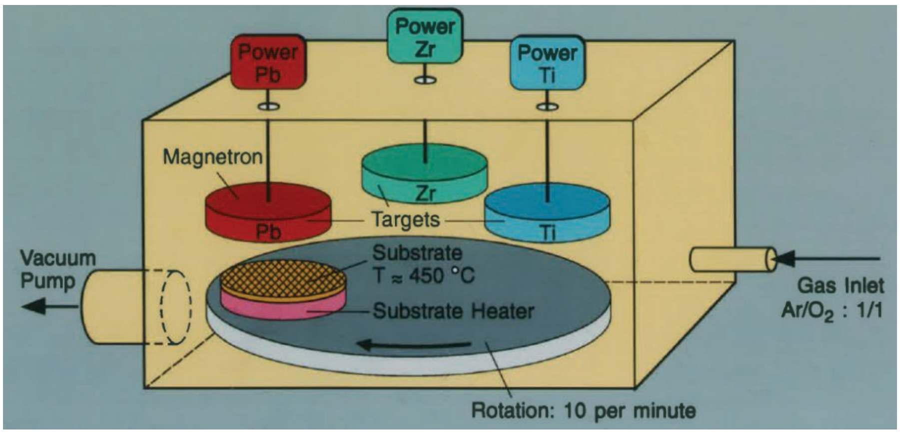

Fig. 1 sputtering facility schema

Typical PZT film thickness of 1 µm allows standard semiconductor/MEMS processing.
Cost effective customisation of sensor layout could be realised by a simple mask change, all array sizes and arrangements are possible.

The PZT films show high pyroelectric coefficients of $1.8 \cdot 10^{-4}$ C/(m^{2}K), very low dielectric losses tan δ of 1% and favourable dielectric constants of about 270 in combination with a so called self-polarization.

The backside of the wafer is subsequently etched to release the thin film PZT sensor arrays on a thin supporting silicon oxide/nitride membrane. The cross section of a single pyroelectric PZT pixel and the layout of the 3 x 3 chip are shown in fig. 2.

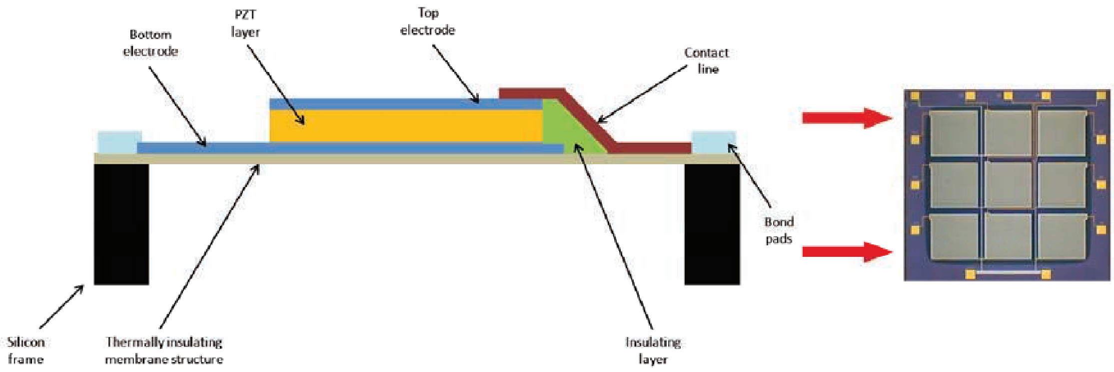

Fig. 2: Schematically cross section of a pyroelectric pixel and chip layout

The thin film PZT technology enables to manufacture chips of very small sizes which allows to fully illuminate an array of (3 x 3) individually addressable pixels with a 1.5 mm diameter beam. The thickness of the PZT thin film is adjusted to 1.4 µm to maximize the absorption in the wavelength range of 4–5 µm by multiple interferences within the PZT film (see fig. 3). This spectral response is optimized for the detection of CO2 emission of hydrocarbon flames.

