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Design of a Regulated Micromachined Air-Sniffer Using Thermal Transpiration Effect for e-Nose Applications

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ABSTRACT

Microfluidics artificial olfaction systems are used for plant disease diagnosis in the agricultural field. In an electronic nose, the sniffer draws the air towards an array of gas sensors that detect volatile organic compounds corresponding to diseased plants. The currently available electronic noses involve a mechanical pump of moving parts prone to friction losses, limiting large-scale application. In this work, a microchannel that works on thermal transpiration principle to control the airflow inside it is proposed and designed. It has the potential to be employed as a sniffer component for electronic noses, designed using micromachining techniques.

COMSOL Multiphysics simulation software is used to develop a three-dimensional model of the microchannel and determine the airflow velocity resulting from the applied temperature using the Navier-Stokes and Energy equation. The heat transfer and fluid flow have been modelled for two different channel geometries (i.e., rectangular, and cylindrical) and two materials (i.e., pyrex and silicon). The proposed microchannel geometries are optimised to obtain the Knudsen number in the range of $0.001<Kn<0.1$ corresponding to a slip flow regime, for a maximum temperature of 70℃ at the end of the microchannel, connected to the sensor array. The results show that the geometry does not influence the temperature distribution and velocity of airflow in the microchannel. Hence, a rectangular microchannel design was chosen to simplify the microfabrication step. The material selection analysis revealed that the ability to endure temperature differences was significantly higher for pyrex than silicon. The heat transfer capacity and airflow velocity studied by varying the microchannel wall thickness showed that they were unaffected by wall thickness. The influence of temperature on the microchannel and the volume of air pumped in by thermal transpiration is evaluated for four different temperatures, namely 40℃, 50℃, 60℃ and 70℃. It is observed that the temperature influences the velocity and volume of air pumped inside the microchannel and 70℃ projected the highest flowrate velocity with maximum air volume. Natural convection method is applied to calculate the cooling down time for the microchannel, which is in the range of 2.5 $Wm^{-2}K$ – 25 $Wm^{-2}K$ when exposed to a real-time environment. The microchannel cooling rate is inversely proportional to the heat transfer coefficient. In conclusion, the optimal thermal transpiration effect inside a rectangular microchannel occurred at 70℃, and the material pyrex can serve as an ideal choice for the microchannel fabrication.

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