Infrared Sensor to Control Temperature of Pots on Consumer Hobs

Uwe Has, Bosch-Siemens Hausgeräte GmbH
Jörg Schieferdecker, EG&G Heimann Optoelectronics GmbH
Dimitar Wassilew, DIAS Infrared GmbH

1 Summary of the problem

Anytime food is cooked in a pot the temperature of the food has to be controlled carefully. Two major ways have been tried to achieve an automatic cooking system for hobs capable to do this. First, measuring the temperature of the pot bottom by a contact probe [1] and, second, putting a temperature probe into the food [2].

Both systems show problems: The thermal contact between a contact probe and the bottom is not reproducible. The heat of the heater disturbs the probe. Therefore, the signal provided by a contact probe is not accurate. Temperature probes to put into the food are difficult to handle because they must be placed correctly. The temperature signal is to be transferred to a controller by wire. Furthermore, due to hygienic and culinary reasons this system is not accepted everywhere. Therefore, these probes are not user friendly. A reliable and user friendly way to measure the temperature of food is needed.

2 The new solution

It has been suggested to measure the temperature of the food without contact of food and probe by using an infrared-sensor [3]. The infrared sensor measures the temperature on the side of the pot. This paper describes the first infrared system suitable in hobs for mass production.

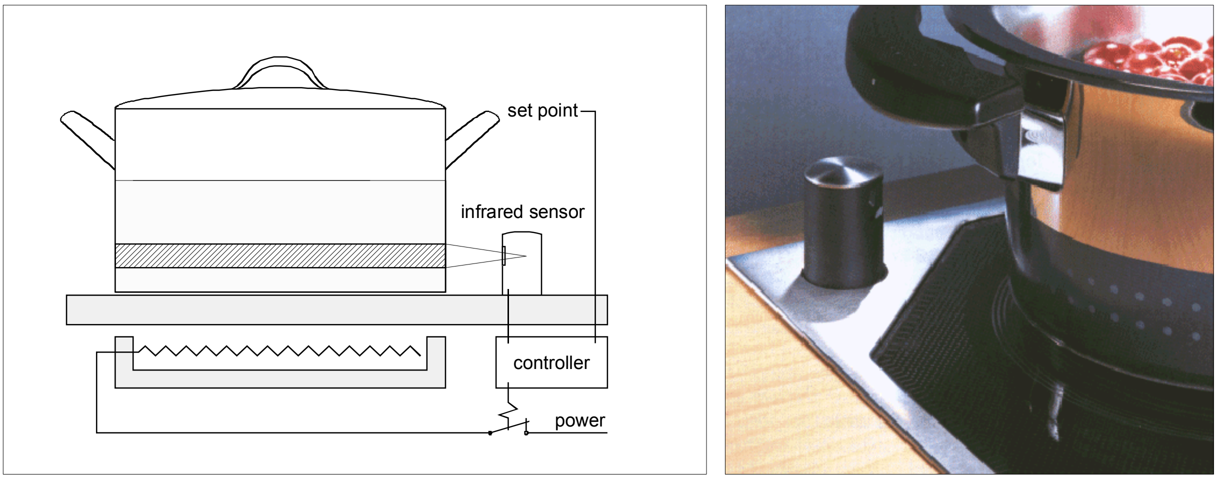

Figure 1: Construction of hob with infrared sensor.

3 Technical implementation

Figure 1 shows the construction of a ceramic hob with infrared sensor. The temperature of the wall of the pot represent the temperature of the food to be cooked. The pot is placed in front of the infrared sensor. The infrared detector is placed in a little sensor casing. It measures the temperature of a well defined spot on the side of the pot. The measuring spot is covered with enamel. The distance between pot and sensor is about 45 millimetres. The measuring spot is in a high of about 30 millimetres above hobs surface. The signal of the infrared sensor is evaluated by a rule based control algorithm. It is implemented in a 8 bit micro controller.

4 Description of the sensing system

The infrared radiation emitted by the enamel passes trough a first window into the sensor casing. Then, the radiation is focused into the sensor by a ellipsoid mirror. The radiation passes into the infrared detector trough a second window. In the Figure 2 the sensor system is shown in detail.

