Sensors and Actuators A 232 (2015) 353–358

Contents lists available at ScienceDirect

Sensors and Actuators A: Physical

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

Micromechanical high-doses radiation sensor with bossed membrane and interferometry optical detection☆

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ARTICLE INFO

Article history:
Received 3 November 2014
Received in revised form 8 May 2015
Accepted 8 May 2015
Available online 16 June 2015

Keywords:
MEMS radiation sensor
High doses of radiation
Bossed membrane
Optical read-out
Polyethylyne
Membrane deflection

ABSTRACT

The silicon-glass MEMS high dose radiation sensor with the optical read-out, acting above 10 kGy has been presented. The sensor consists of a microchamber filled with small portion of high density polyethylene (HDPE) and thin silicon membrane. The principle of operation of the sensor is based on radiolysis effect of the HDPE which, upon radiation exposure, releases the hydrogen. The hydrogen increases the pressure inside the microchamber causing the deflection of the membrane, which is proportional to the pressure, thus to radiation dose. The sensor has been irradiated with high energy electron beam with dose 5 ÷ 40 kGy. The displacement of the membrane has been detected by optical interferometer. The relative generated pressure inside the sensor chamber has been found very high (up to 180 kPa). It shows that response of a micro-scaled MEMS sensor is much more effective in comparison to macro-scaled solutions.

1. Introduction

According to the today's state of art, high-doses of radiation (above 10 kGy) may be only estimated *post factum* by a family of passive thermo-, radio- and photoluminescence indicators or hydrogen pressure dosimeters [1–3]. *In situ* measurements have been up-to-date obtained only for low or medium doses (below 10 kGy) by solid-state MOS based sensors.

The authors goal is to develop a new type of sensor for high-dose radiation measurements compatible with in situ readout methods. It will solve the problem of high-dose measurements in newly developed nuclear reactors with increased power [4] or in industrial accelerators as well as a research facilities like Large Hadron Collider. There is a great need for new, cheap, easy-to-use type of sensors, able to measure high doses of ionizing radiation (gamma and/or high energy electron beam) from several to hundreds of kGy [5].

The idea of MEMS sensor for measurement of high radiation levels above 10 kGy have been shown in our previous work [6]. In that solution, thin silicon membranes made over a reference chamber, filled with a pill of HDPE, had been deflected under pressure of H_2, being the result of degradation of irradiated HDPE. Membranes crashed if the radiation dose reached the designed level. Concept of the MEMS threshold sensor has been confirmed.

In this paper we focused on proportional MEMS radiation sensor. The deflection of the membrane has been realized by interferometry optical detection method. The effects of HDPE degradation in micro-scale have been discussed here.

2. Construction and fabrication

As mentioned, the work principle of a MEMS sensor is based on radiolysis of HDPE. As a result of this phenomenon, released hydrogen causes drop of pressure (p_1) inside encapsulated chamber and deflection of a thin silicon membrane. The pressure p_1 must not exceed the pressure causing membrane destruction p_{max} (Fig. 1). The membrane deflection is proportional to the hydrogen pressure, thus to a radiation dose.

This principle of the work stays behind a construction of the sensor schematically shown in Fig. 2a. Fabrication process is described below. First, (100) oriented, double side polished silicon wafer (4") is deeply micromachined in TMAH based wet etchant, to form a bossed membrane and container for HDPE (Fig. 2b,c). Following

☆ Selected papers presented at EUROSENSORS 2014, the XXVIII edition of the conference series, Brescia, Italy, September 7–10, 2014.

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http://dx.doi.org/10.1016/j.sna.2015.05.006
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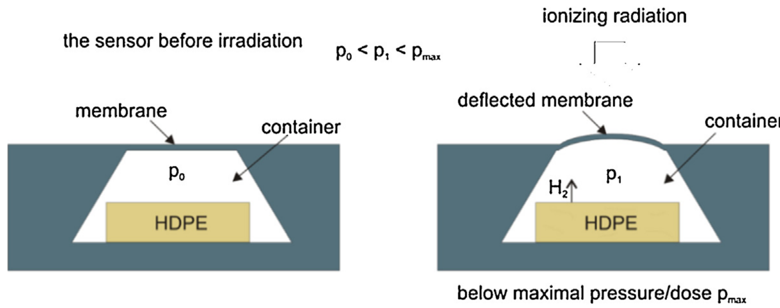

Fig. 1. Principle of operation of the sensor [6].

