Sensors and Actuators A 241 (2016) 135–144

Contents lists available at ScienceDirect

Sensors and Actuators A: Physical

journal homepage: www.elsevier.com/locate/sna

MEMS thermal flow sensors

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ARTICLE INFO

Article history:
Received 17 September 2015
Received in revised form 14 January 2016
Accepted 6 February 2016
Available online 10 February 2016

Keywords:
MEMS
Thermal flow sensor
Parylene-C
Wheatstone bridge
Flow rate measurement

ABSTRACT

This paper presents micromachined thermal flow sensors for measuring liquid flow down to 0.05 μl/min. The sensing element is a parylene-C thin film with two thin film platinum resistors as heating and sensing elements. The sensors are integrated with AWG 24 Teflon tubing and additional two external constant resistors to form a Wheatstone bridge. In this study, we investigated the efficacy of the orifice type sensor in two configurations, vertical and horizontal. In vertical configuration, the sensor was arranged perpendicular to the flow direction. The orifice flow allows maximum heat transfer from the sensor to the flow but leads to higher flow resistance. After redesigning the geometries of the sensor, the dumbbell type thermal flow sensor was further developed. The sensor is suspended in the middle of the channel to improve thermal insulation and achieve better sensitivity. The sensors have demonstrated a flow rate resolution below 0.05 μl/min. The experimental results show that the sensor has a sensitivity of 7.7 mV/(μl/min) at 0.13 mW power consumption and 0.05 μl/min volumetric flow rates. Comparison with related literature has been made to judge how good the flow sensors developed in this study are.

1. Introduction

Ever since the micromachining and microelectromechanical systems (MEMS) technologies were established in the 1980s, many efforts have been made by scientists to develop micromachined flow sensors [1–4]. The advantages of the micromachined flow sensors such as: low power consumption, accuracy, small size, and sensitive to low flow rates make micromachined flow sensors exceedingly useful to not only industrial but biomedical applications [5]. Among various flow sensors, thermal flow sensors have been investigated extensively due to their structural (no moving parts) and electronic simplicity. There are three transduction methods of thermal flow sensors: hot-wire/film, calorimetric, and time-of-flight [2]. The basic elements in a thermal flow sensor are heating and sensing element(s). Heat transferred from the heating element to the working fluid results in electrical signal variation in the sensing element of thermal flow sensors. Better sensitivity can be achieved if all the heat generated by the heating element can be transferred to the fluid and detected by sensing element. However, due to packaging difficulties and flow-induced signal fluctuations, most thermal flow sensors were built on the wall of the flow channel and suffered inevitable heat loss [6–10]. The heat loss not only increased power consumption but also decreased sensitivity. Suspending in the channel allows more heat to be transferred to the fluid from heating element, and hence achieves better sensitivity. Suspending sensors as a practice has been reported in many other studies [11–16]. For other applications, thermal flow sensors can also be used for gas [7,8,10,11–13–16] or liquid [6,9,12,13,17].

In this study, hot-film transduction method and constant current mode were chosen. Two types of thermal flow sensors were developed, fabricated, and tested. Based on the geometric characteristics of the thin film sensing elements, they were named orifice and dumbbell type sensor in this study. In the orifice type sensor, there is an orifice on the thin film that allows fluid to pass through. With the orifice type sensor, the efficacies of the sensors were measured under two different configurations separately, vertical and horizontal. In vertical configuration, the sensor was arranged against the flow direction. In horizontal configuration, the sensor is not attached or built on the channel wall but was suspended in the middle of the channel to increase the sensor's sensitivity. However, the measured sensitivity of orifice type sensor did not reach our expectation in either vertical or horizontal configurations. The heat loss from heating element to the metal wire may have reduced sensor's sensitivity. Thus, the geometric parameters were reviewed to develop the dumbbell type thermal flow sensors. With the dumbbell type thermal flow sensor, the measured data

