https://doi.org/10.3176/eng.2007.4.19

Miniaturized thermal generators

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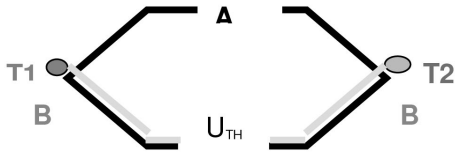
1. What is a thermal generator?

1.1 Theoretical basis

A thermal generator is a sensor in which a great number of thermocouples converts the thermal energy into electricity. These thermocouples are arranged in row and make thus a summation of the thermoelectric voltages. This thermoelectric voltage results from the higher charge carrier density with higher thermal speed on the warm side. Thus a diffusion current develops to the cold side, which is illustrated by the difference of potential. This thermoelectric effect is called after the inventor Thomas Johann Seebeck (1821). This effect was already implemented into the practice and used as temperature sensor for the measurement of higher temperatures. The appropriate thermal pair tolerances can be reread in the DIN EN 60,584. Also so-called Thermopile elements for the infrared measurement in thin-film technology were developed.
In the last years the reversal of this Seebeck effect became more up-to-date e.g. for the cooling of integrated circuits (ICs). This effect was called after the inventor Jean Charles Athanase Peltier (1834).

Sketch: a thermocouple

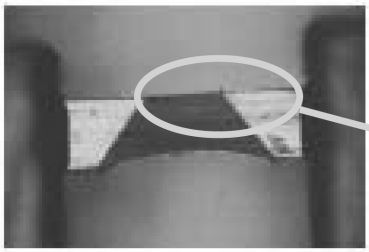


The energy at the thermocouple results from the fact that it interconnects two different temperature levels and brings them in contact with two different materials (A, B). The thermovoltage U_{TH} results from the multiplication of the temperature difference (T1-T2) with the so-called Seebeck coefficient. The material composition affects the power production substantially. The higher thermovoltage of Thermocouples gives the higher energy output. The combination of silicon with aluminum is very good, however, it must be noted that silicon is a good heat conductor and can therefore develop a fast temperature equalizing. This was one of the major tasks, which could be optimized by mechanical types.
By the micro-system-oriented structure a great number of thermocouples on a small area of silicon is to become. The production process is a small part of the production of integrated circuits (IC) on silicon. This production of µP and other ICs is optimized by its high mass production, therefore we can use the IC technology also for inexpensive thermal generator manufacturing.

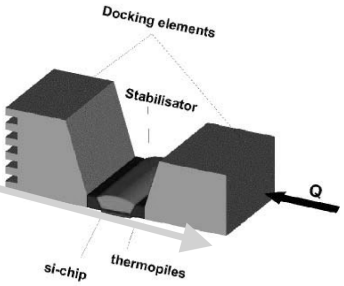
1.2 Thermal generator execution 1

This thermal generator was already developed in 1996 and should replace the lithium batteries in our Heat Allocator. Therefore the thermal generator with a length of a 10 mm, width of 500 µm and a thickness of 10 µm was implemented. In order to be able to accommodate a high number of thermocouples on a silicon chip, a structure of micro mechanism sensor was selected.

Sketch: Cut by thermal generator

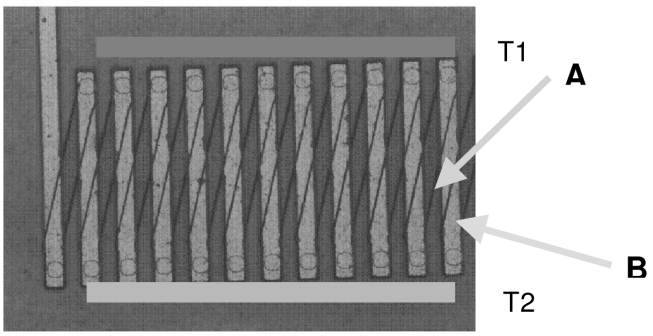


Structure with warming and cooling section



We let manufacture different versions with 200 and 500 thermocouples on a chip. The reached internal resistance was still too high for us, also the energy output did not correspond yet to our expectations.

Sketch: Thermal generator execution 1



The thermoelectric coefficient of the mating silicon aluminum was 120-150 µV/K. With an internal resistance of 1 MΩ resulted typical voltages of 1.3 V per 10 Kelvin temperature difference.

1.3 Thermal generator of the next generation

The prototype phase with the execution 1 had shown the fact that with the material combinations silicon and aluminum the useful results can be obtained with lower internal resistance and higher energy. In order to receive a higher mechanical stability and a larger heat sink, the execution was changed over to a square solution. For the realization, two different surface sizes were planned. The realistic size was defined with 3,8 x 3.8 mm². An integration is intended by 1600 thermocouples. The necessary smallest structure will have with 1,5µm and/or 0,8µm resolution.

