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Diamond-based sensors for in vitro cellular radiobiology: Simultaneous detection of cell exocytic activity and ionizing radiation

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ABSTRACT

The investigation of secondary effects induced by ionizing radiation represents a new and ever-growing research field in radiobiology. This new paradigm cannot be investigated only using standard instrumentation and methodologies, but rather requires novel technologies to achieve significant progress. In this framework, we developed diamond-based sensors that allow simultaneous real-time measurements with a high spatial resolution of the secretory activity of a network of cells cultured on the device, as well as of the dose at which they are exposed during irradiation experiments. The devices were functionally characterized by testing both the above-mentioned detection schemes, namely: amperometric measurements of neurotransmitter release from excitable cells (such as dopamine or adrenaline) and dosimetric evaluation using different ionizing particles (alpha particle and X-ray photons). Finally, the sensors were employed to investigate the effects induced by X-rays on the exocytotic activity of PC12 neuroendocrine cells by monitoring the modulation of the dopamine release in real-time.

1. Introduction

Historically, the predominant paradigm in radiobiology was based on the assumption that the biological effects induced by ionizing radiation are exclusively pertinent to the directly irradiated cell nuclei, and therefore that all the subsequent biological effects (such as the cell death or dysfunction) were strictly correlated with unrepaired or mis-repaired DNA (Steel et al., 1989). In the modern conception, in addition to these direct effects, the relevance of secondary consequences such as bystander and abscopal effects has attracted increasing interest due to several studies that unequivocally highlighted these phenomena (Schaue and Mcbride, 2015). Moreover, numerous research groups are working on the minimization of these phenomena, which are important for cutting-edge fields as for example in the field of FLASH therapy (Durante et al., 2017; Favaudon et al., 2014). Nonetheless, a complete understanding of the mechanisms underlying these effects is still missing and novel systematic investigation approaches are under development (Lacombe et al., 2016; Niklas et al., 2016). In this context, the integration of complementary detection schemes providing a comprehensive description of the interaction between ionizing radiation and living systems is still largely unexplored due to several technological obstacles, despite its paramount importance. Related experiments are generally

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