Nanotechnology and health nanodiagnostic tools

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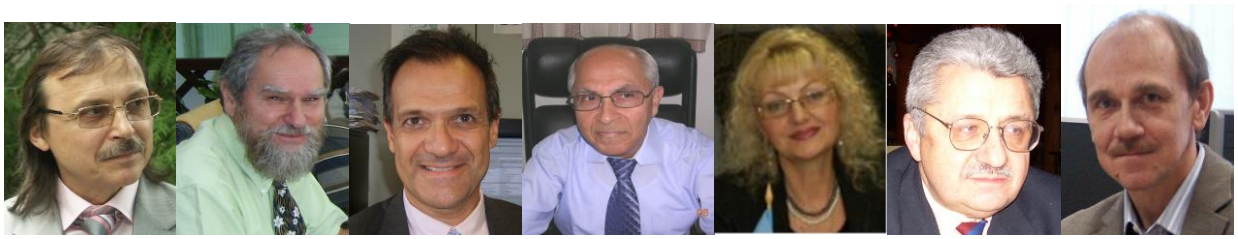

Abstract

Health nanodiagnostic tools include nanobiosensoring devices and their various interfaces which allow processing a continuous flux of medical information in a digital form. This information can be collected and processed in external data bases or intelligent expert systems providing the permanent health monitoring of biological systems. Possible nanosensoring health monitoring systems are discussed in connection with HORIZON202O EP strategies.

Keywords: ion tracks, microbeams, polymers, etching, cells, bacteria, biosensors, biomolecules, signaling molecules, quorum sensing, nanocarbon-based sensor systems

1 Introduction

There are a number of actual research directions of The EU Framework Programme for Research and Innovation HORIZON2020 (see also Figure 1) [1]:

- Agriculture & Forestry
- Aquatic Resources
- Bio-based Industries
- Biotechnology
- Energy
- Environment & Climate Action
- Food & Healthy Diet
- Funding Researchers
- **Health**
- ICT Research & Innovation
- Innovation
- International Cooperation
- Key Enabling Technologies
- Partnerships with Industry and Member States
- Raw Materials
- Research Infrastructures
- Security
- SMEs
- Social Sciences & Humanities
- Society
- Space
- Transport

FIGURE 1a **Horizon 2020 video - General overview**. Horizon 2020 in this three-minute animation clip. http://ec.europa.eu/programmes/horizon2020/en/news/horizon-2020-video-general-overview

FIGURE 2b Horizon 2020 video - How to apply? http://ec.europa.eu/programmes/horizon2020/en/news/horizon-2020-video-how-apply

FIGURE 1c **High-tech nano-science helps for cultural treasures**. Conservators use heat transfer for restoration – from paintings, works on paper and textiles to murals, 3-D objects and more. It has been developed a revolutionary heating system based on carbon nanotubes and silver nanoparticles. http://ec.europa.eu/programmes/horizon2020/en/news/high-tech-nano-science-help-cultural-treasures

FIGURE 1d **EU research shows need for action now on climate change**. Scenarios on climate change and its effects on society have found that taking action sooner rather than later will reduce the costs of mitigation. http://ec.europa.eu/programmes/horizon2020/en/news/eu-research-shows-need-action-now-climate-change

2 General Health topics of Horizon2020 EP

We pay attention to the Health division of Horizon2020 in our research: **'Health is wealth, as an old saying goes'.**

The key direction of Health Roadmap in Horizon2020 is ***Personalising health and care.***

Research and Innovation which are supported by actual Horizon call in the mentioned respect are [1]:

- improve our understanding of the causes and mechanisms underlying health, healthy ageing and disease;
- **improve our ability to monitor health and to prevent, detect, treat and manage disease;**
- support older people to remain active and healthy;
- test and demonstrate new models and tools for health and care delivery.

Thus, diagnostics and continuous monitoring of human organism qualities and lacks are the key points of Horizon strategies. The current research topics of HORIZON2020 look as follows:

Topic 1:	PHC-21-2015: Advancing active and healthy ageing with ICT: Early risk detection and intervention
Topic 2:	PHC-25-2015: Advanced ICT systems and services for integrated care
Topic 3:	PHC-27-2015: Self-management of health and disease and patient empowerment supported by ICT
Topic 4:	PHC-28-2015: Self management of health and disease and decision support systems based on predictive computer modelling used by the patient him or herself
Topic 5:	PHC-29-2015: Public procurement of innovative eHealth services
Topic 6:	**PHC-30-2015: Digital representation of health data to improve disease diagnosis and treatment**

Topic 6 is the subject of our research activities.

HORIZON2020 formulated specific challenge [1]. Digital personalised models, tools and standards with application for some specific clinical targets are currently available. There is however, a need for greater integration of patient information, for example, of multi-scale and multi-level physiological models with current and historical patient specific data and population specific data, to generate new clinical information for patient management. Any such integrative digital representation (***Digital Patient***) must also allow meaningful knowledge extraction and decision support.

Requirements for research. Proposals should focus on new decision support systems (DSS) based on a complex integration of heterogeneous data sources and subject-specific computer models. This should enable an integrated data analysis, and should reveal a highly visual data representation, applying user-friendly interactive exploratory interfaces in order to assure usability and acceptability. Proposals should enable the application of DSS by health-care professionals for personalised prediction and decision making in prevention, diagnosis or treatment and should take into account data protection and ethical considerations, as well as those pertaining to the inherent uncertainties and limits of prediction. The models should be already available, multi-level and multi-scale ones and should be integrated with the individual and population data relevant to the targeted clinical situations, e.g. the required molecular and cellular data, including genomics and epi-genomics, ***in vivo*** and ***in vitro*** imaging data, or data on administration of therapeutics and on nutrition/exposure to environmental factors. These will be linked with relevant computer models of personalised physiology, functional disorders and other diseases. The proposed systems should take advantage of the personal medical data accumulated over time. Proposals should include the standardisation of data formats. The integration of data coming from other new technologies for e.g. key-enabling technologies should be considered. Gender and ethical issues should be duly considered.