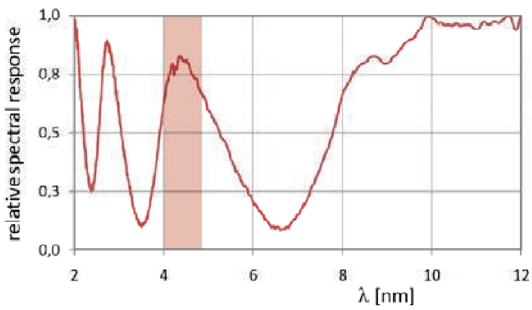

Fig. 3: Spectral response of the flame detector

DETECTOR DESIGN

The pyroelectric 3x3 sensor arrays with an active area of 1,5mm x 1,5mm are integrated with a 9 channel transimpedance amplifier inside the housing, which is shown in fig. 4. A built-in lens (see fig. 5) forms an intra-focal image of the detected flame enabling the interpolation between the individual pixel signals.

Fig. 4 Header and wiring board of the flame detector

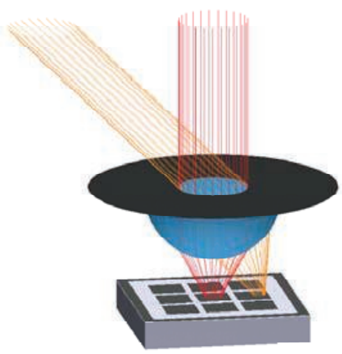

Fig. 5 built-in sapphire lens and aperture

DETECTOR PROPERTIES

A high responsivity of about 55 000 V/W (500 K, 10 Hz, without window and optics) was realized. Even for a pixel size of only (500 x 500) µm a high D* of $2 \cdot 10^8$ cm√Hz/W can be guaranteed. The complete detectors with integrated optics and antireflective window realize a responsivity of about 8 000 V/W and the specific detectivity of $2{,}5 \cdot 10^7$ cm√Hz/W. This is clearly higher compared to other low cost detectors for motion detection or thermopile arrays.

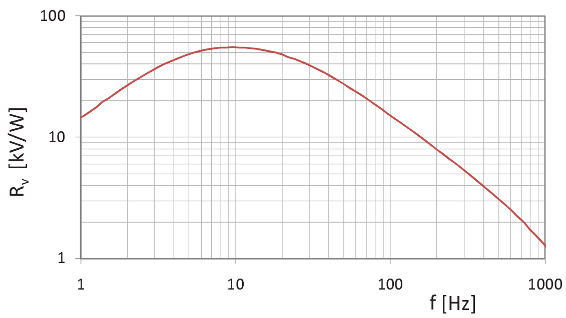

Fig. 6 Responsivity without window and optics

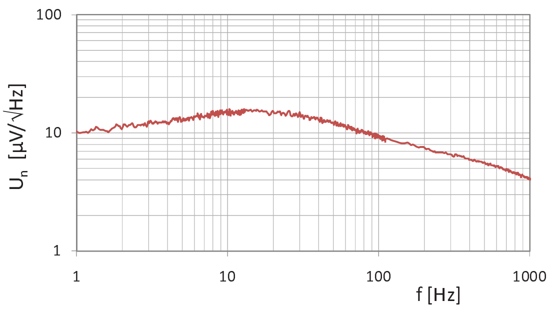

Fig. 7 Noise density

ANGLE INTERPOLATION

The incidence angle of the IR-radiance can be measured indirectly by the analysis of the signals of the 9 individual pixels. Figure 8 illustrates the calculation of the pseudo-coordinates X(φ, θ) and Y(φ, θ) from the pixel signals C1…A3.

