Temperature Profile of Hollow Aluminum Heated using Thermoelectric on Both Sides

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Abstract. The use of QCM sensors for gas sensors requires a reaction space known as headspace. Gas sensor headspace is needed to be heated to enable the gas molecule to react with the sensor sensitive layer. In the development of a sensor array, sensor placement requires space. As a result, the sensor experiences a temperature condition influenced by the sensor's placement. Our headspace was made of a rectangular aluminum hollow. The hollow dimension was 40mm in height and 20mm in width with an aluminum thickness of 1mm. The aluminum hollow was heated on two sides using two thermoelectric TEC-12706. The temperature distribution of the aluminum heated by thermoelectric on both sides shows the temperature distribution profile, which depends on its position towards the thermoelectric. At the elevated temperature of 80°C, aluminum's surface temperature shows a uniform temperature distribution in the direction perpendicular to the thermoelectric surface. In the direction parallel to the thermoelectric surface, the temperature profile shows a curved curve with the thermoelectric midpoint's highest temperature. The temperature difference between the point parallel to the midpoint and the thermoelectric edge is 5°C. A temperature difference of less than 1°C is only obtained in an area 1cm wide from the thermoelectric midpoint position. This result suggests that a wider thermoelectric surface should be considered to obtain a wider area with uniform temperature.

1. Introduction
Volatile organic compounds (VOCs) are an organic chemical that easily becomes gaseous at room temperature. Emission of VOC would come from building materials such as paint and varnishes that contain toluene, ethylbenzene, and xylene [1], [2], home and personal care products such as air fresheners which contain benzene, formaldehyde, toluene, ethylene, and linalool [3], [4], even emission through transportation. Continuous inhalation of VOCs can cause headaches, skin allergies, even cancer. Thus, we need a system to detect the presence of those gases in the atmosphere.

QCM sensors are widely used as gas sensors because they have a good limit of detection (LoD), low cost, real-time, and rapid detection. Headspace is an important part of a gas detection system using a QCM sensor. Liquid/solid, which contains VOC, is put in the heated closed chamber, then VOC evaporates and collected in a headspace [5]. Those VOC gaseous will be reacted with the sensitive layer of the sensor. In the sensor arrays, the sensor placement affected the reaction among VOC and sensitive layers [6] because of the headspace's thermal distribution. The VOC emission was dependent on the partition coefficient, which increases exponentially with temperature [7]. The partition coefficient is the analyte concentration ratio in the sample phase (liquid/solid) to the analyte concentration in the gaseous phase at equilibrium [8]. A lower partition coefficient of the analyte leads to more molecules pass into the headspace. Thus, increasing the sensitivity of the sensor. In this experiment, the headspace's thermal distribution was observed as a preliminary study to enhance QCM sensor array sensitivity.

2. Material and Method
Aluminum hollow with dimensions 40x40 mm and thickness 1mm used as headspace. Thermoelectric TEC-12706 was put on both sides of the headspace to heat the aluminum hollow. The Pulse Width Module (PWM) duty cycle was varied from 50% to 100%. The setpoint temperature of headspace was 70°C, 80°C, and 90°C. The thermal distribution of aluminum hollow was measured using a Fluke-TiS20 infrared camera, which put perpendicular to the headspace to capture the image. The temperature...
measurement was done until it reaches the setpoint temperature. Figure 1 shows the experimental setup for this experiment. The Fluke-TiS20 is placed above the aluminum hollow (see Figure 1a). TEC elements were place on the left and right side of the aluminum hollow (see Figure 1b).

![Figure 1(a) and 1(b)](image)

**Figure 1.** (a) Top view of the measurement in the experiment, (b) rear view of the headspace, the TEC was put on both sides of the aluminum hollow

### 3. Result and Discussion

Measured data using the thermal camera was processed to see the temperature distribution on the hollow aluminum surface. Figure 2 shows the thermal distribution with a set point temperature of 80°C and duty cycle of PWM 50%. Horizontal and vertical lines are drawn on several parts, representing how the hollow aluminum surface's temperature is distributed. Figure 2(a) shows the temperature distribution over the headspace at the first stage of heating. The headspace wall has a higher temperature than its surroundings because it interacts directly with the thermoelectric. The temperature on the hollow aluminum wall is around 55°C. Meanwhile, the area between the two thermoelectric shows a homogeneous thermal distribution around 40°C. When the thermoelectric reaches a temperature of about 70°C, there was an uneven thermal distribution in the headspace (Figure 2(b)). In a direction parallel with the thermoelectric surface, the headspace surface temperature ranges from 60-70°C, with the headspace's midpoint having the highest temperature.

Whereas in the direction perpendicular to the thermoelectric, the midpoint has a temperature of 70°C, and the surrounding area has a lower temperature around 65°C. The headspace heating process continues until it reaches a set point temperature of 80°C (Figure 2 (c)). The area parallels to the thermoelectric experiences a homogeneous thermal distribution, which is 80°C. However, the region perpendicular to the thermoelectric temperature fluctuates by 5°C, with the midpoint having a maximum temperature.

Based on the line drawn in the perpendicular area with a thermoelectric, it appears that there is a temperature difference between the two walls of the hollow aluminum. The temperature difference occurs at both edges and midpoint of thermoelectric. Figure 3 shows the temperature difference of headspace due to its position on the thermoelectric. For all duty cycles used, the headspace's midpoint always has the lowest temperature difference compared to its edges. The heat coming from the thermoelectric propagates on the headspace surface; the center area of the headspace, which is the center point, receives heat from various points. As a result, the heat distribution between the two hollow aluminum walls will be more even at the midpoint.

On the edges side of the thermoelectric, the heat distribution that occurs is uneven. This uneven temperature caused by the heat spreads across the other headspace surfaces and to the environment. The use of PWM100 causes the largest temperature difference, which is 11°C. The nature of heat conduction causes this big difference.
Figure 2. Thermal distribution profile of Aluminium hollow which heated using thermoelectric duty cycle 50%.

Figure 3. The temperature difference of headspace dependent on its position to the thermoelectric.

Therefore, the PWM to reach the target temperature was selected. In this experiment, PWM50 and PWM60 were used to heat the hollow aluminum surface temperature of 70°C, PWM70 and PWM80 for
80°C, PWM90, and PWM100 for temperatures of 90°C respectively. Figure 4 shows the hollow aluminum temperature change to the set point temperature at a given PWM. The PWM50 and PWM60 show a similar pattern. Whereas for higher temperatures, there is a slight temperature difference between the two PWMs used. The three graphs show how each PWM reaches the setpoint temperature during the process. The time difference required to return to the initial temperature of 35°C is normal because the difference in initial temperature and the heat dissipation occurs through natural conduction and convection processes.

![Figure 4. The temperature change of hollow aluminum during heating and cooling](image)

**Figure 4.** The temperature change of hollow aluminum during heating and cooling

4. **Conclusion**

The surface temperature of the hollow aluminum headspace depends on the position. The midpoint headspace area has a higher temperature than the surrounding area and has the lowest temperature difference between the two aluminum hollow walls. Whereas at both ends of the thermoelectric, the temperature is lower than the set point temperature and the temperature difference between the two walls is the largest. Higher thermal energy given at the hollow aluminum wall results in a higher temperature difference on the surface. The temperature difference between the point parallel to the midpoint and the thermoelectric edge is 5°C. A temperature difference of less than 1°C is only obtained in an area 1cm wide from the thermoelectric midpoint position.

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