Flexible Thermoelectric Flow Sensors

Summary

Based on an existing approach, the Microsystems Center Bremen (MCB) develops a thermoelectric flow sensor on a 10 µm thick polyimide foil. The result is a new thermal flow sensor on a thin film substrate which can be easily integrated into different shaped surfaces. The first prototype has been developed at the MCB (see fig. 2).

State of the Art

There are several approaches to thermal flow sensors that are commonly based on inflexible substrates like silicon or quartz. The sensors developed by MCB consist of a central heating element with thermoelectric temperature sensors (thermopiles) lateral to the heater. Heater and thermopiles are placed on a thin membrane of silicon nitride for better thermal isolation (see fig. 1, right).

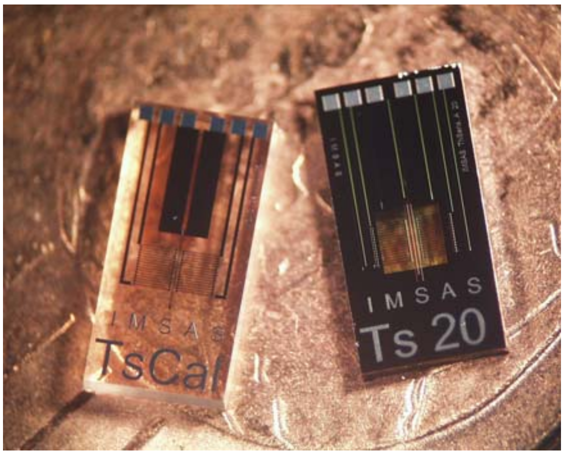

Figure 1: Conventional thermal flow sensors on quartz (left) and silicon substrate (right)

During operation, the heater dissipates heat. This leads to a symmetrical temperature distribution up and downstream to the heater if there is no fluid flow. In case of a fluid flow over the membrane, the temperature distribution becomes unsymmetrical. This in turn leads to a measurable temperature difference between both thermopiles. As a result the sensor can detect different flow rates of the fluid bidirectionally.

The sensor's heater and thermopiles are made of titanium-tungsten and polysilicon, further passivated by a protective coating of LPCVD-silicon nitride (Low Pressure Chemical Vapour Deposition) for higher chemical and mechanical stability.

Fabrication Process

The fabrication of a flexible thermal flow sensor is based on the process on inflexible substrates. A schematic describing the most important steps can be found in fig. 3.

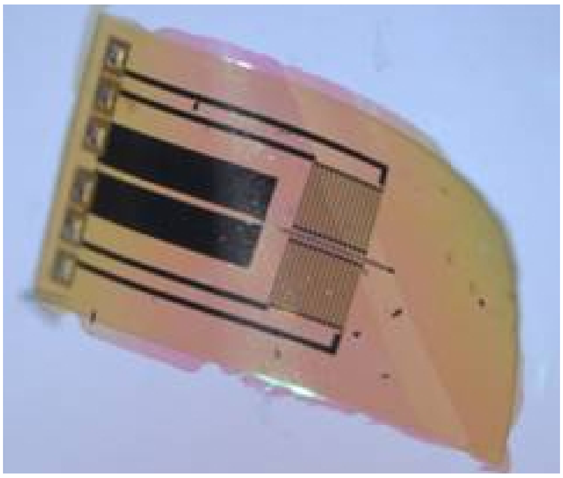

Figure 2: Flexible thermal flow sensor prototype on polyimide foil

Fig. 3a shows a silicon wafer where silicon dioxide (SiO_2) and low stress silicon nitride (Si_xN_y) are deposited. The heater and thermopile structures are made of polysilicon and tungsten titanium (WTi) which is shown in fig. 3b. Both structures are further passivated by a protective coating of silicon nitride.

In the next step, a photosensitive polyimide is deposited on top which can be structured by a photolithographic process. The result is shown in fig. 3d. After structuring of polyimide, bumps for electrical contacts are electroplated (see fig. 3e). To release the polyimide, the sensor is then processed by means of DRIE (Deep Reactive Ion Etching).

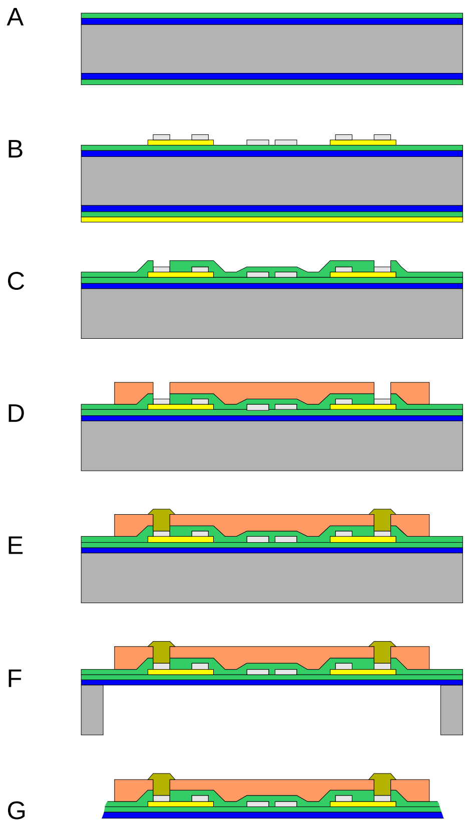

Figure 3: Fabrication process of flexible thermal flow sensors

After separation of the sensor die, functional structures including heater and thermopiles are hold by polyimide only (see fig. 3g).

Application

Thermal flow sensors on polyimide substrates are particularly developed to widen the field of application. The new concept makes it possible to operate thermal flow sensors in limited space and different profiles (e.g. pipes, tubes). Furthermore the reduced height of the sensor minimises turbulences which affect the measurement results dramatically.

A future project is the integration of flexible thermal flow sensors into remote sensing systems. The flexible flow sensor is integrated to a flexible polyimide circuit board which can be easily placed into pipes with different diameters. Data transfer as well as the electrical power supply is realised by wireless transmission.

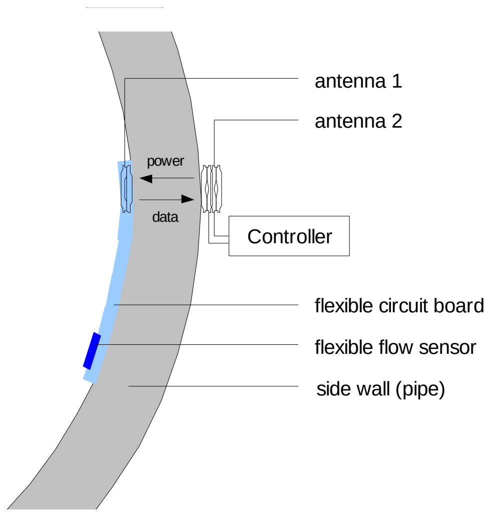

Figure 4: Measurement of flow in pipes through flexible sensors with remote sensing system

As it can be seen in fig. 4, the flexible circuit board with integrated sensor is placed inside the pipe. For the flow measurement realisation, an external antenna (antenna 2) induces an electromagnetic field which will be picked up by another antenna inside the tube (antenna 1). The induced energy can be used as a power supply for the integrated circuits and flow sensor which then performs a measurement. After receiving the measured values, the data is telemetrically transmitted back to the external controller.

The principle makes it possible to measure flow within different profiles without power supply or data lines. This leads to higher sensitivity and reduced costs in flow measurement for many applications.

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