CONSTRUCTION OF REMOTE-SENSING PLATFORM FOR STRATOSPHERIC EXPERIMENTS

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Abstract: Nowadays remote sensing represents alternative to standard laboratory analysis. It also remains the only possibility to perform analysis in dangerous or for other reasons inaccessible conditions like volcanoes, atmosphere or highly contaminated areas. These devices perform *in situ* analysis in order to minimize processes, which can negatively influence results. Manual sample handling, sample contamination or changes during transportation are some of them. The research of atmosphere is appealing field of science. The effects of UV radiation on living organisms which is presented above the ozone layer is known for decades, nevertheless laboratory researches are not able to evaluate the additive effect of several others negative effects like low pressure, temperature or presence of highly energetic particles. The aim of our research was to create remote sensing platform, which will be able to perform several electrochemistry-based analysis in stratosphere and enable us to quantify the effect of above-mentioned conditions on DNA.

Key Words: DNA, electrochemistry, electrode, stratosphere, UV

INTRODUCTION

Nowadays, remote sensing represents an alternative to standard laboratory analysis and remains the only possibility to perform *in situ* analysis in dangerous or for other reasons inaccessible conditions like volcanoes, atmosphere or highly contaminated areas (Nejdl et al. 2014, Solikhin et al. 2015, Wu et al. 2015). Progress in the field of electronics constantly lowers demands for labor to carry out dangerous tasks and pushes man to the role of just an operator, who due to the effective communication technologies controls the device from the operator site.

Fluidic detection devices are essential parts of these robotic platforms. It is consistent with development of "lab-on-chip" technologies in last two decades, which try to integrate all steps of analysis including sample pretreatment, reagents addition and mixing, separation and detection into one device. They include peristaltic pumps, which enable suction of samples, their mixing with reagents and feeding to detectors. Among others, micro- and nanofluidic devices operating with minimal amount of samples are attracting big attention.

The electrochemical detection methods are suitable for above-mentioned devices. It possesses superior properties due to their high selectivity, sensitivity, possibility of miniaturization, integration to fluidic devices and analysis of turbid samples (Hynek et al. 2013, Nejdl et al. 2015).

Nowadays, stratospheric researches mostly deal with the decrease of ozone in lower parts of stratosphere (McLandress et al. 2010). Although broad tolerance to UV was described in case of different taxonomic groups and species, UVB light (280–315 nm) among others disrupts gene integrity and other cellular processes in organisms from prokaryote to mammals (Hader et al. 2007, Sinha et al. 2008, Solomon 2008). Deamination of bases, hydrolytic damage and/or double strand breaks are some of negative effects of UV light on DNA. Nevertheless, these effects alone do not cause the apoptosis but lead to the carcinogenesis or decrease fertility.

The aim of our research is to fabricate an automatic fluidic electrochemical analyzer in order to quantify stratospheric UV damage of DNA. Nevertheless, the electrochemical analyzer without fluidics will be taken to stratosphere by probe to evaluate the functionality of this technology.

MATERIAL AND METHODS

Fabrication of the analyzer

The models of the outer shell and inner parts of stratospheric probe were created in SolidWorks software (Dassault Systèmes SolidWorks, Brno, Czech Republic). Most of these parts were printed using 3D printer profi3Dmaker (Aroja, Straznice, Czech Republic) with printing resolution of 0.300 mm in *x* and *y* axis and resolution of 0.13 mm in *z* axis. Acrylonitrile butadiene styrene filament with diameter of 1.75 mm (ABS) (Prusa Research, Prag, Czech Republic) was used as a source material for 3D printer and the parts were created using fused filament fabrication (FFF) method. The probe included only several parts, which were not fabricated using 3D printer.

The detection part of the analyzer consisted of an amalgam working electrode, Ag/AgCl/3M KCl reference electrode and platinum counter electrode (both CH Instruments, Austin, USA). The signals were recorded using potentiostat 910 PSTAT mini (Metrohm, Herisau, Switzerland) and evaluated using software PSTAT software 1.0 (Metrohm, Herisau, Switzerland). The electrochemical cell was fabricated from LedStone water clear casting resin (16.00 g resin + 0.16 g catalyst) and hardened for 8 hours on a pad (80°C). The evaluating software run on and the data are stored to NUC 5I3RYK (Intel, Santa Clara, USA), which is powered by GENS ACE Li-Po battery (5000 mAh, 18.5 V, Acepow Electronics, Shenzhen, China).

Fabrication of amalgam electrode

Copper wires (Thermo scientific, Cambridge, UK) were used as working electrodes after modification. The copper wires were inserted into 0.01 M $Hg(NO_3)_2$ solution, prepared by the dissolving of 0.086 g mercury(II) nitrate in 25 mL of acidified (5% HNO_3, v/v) Milli-Q water. The electrodes were immersed in this solution for 0–480 seconds, which resulted in the formation of a thin-film of amalgam on the surface.

