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DESIGN AND CUSTOM FABRICATION OF A SMART TEMPERATURE SENSOR FOR AN ORGAN-ON-A-CHIP PLATFORM

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ABSTRACT

Incubators in cell cultures are used to grow and maintain cells under optimal temperature alongside other key variables, such as pH, humidity, atmospheric conditions etc. As enzymatic activity and protein synthesis proceed optimally at 37.5 ºC, a temperature rise can cause protein denaturation, whereas a drop in temperature can slow down catalysis and polypeptide initiation [1].

Inside the incubator, the measurements are gauged according to the temperature of the heating element, which is not exactly the same as that of the cells. Time spent outside the incubator can greatly impact cell health. In fact, out-of-incubator temperature and its change over time are unknown variables to clinicians and researchers, while a considerable number of cell culture losses are attributed to this reason.

To accurately monitor the temperature of the culture throughout cell growth, an in situ temperature sensor with at least ±0.5 ºC of resolution is of paramount importance. This allows the growth of the cultured cells to be optimized.

This work reports on the design and fabrication of a time-mode signal-processing in situ temperature sensor customized for an organ-on-a-chip (OOC) application. The circuit was fabricated using an in-house integrated circuit technology that requires only 7 lithographic steps and is compatible with MEMS fabrication process. The proposed circuit is developed to provide the first out-of-incubator temperature monitoring of cell cultures on an OOC platform in a monolithic fabrication. Measurement results on wafer reveal a temperature measurement resolution of less than ±0.2 ºC (3σ) and a maximum nonlinearity error of less than 0.3% across a temperature range from 25 ºC to 100 ºC.

To the authors' best knowledge, no in situ temperature-sensing fully integrated on an OOC platform exists to date. This is the first time such integration is being performed using a custom-designed circuit fabricated on the same silicon substrate as that of the OOC. The simple, robust, and custom IC technology used for the sensor fabrication grants a very cost-effective integrated solution in virtue of the reduced cost per wafer along with the large silicon area available on the platform [2]. Moreover, no further complicated assembly and subsequent protection of the pre-fabricated components is required. This minimizes the extra processing steps, along with the related handling risks, leading to higher yields. Finally, the freedom enjoyed by the MEMS-electronics co-design offers a large degree of versatility to accomodate electronics in a range of different OOC shapes and structures.

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