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ON-CHIP CELL-CULTURE SUPPORT AND MONITORING DEVICE WITH INTEGRATED THIN-FILM SENSORS AND ACTUATORS

Abstract

This work describes the design, fabrication and test of a lab-on-chip device along with its front-end electronics for the execution of experiments on bacterial cultures on nanosatellite missions. The motivations for such systems lie in the need to improve the quantification of the effects of the space environment on living organisms and facilitate the development of countermeasures to mitigate them. Ground-based studies often suffer the limitations of the available risk models for radiation exposures beyond low-Earth orbit arising from the difficulty to fully reproduce the deep-space energy spectrum and the multi-directional flux of the cosmic radiation. On the other hand, in-situ experiments have been mainly limited by the need of human support for their execution thus restricting them to space station missions or sample-return missions and, up to now, only few biology-oriented cubesat missions have been launched or scheduled for the near future. In this framework, the proposed payload aims to enable extended in-situ studies taking advantage of the characteristics of nanosatellite missions as low-cost and timing. The constraints of nanosatellite missions guided the definition of the system requirements, with particular focus on device compactness, power consumption and data budget that proved to represent the main limitations toward the implementation of biological experiments in small (up to 3U) cubesats. The proposed payload is based on an on-chip micro-incubator with integrated thin-film sensors and actuators for the active control of the environmental conditions of a bacterial culture and for the monitoring of its metabolic status. The device is composed of an incubation chamber connected to a microfluidic network designed to ensure the supply of nutrients and/or pharmaceuticals in a controlled manner in order to enable different experimental protocols, according to the type of cells and experiment target. The microfluidic network is bonded on a glass substrate on which hydrogenated amorphous silicon sensors and thin-film resistive heaters are fabricated. The on-chip photodiodes allow the implementation of luminescence-based analytical protocols commonly used in laboratory. Accurate temperature control is achieved by means of additional on-chip thin film diodes and a transparent indium-tin-oxide heater located beneath the culture chamber.