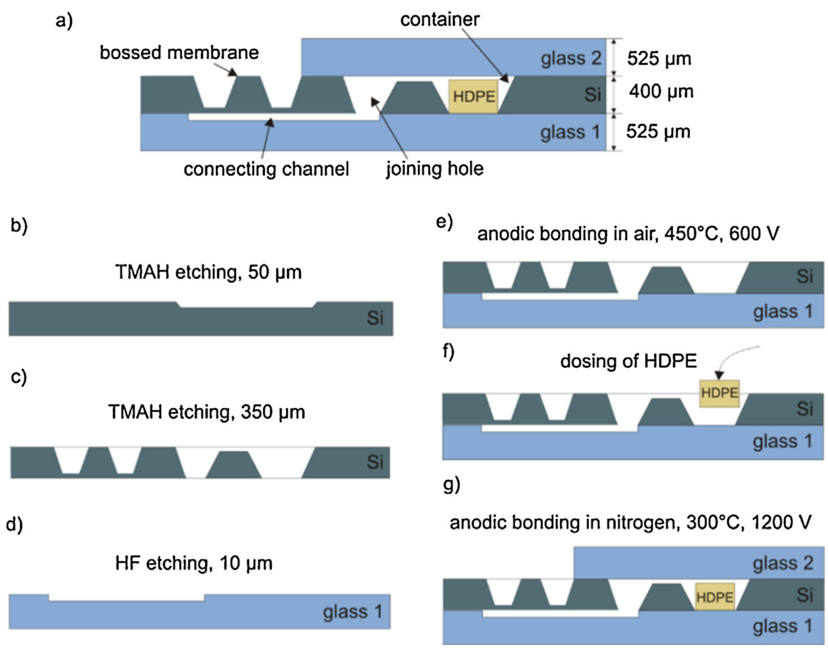

Fig. 2. Scheme of the construction of the sensor (a) and the fabrication steps: (b) etching the container in silicon; (c) etching the container in silicon and boss membrane; (d) etching a connecting channels in glass 1; (e) anodic bonding the silicon wafer with glass 1; (f) dosing the portion of HDPE to the container; (g) anodic bonding with lower temperature the silicon container filled with polymer and glass 2.

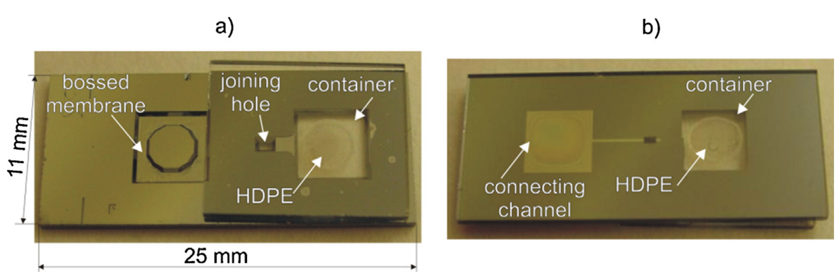

Fig. 3. Sensor at the glance: (a) top of the sensors; (b) back of the sensors.

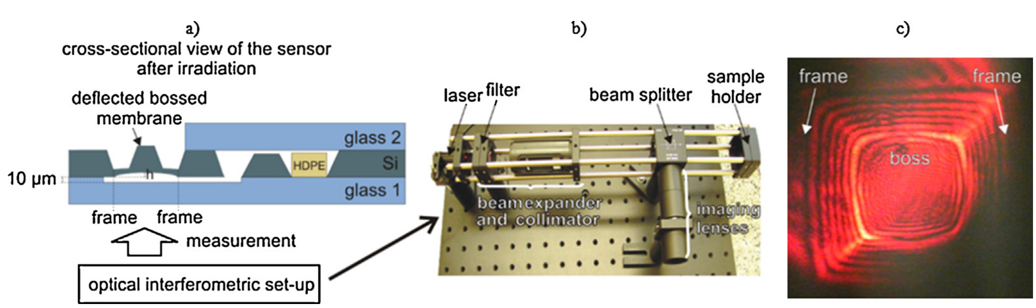

Fig. 4. Sensor and interferometric measurement set-up: (a) schematic of irradiated sensor; (b) view of the set-up; (c) sensor and interferometric views of boss membrane - deflection 3,79 μm for sensor irradiated by 30 kGy.