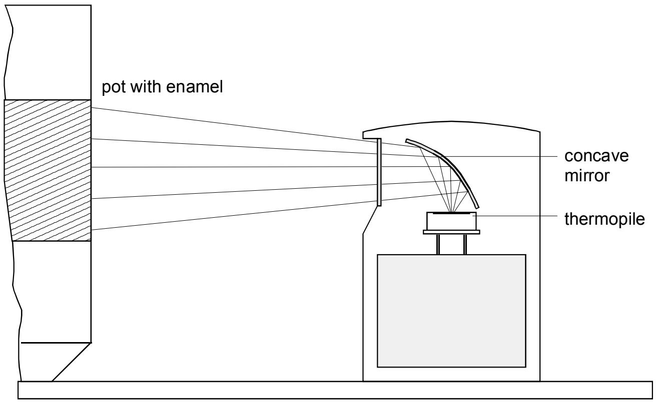

Figure 2: Detailed view of the sensor system

The window in the sensor casing and the one in the thermopile are made of silicon. They form a spectral filter. This filter limits the spectral range used for the measurement from 6 µm to 15 µm. In this range the filter has an transmittance of about 70 % and nearly no absorption. In the spectral range from 6 µm to 15 µm the enamel shows an average emissivity of 0.9. This is the emissivity of dried food, too. Therefore, the measurement is insensitive against this kind of dirt as it might stick on the side of the pot.

The infrared detector is an uncooled thermopile [4]. It works in a temperature range from room temperature to 100 °C. During operation of the hob the typical ambient temperature of the thermopile is in the range of 30 °C to 60 °C. The thermopile contains a thermistor to measure the temperature of the thermopile. Therefore, it is possible to compensate errors in measurement of the pot temperature caused by variations of the ambient temperature of the thermopile. This compensation is done by circuit placed on the printed circuit board inside the sensor casing.

The ellipsoid mirror focused on a measuring spot on the side of the pot that has a diameter of less than 20 millimetres. This spot provides 95 % of the signal. Figure 3 shows the energy distribution in the field of view of the sensor system. The different shades of grey indicate the relative intensity as given in the bar and the logarithmic diagram shown above. In Figure 3 the measuring spot is turned 90° to the left side. That means, the upper side of the spot is on the left side in Figure 3.

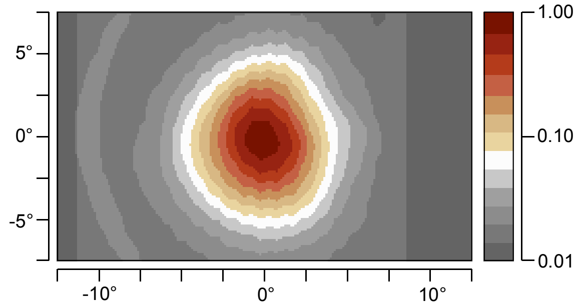

Figure 3: Field of view of sensing system

It has been tried to use a lens to focus the infrared radiation into the thermopile. The lens was made of polyethylene. In the spectral range used for the measurement this material has an absorption of about 40 %. The absorption affects the accuracy of the measurement. Therefore, this approach did not lead to success.

The typical temperature resolution of a single sensor system is shown in Figure 4. At a pot temperature in the range from 80 °C to 100 °C and an emissivity of the enamel 90 % the sensor systems shows a sensitivity of about 27 mV/K.

Under household conditions heating of water is the most critical point. For set points in the range from 80 °C to 100 °C the temperature of the food varies in the range of set point ±1.5 K if the operating instructions are observed.

Due to tolerances in production every sensor system has to be calibrated after mounting into the hob. Tolerances in the temperature of the food are not only caused by the sensor system itself. More important are tolerances in the emissivity of the enamel that forms the measuring spot.

