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CHEMILUMINESCENCE LIGHTS UP BIOSENSORS FOR SPACE EXPLORATION

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Space is attracting more and more interest and great efforts are aimed at achieving unexplored destinations, such as Mars. In particular, the exploration of Mars is scheduled for 2030 and in view of this goal many issues must be solved. Indeed, Mars involves long-term missions, since the journey requires 6 months meaning that the astronauts will have to be trained and equipped for any eventuality. In this context, one of the most important issues is the on-board monitoring of astronauts' health. There is a strong demand for simple portable analytical devices that astronauts can use to perform clinical chemistry analyses during space missions. These devices should be sensitive, allowing quantitative analyses of samples such as saliva or sweat without preanalytical treatment using very simple procedure and they should be unaffected by microgravity. Moreover, they should be light, energy-efficient, and occupy minimal space remaining stable over long-term storage. In addition, they must meet NASA's strict safety requirements for flying payloads.

In recent years we participated to MARS500, a simulated mission to Mars organized by the institute for Biomediacl Problems (IBMP) and by the European Space Agency (ESA) in Moscow. In order to monitor the subjects' gastrointestinal system health status, we developed portable bioassays to evaluate gastrointestinal motility through breath tests and to measure inflammation biomarkers in stools [1].

More recently a real flight experiment was performed onboard the International Space Station (ISS). As part of the IN SITU Bioanalysis project, we designed and developed a device for analysing salivary levels of cortisol, a marker of chronic stress. The device comprises a chemiluminescence (CL) reader, which uses a sensitive cooled CCD camera, and disposable cartridges produced by 3D-printing technology. Cortisol analysis is performed with a CL-based Lateral Flow ImmunoAssay (LFIA), in which the flow of sample and reagents is driven by capillarity. It thus operates in a gravity-independent manner, bypassing the need for pumps [2,3]. The LFIA strip and reagents are located in a sealed microfluidic element, which provides the level of containment according to NASA's safety requirements. This microfluidic element, enclosed in the cartridge, is operated by external buttons and valves. To perform

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sensitive quantitative analyses, the device uses enhanced CL imaging based on the horseradish peroxidase (HRP)/luminol/peroxide CL system.
The project, carried out in collaboration with ALTEC SpA (Turin), was financed and coordinated by the Agenzia Spaziale Italiana (ASI), which also provided its own resources aboard the ISS, and supported by Kayser Italia (Livorno) as an ISS control centre, interacting with NASA. The astronaut Paolo Nespoli tested the device onboard the ISS during "VITA" mission (July-December 2017).
Another important aspect for the future missions, is the possibility of analyzing in-situ material samples in search of organic molecules, amino acids, nucleic acids, polysaccharides and other biological systems molecules.
Recently, the increasing development of extremely compact systems relying on microfluidics, commonly known as lab-on-chip devices, has gained much attention thanks to their favorable characteristics in terms of reduced size and weight, very low sample and reagent consumption, reduced analysis time and, often, superior achievable performances in terms of limits-of-detection. Lab-on-chip devices are extremely suitable for space missions. In this context, we report about the design and optimization of new analytical platform for the multiparametric detection of bio-organic molecules outside of the Earth. In particular we optimized a DNA switch based on CL detection for the identification of adenosine triphosphate (ATP) which is an extant life biomarker. The DNA switch was implemented into a portable device, composed of a microfluidic network based on capillary forces for the handling of samples and reagents, a set of functionalized detection sites where the bioassay was carried out and an array of thin-film hydrogenated amorphous silicon (a-Si:H) photosensors for the detection of the analytical CL signal. The implementation of this functional module provided a compact and fully integrated device together with a low power consumption.

Financial contributions from the Italian Space Agency (ASI). We are grateful to the Italian Space Agency (ASI) for making available its resources onboard the ISS.

References

[1] Roda, A., Mirasoli, M., Guardigli, M., Simoni, P., Festi, D., Afonin, B., Vasilyeva, G. (2013). World Journal of Gastroenterology, 19, 2208-2216.
[2] Zangheri, M., Cevenini, L., Anfossi, L., Baggiani, C., Simoni, P., Di Nardo, F., & Roda, A. (2015). Biosensors and Bioelectronics, 64, 63-68.
[3] Roda, A., Mirasoli, M., Michelini, E., Di Fusco, M., Zangheri, M., Cevenini, L.,Roda, B., Simoni, P. (2016). Biosensors and Bioelectronics, 76, 164-179.