Temperature differences can generate the energy, which is expected as follows:

I. Temperature difference	TGDelivering current	Delivering power
1K	3 µA	1,5 µW
3 K	12 µA	18,0 µW
8 K	33 µA	132,0 µW
32 K	132 µA	1,6 mW
200K (engine, exhaust, catalyst)	825 µA	66,0 mW
Internal resistance Ri	120 kOhm	

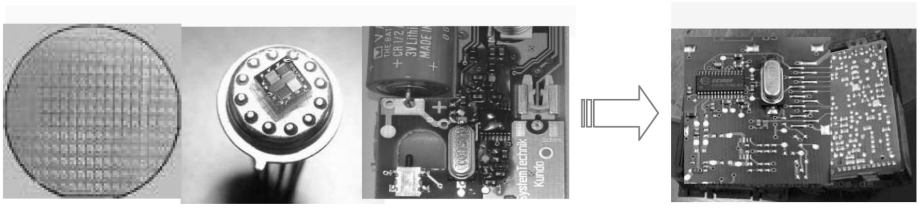
2 Ranges of application

2.1 General information

The ranges of application are very various and concern nearly all ranges from applications of sensors. Of the medicine range: Measured values at the human body, security of children, women and older persons as well as building protection and clothing industry.

In the future one will supervise with this system also the medical findings of a driver. For example a sudden heart failure can be recognized and be sent this information, by radio to the on-board system over a sensor system by the body of the driver, so that the vehicle can be brought automatically surely to holding.
The sensors can take up different measured values, like temperature, number of revolutions, position of different actuators and also condition recognition.
In the vehicle or with stationary patients with sensors at the body one can do without the cable and arrive the measuring data by radio at the on board computer or into the nurse room. This can, as previously mentioned, with the help of one transmit-distance to be settled. However, certain time frames must be considered, in order to use not too much energy for the data communication.
For the energy increase several thermal generators can produce the necessary power requirement with one another. The won energy can be used for the collection by measuring data or control of actuators and supply of a radio transmitter, to the data communication. In connection with a radio net, the thermal generator is conceivable as replacement of cable-bound data communication.

2.2 Example of a simple measuring data transmission with transmitter and receiver



Thermal generator Sensor Transmitter with µprocessor Receiver

Photo: Kundo system engineering

If one extends the pure measurement data recording toward control and regulation, then the transmitters and receiver modules must be replaced by Transceivermodule.

2.3 Concept possibilities

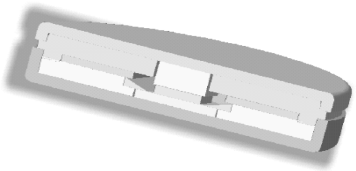
For the function of energy production the thermal generator needs a temperature difference, which are produced by different elements, which are present.
The temperature differences can be produced for the ambient air, interior air in the vehicle by the engine warmth. Sun exposure, interior and outside temperatures in buildings, as well as the body temperature and room air temperature lead likewise to temperature differences.
If the cables were replaced to a large extent to the engine sensors, then the energy is constantly produced by the high temperature difference by circulating air and engine.
When the engine are stopped also the energy of the thermal generator decreases/goes back.
After stop it must be able to accomplish the start of the vehicle surely even after longer time.
This can be considered e.g. by a pre-defined starting position of the actuators.

Another possibility would be storing of small energy values of the thermal generator in energy stores as summed Goldcaps or Accus.
This is possible, because the thermal generator already works with smallest temperature differences, e.g., 1 K.

2.4 Thermal generator in a button cell

If one integrates the thermal generator into an appropriate button cell housing, then these can be used, to appropriate optimization of the heat flow for many applications. These devices do not need „battery change “anymore.

The sensor can be accommodated thus in the housings by button cells, the button cell cover corresponds to the positive pole and the heat sink at the same time for delivering the heat energy. The lower surface of the button cell is the negative pole and the heat accumulator to supply of the higher temperature to the sensor.



The thermal generator sensor can replace thus lithium batteries, button cells or small accus and supplies the necessary energy for the consumer. This can be used e.g. for mobile control units such as function wrist-watch, carkey and remote control of the radio. Further applications in the medicine and Consumer area are conceivable.

2.5 New car key integrated in the wrist-watch

Application in the integrated wrist-watch car key makes the extension possible for new functions. For opening and locking the car door is sufficient to pressing the key at the wrist-watch. Further data, like personal setting values (seating position, interior temperature, favourite transmitter at the radio), DCF77-radio controlled value and the like can be transmitted to the electrical system.