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http://dx.doi.org/10.1016/j.sna.2016.02.018
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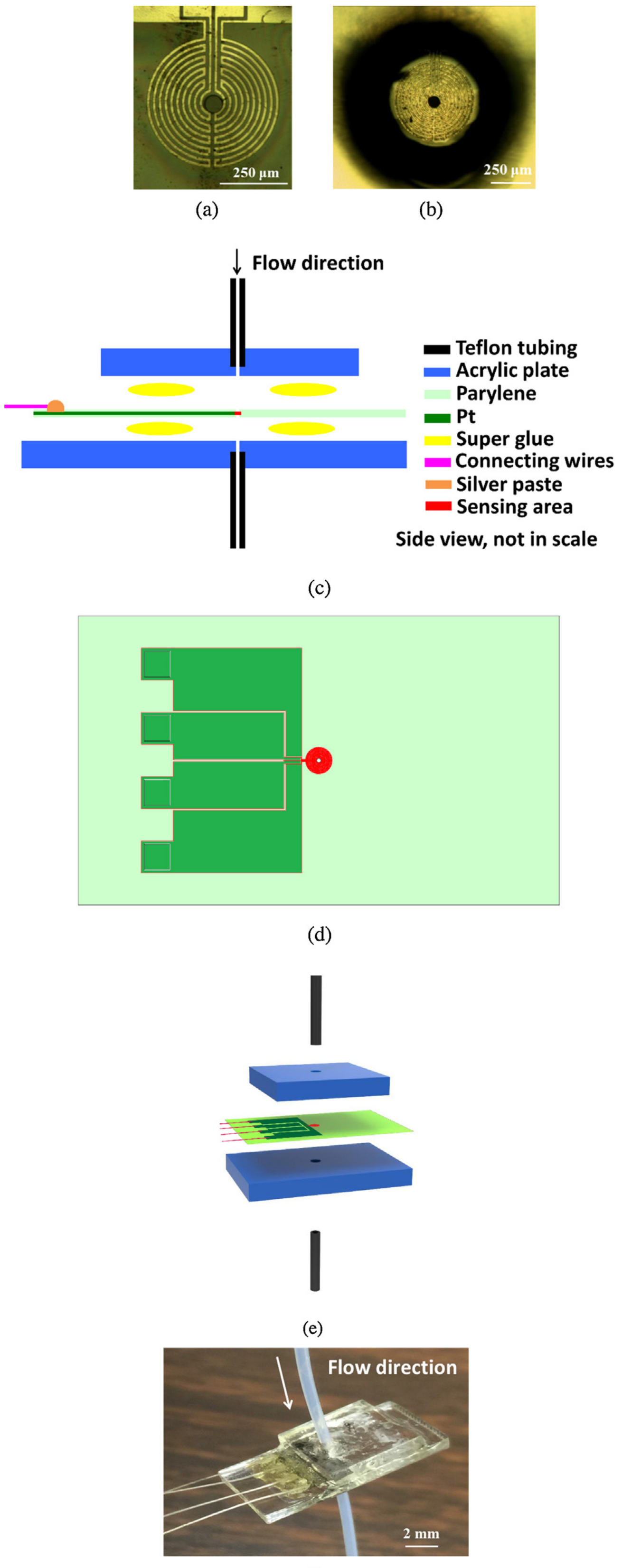

Fig. 1. (a) photograph of platinum resistors embedded in the parylene-C membrane (b) photograph of the sensor #1 from the drilled hole (c) scheme (d) design of the sensing element used in sensor #1 and #2 (e) exploded view (f) photograph of integrated thermal flow sensor #1.

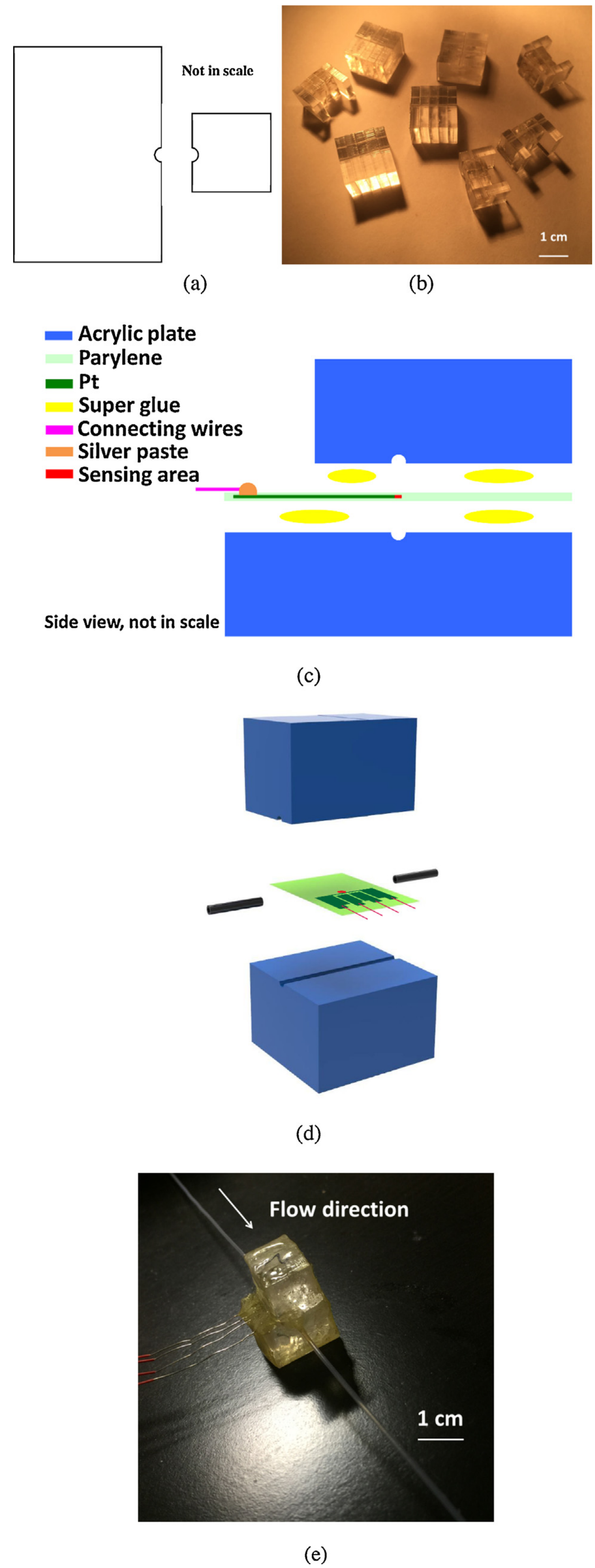

Fig. 2. (a) scheme of acrylic plates with groove (b) photograph of glued acrylic pieces used in sensor #2 (c) scheme (d) exploded view (e) photograph of integrated thermal flow sensor #2.