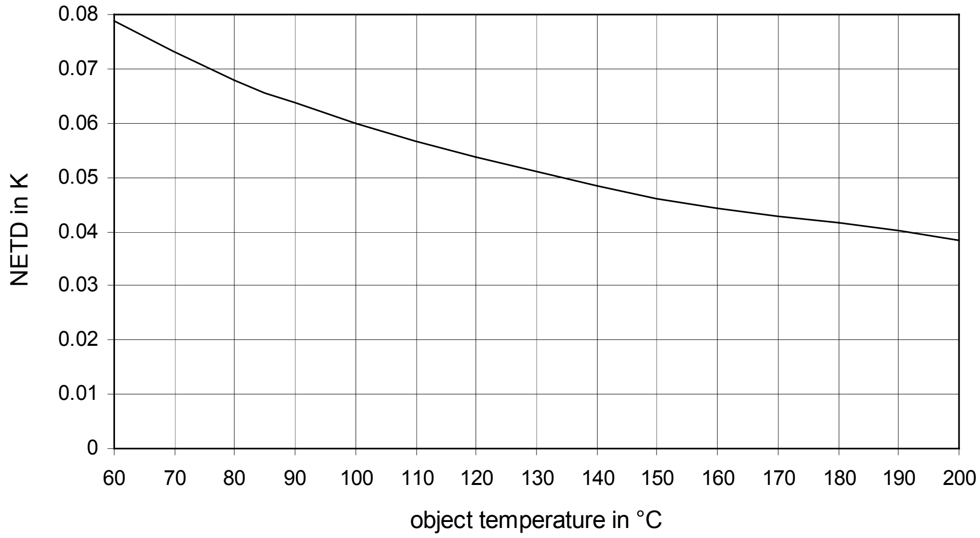

Figure 4: Typical temperature resolution of a single sensor system

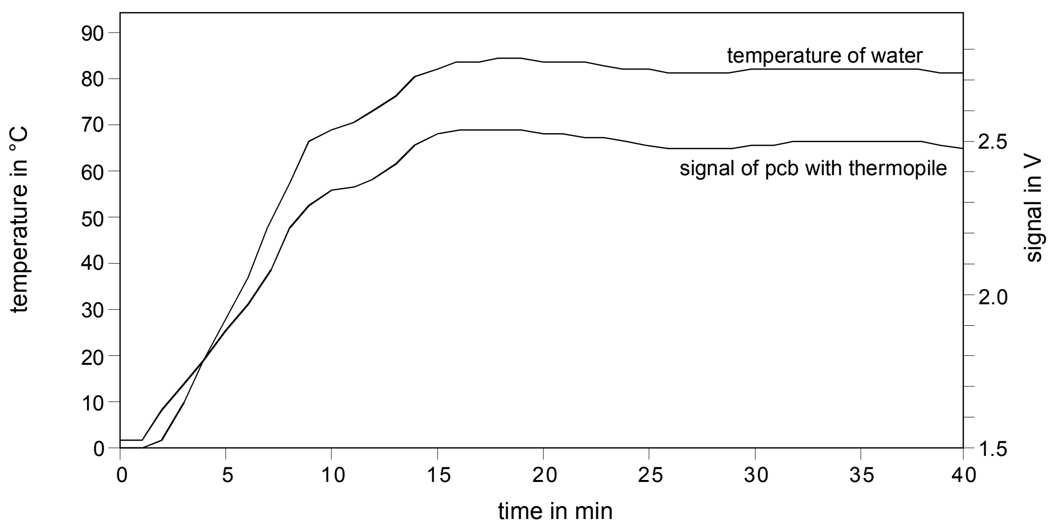

Figure 5: Sensor signal and temperature of water during experiment

5 Experimental results

Water was heated to test the temperature measurement. The set point was a temperature of 85 °C. Figure 5 shows a chart of the water temperature and the signal of the infrared sensor during the experiment. The temperature of the water is measured with a thermocouple inside the water. The temperature signal obtained as an electrical voltage satisfies the needs of a temperature controller.

6 Conclusion

The IR-sensor-system consisting of enamel covering the measuring spot, a thermopile with correction circuit, a filter and a focal mirror is suitable to provide a temperature measurement that can be used for control purpose. If the ambient temperature of the thermopile stays in the range of 30 °C to 60 °C the error of the complete system is less than 1.5 K.

7 References

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[2] S. Koide, K. Hiejima: *Temperature Controlled Induction Heating and Cooking Apparatus.* United States Patent 4,617,441

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[4] J. Schieferdecker, M. Schulze, R. Quad, A. Beudt: *Thermopile-IR-Sensormodul zur berührungslosen Temperaturmessung in Haushaltsgeräten.* Wissenschaftliche Zeitung der Technischen Universität Dresden 43 (1994) 6, S. 41-44