Radio auto-key

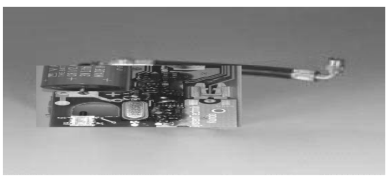
Wrist-watch with DCF77 Radio receiver

From SPOT - (Smart-Personal-Object-Technology) from Microsoft

The wrist-watch is now the fully electronic ignition key. It can be done without the starter lock. A starter key is pressed at the steering wheel or at the wrist-watch, for starting the engine.

2.6 Automatic tire pressure monitoring

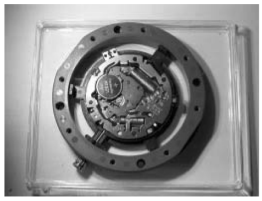
Today in most newer trucks the tire pressure monitoring is already accomplished by sensor with radio. In the USA is the tire pressure monitoring an obligation since Nov. 2003. If one uses here additionally a thermal generator, then electronics is independent of the lithium battery. The requirements of the lithium battery are very high, on the one hand by the ambient temperature of more as 100°C and on the other hand one life span of more than 10 years are needed.



3 What´s already on the market?

3.1 Discrete technology

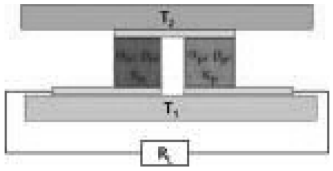
These pictures were made by the Citizen wrist-watch. In this clock a ring was developed as thermal generator, which produces approximately the same energy as our thermal generator of the generation 2.

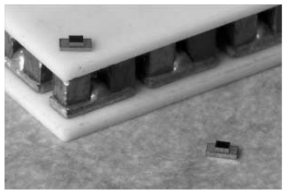


Fotos: IPM

3.2 Thin-film technology

This thin section technology in miniaturized design with only one volume of 0,2 cm^3 was developed. Advancements were made by MicroPelt and are under www.micropelt.com to be seen.





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Fotos: MicroPelt

If one regards the efficiency of thermal generators in energy output per area requirements, then the semiconductor technology has a higher efficiency than the thin-film technology. However it is to be considered that with some applications the thin-film technology offers corresponding advantages by the small internal resistance, which must be paid with a higher price.

4. What do we expect in the future?

4.1 Energy reduction

Our goal is to receive a high energy availability by the thermal generator, in order to activate also actuators with higher power requirement. This could be solved by micro-system-oriented actuators of the future, since these need substantially smaller energies.
In the optical development of cameras Institut for Microsystems in Stuttgart showed that it is possible to reduce the power requirement to 10% by certain chip solutions (info. from Prof. Höflinger).

4.2 New material combinations and higher integration

New fixed and flexible Materials will be developed and examined toward higher energy and more inexpensive thermal generators. Additionally, the nano-range integration makes possible to have new horizons of applications. The energy recovery in connection with an energy-storage system will come in the vehicle, since only 10 to 20% of the primary energy for the progressive movement of the vehicle can be converted.

4.3 Autonomous system

It is also possible to bring the sensor to the energy production by means of obligation warmth. Here a prototype was developed for the burn by hydrogen directly on the thermal generator and tested with success. The catalyst can simply be manufactured by evaporation on the thermal generator. The hydrogen gas is led over the catalyst, it develops a self inflammation during the contact with the catalyst and air and hydrogen gas to burn and warm up.

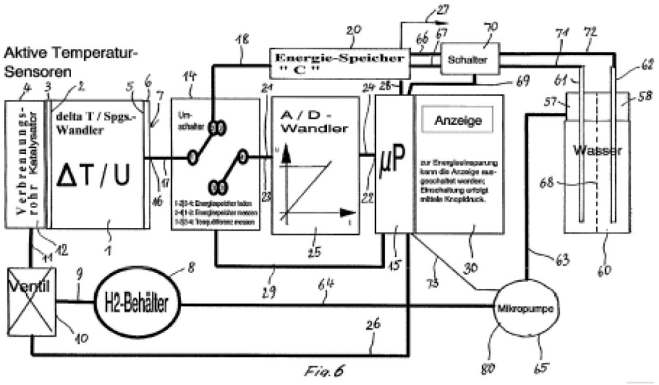

Fig. 6

5. Appeal:

Use the chance of a thermal generator for your products, so that you bring and/or hold your technological high-quality products on the market or to become the market leader. Hereby you also make a substantial contribution to the environment. The fewer cables and small batteries are manufactured and disposed of, the less loaded is our environment.

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