RESULTS AND DISCUSSION

Stratospheric remote sensing platform

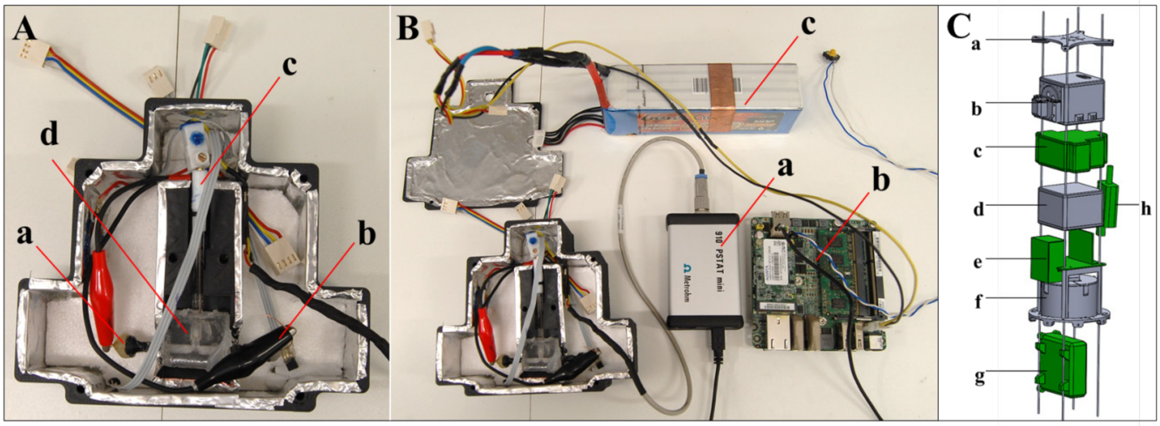
For the construction of analyzer, the common thermoplastic polymer ABS was chosen. It is tough and hard material with low heat conductivity and high resistance to UV and other atmospheric impacts. ABS parts of the analyzer were printed using FFF, which represents one of 3D printing techniques. It is an additive method, where substrates are layered down while the substrate (filament or wire) is unwounded from coil and supplies the printer. In the printer, the filament is heated above the glass transition temperature and then deposited according to the software model.

Molecule of DNA interacts with several chemical and physical agents. Negative effects on DNA often results in DNA damage and lead to the mutagenesis and cancer. It is necessary to possess an analytical tool to evaluate and quantify these effects in order to adequately respond to this danger. In past decades, it was shown that electrochemical methods are able to answer the questions about DNA structure, interactions and damage (Fojta 2002). For this experiment, we selected the amalgam electrode since it possesses a comparable sensitivity with mercury electrode but from the mechanical point of view, the mercury electrode is impossible to be used in conditions such as stratosphere.

Stratospheric balloons are the main tools, which are used in *in situ* stratospheric researches (Favela et al. 2012, Martinerie et al. 2009). We fabricated the electrochemical analyzer, which can perform analysis in harsh stratospheric conditions especially low pressure and low temperatures. The construction of analyzer was designed in order to bear these conditions. Although the electrochemical analysis needs to be performed in water solutions, the inner part of analyzer needs to be thermostable to prevent the temperature fall below zero degrees Celsius. It is guaranteed using three heaters and three digital thermometers controlled by the computer. This computer controlled also the functions of the analyzer and was managed by the operator site from the ground using wireless communication technology.

The electrochemical analyzer (see Figure 1), which was designed and its performance was tested will be in several next months taken to the stratosphere by stratospheric balloon and try to measure electrochemical signal there. Although several stress tests were performed, stratospheric conditions cannot be effectively simulated in laboratory. After this necessary test step, fluidic device will be integrated to the above-described technology, which will enable us to expose molecules of DNA to UV radiation in stratosphere and evaluate damage to DNA.

Figure 1 Scheme of electrochemical analyzer



*Legend: **A**: a – working electrode, b – counter electrode, c – reference electrode, d – electrochemical cell; **B**: a – potentiostat, b – computer, c – battery, **C**: a – holder for cameras, b – florescence analyzer, c – electrochemical analyzer, d – cultivation of bacteria, e – thermoregulation of probe, f – cultivation of viruses, g – computer, h – potentiostat (green parts of scheme relates to this contribution)*

CONCLUSION

The result of this work was design, fabrication and test of analyzer, which is able to electrochemically detect DNA in stratosphere. The sensor is modular and can be improved and/or modified. The next step of our research will be in situ stratospheric test and integration of fluidic device in order to enable DNA damage measurement in stratosphere.

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