Expected impact:

- Better coherent use of health data available for a subject in conjunction with the existing medical knowledge in clinical decision making
- Design of predictive and therapeutic interventions
- Better management of complex clinical situations.
- Enabling use of the same information by different medical services and the other relevant healthcare professionals.
- **Better control and inter-service coordination in the management of the patient health.**
- Providing a consistent view of a patient's care needs.

3 Research proposal 'Information Technologies for Bacterial Infections Theranostics'

New *multifunctional* ion irradiation-based 3-dimensional electronic structures are developed for biotechnological applications, specifically for sensing of biomaterials, bacteria and mammalian cells. This is accomplished by combined micrometric surface and nanometric bulk microstructuring of insulators (specifically of polymer foils and SiO_2/Si hybrid structures) by adequate ion beams. Our main goal is the

producing of a cheap small universal generic working platform with multifunctional properties for biomedical analysis. Surface engineering of this platform enables cell bonding and its bulk engineering enables the extraction of *cell secrets* for the sake of intercepting and analyzing the biomolecules used in cell communication. The exact knowledge of the spectrum of these cell–secreted signaling molecules should enable the unambiguous identification of the cell type. This knowledge will help to develop strategies for preventive quorum sensing of bacteria with the aim of fighting bacterial infections in an ecologically secure way [2].

We intend to demonstrate the application of the digital representation of health data for the case of the development of new methods in medical practice for early-stage diagnosis of bacterial infectious diseases and novel therapeutic methods for their treatment. To achieve this goal we will solve three problems. First, it is the creation of sensor devices, which will allow simple enough and accurate measuring of the human health parameters. These devices should provide the wireless transmission of data to the Analytical Center. The next problem is the creation of an effective approach for mathematical treatment of the obtainned results. The results concerning the dynamics and characteristics of health parameters will be qualified as complex data, and the methods of the Theory of complex systems will be applied to their analysis. This approach will allow to prepare the obtained data for further analyses and to precisely extract knowledge from large complex data collections. Furthermore, the third and the main objective of the project is to develop a new generation of biosensors based on the recent advances of "track electronics" that allow monitoring and tracking primarily in such area as health. The ion track-based structures form a principally new foundation for interfacing conventional electronics and nanoelectronics with bio-active sensor compounds. These nanostructures can be used for the creation of novel electron devices with unique parameters hitherto unknown in electronics.

One of the fundamental goals of the project is nanofabrication of such state-of-the-art devices and to explore them for obtaining information about health parameters for their transferring and treatment.

The first fabricated prototypes of the ion track-based nanosensors provide high sensitivity, low power and low cost portable tools for *in-situ* chemical analysis in space and terrestrial applications. Our generic nanosensor platform allows creating devices suitable for the analysis and detection of gases and volatile organic compounds. Novel nanosensors will greatly increase science measurement capability for life support systems also in long duration missions, and planetary exploration. For biosensing applications the ion tracks will be functionalized either directly by attaching organic or bioactive compounds (such as enzymes) to their walls, or indirectly by the attachment of biosensing materials to metal oxide nanowires or tubules grown therein [2-4].

The next objective is to use the data integration approach to provide a data warehouse over different data sources using the ETL (Extract, Transform, and Load) process. We plan to use data description languages such as XML, RDF-RDF/S to take account of the structural and semantic data heterogeneity and to use a full generic data warehousing and online analysis process that include two broad axes: data warehousing with complex data integration and modeling and complex data analysis. And lastly, we envisage developping digital personalized models for bacterial infectious diseases and creating a model of Digital Patient. The model will be available to solve practical theranostic problems linked to real clinical situations. The opportunity will be provided to use the developed in the project methods by different medical services and other relevant healthcare professionals.

4 Conclusion

We expect to create a prototype of Health monitoring system based on unique nanosensoring systems with the abilities of functionalization. The developed digital processing of medical information should provide a continuous monitoring of biological objects and communications among medical data bases and intelligent expert systems.

References

[1] http://ec.europa.eu/programmes/horizon2020/en/h2020-section/health-demographic-change-and-wellbeing

[2] Alfonta L, Mandabi Y, Bacakova L E, Dias J F, Fink D, Kiv A, Fuks D, Muñoz G H, Papaleo R M, de Souza C T, Vacík J, Hnatowicz V 2012 Status and perspectives of ion track electronics for advanced biosensing *Nanodevices and Nanomaterials for Ecological Security, Series: Nato Science for Peace Series B - Physics and Biophysics*, ed Yu Shunin and A Kiv Hiedelberg: Springer Verlag 269-280

[3] Shunin Yu N, Zhukovskii Yu F, Burlutskaya N Yu, Gopeyenko V I, Bellucci S 2012 Simulation of fundamental properties of CNT- and GNR-Metal interconnects for development of new nanosensor systems *Nanodevices and Nanomaterials for Ecological Security, Series: Nato Science for Peace Series B - Physics and Biophysics*, ed Yu Shunin and A Kiv Hiedelberg: Springer Verlag 237-262

[4] Shunin Yu, Bellucci S , Zhukovskii Yu, Gopeyenko V, Burlutskaya N, Lobanova-Shunina T 2015 *Computer Modelling and New Technologies* **19**(1A) 35-42