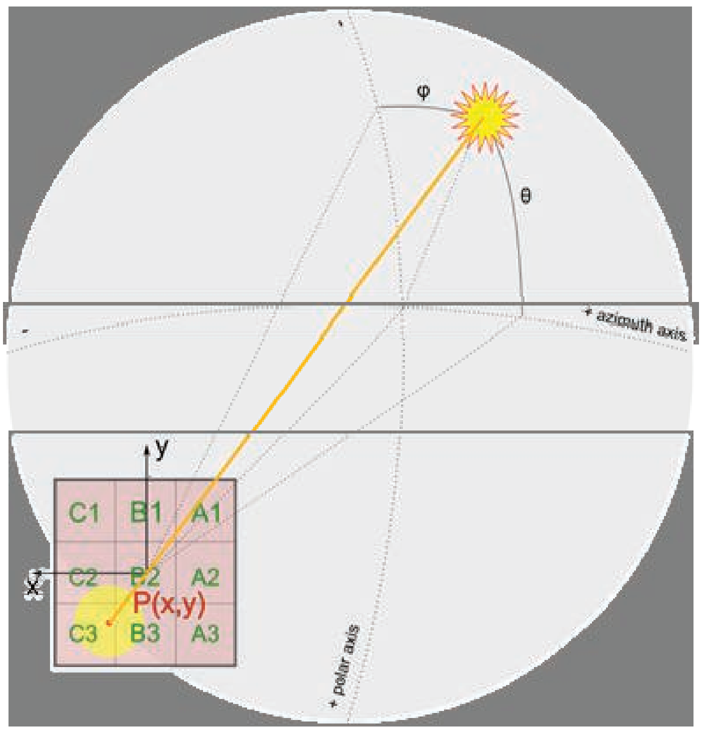

Fig. 8 principal arrangement for measurements of the angular response.

$$X(\varphi,\Theta) = \frac{(C1 + C2 + C3) - (A1 + A2 + A3)}{A1 + A2 + A3 + B1 + B2 + B3 + C1 + C2 + C3}$$

$$Y(\varphi,\Theta) = \frac{(A1 + B1 + C1) - (A3 + B3 + C3)}{A1 + A2 + A3 + B1 + B2 + B3 + C1 + C2 + C3}$$

This results in a remarkable angular resolution of at least 5° within a 100° field of view. Calibration of X and Y have to be realized by measurements of the angular response.

The theoretical prediction and experimental results of angle interpolation can be demonstrated by the simplified one-dimensional case θ = 0°, with

$$X(\varphi) = \frac{C2 - A2}{A2 + B2 + C2}$$

The perfect theoretical prediction is shown in figure 9 and 10.

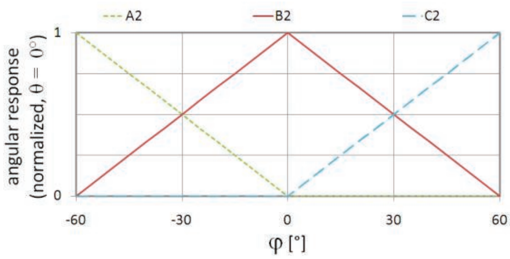

Fig. 9 Theoretical prediction of pixel signals

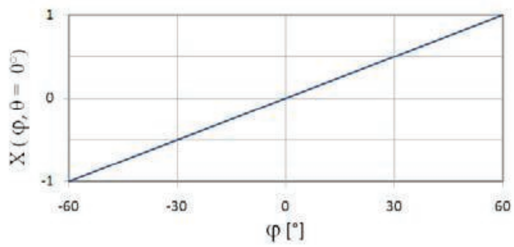

Fig. 10 Theoretical prediction of pseudo coordinate X

The experimental results in figure 11 and 12 are effected by different real conditions, such as engineering design, tolerances, neglected physical effects etc..

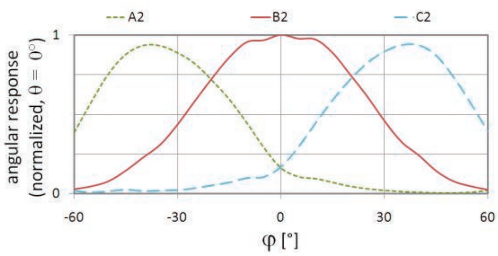

Fig. 11 Measured curves of pixel signals

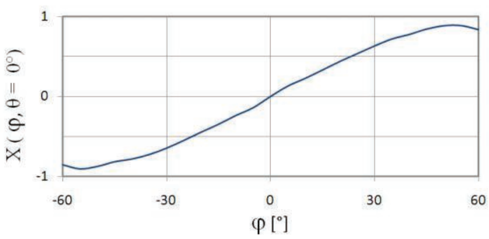

Fig. 12 Real run of pseudo coordinate X

SUMMARY and DISCUSSION

The thin film PZT sputter technology enables to manufacture chips of very small sizes. The 3x3 sensor arrays are integrated with a 9 channel transimpedance amplifier inside the housing. Even for a pixel size of only 500x500 μm^2 a high D* of $2 \cdot 10^8$ cm√Hz/W can be guaranteed. This is clearly higher compared to other low cost detectors for motion detection or thermopile arrays. A built-in lens forms an intra-focal image of the detected flame enabling the interpolation between the individual pixel signals. This results in a remarkable angular resolution of at least 5° within a 100° field of view.