Preface to Special Topic: Plasmas for Medical Applications
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Preface to Special Topic: Plasmas for Medical Applications

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Intense research effort over last few decades in low-temperature (or cold) atmospheric plasma application in bioengineering led to the foundation of a new scientific field, plasma medicine. Cold atmospheric plasmas (CAP) produce various chemically reactive species including reactive oxygen species (ROS) and reactive nitrogen species (RNS). It has been found that these reactive species play an important role in the interaction of CAP with prokaryotic and eukaryotic cells triggering various signaling pathways in cells. © 2015 AIP Publishing LLC.

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There is convincing evidence that cold atmospheric plasmas (CAP) interaction with tissue allows targeted cell removal without necrosis, i.e., cell disruption. In fact, it was determined that CAP affects cells via a programmable process called apoptosis.\textsuperscript{1–3} Apoptosis is a multi-step process leading to cell death, and this process is the one inherit to cells in the human body.

Although CAP has been shown to be lethal to bacteria, it appears to cause little to no damage to mammalian cells. Having different structure and morphology than that of prokaryotes, mammalian cells exhibit different responses to physical and chemical stresses induced by CAP. The ability of CAP to kill bacteria and to accelerate the proliferation of specific tissue cells opened up the possibility to use plasma in various medical applications. CAP is already proven to be effective in wound healing, skin diseases, hospital hygiene, sterilization, antifungal treatments, dental care, and cosmetics targeted cell/tissue removal.\textsuperscript{4–6} More recently, potential of CAP application in cancer therapy has been explored.\textsuperscript{7–10} It was demonstrated that CAP treatment leads to selective eradication of cancer cells in vitro and reduction of tumor size in vivo. Recently, few successful clinical trials have been performed.

Further progress in this highly interdisciplinary field can be expected as a result of strong collaborative research between plasma physicists, chemists, microbiologists, and medical doctors.

It is due to such increased interest in plasma medicine to the plasma physics community that \textit{Physics of Plasmas} dedicates this Special Topic Section on Plasma Medicine. The proposed Special Topic Section will address the following aspects of plasma medicine:

\begin{itemize}
  \item plasma devices and plasma diagnostics for medical applications
  \item biological aspects of plasma interaction with cells and relationship between plasma parameters and cell responses
\end{itemize}

Recently, various unique plasma diagnostic tools were developed to probe low-temperature plasmas. In this special topic section, there are several papers dedicated to plasma diagnostics.

\textit{Shashurin and Keidar} presented a mini review of diagnostic approaches for the low-frequency atmospheric plasma jets. \textit{Robert et al.} described analysis of atmospheric pressure plasma propagation inside the long dielectric tubes through non-intrusive and non-perturbative time resolving bi-directional electric field (EF) measurements. In particular, their study reveals that plasma propagation occurs in a region where longitudinal EF exists ahead of the ionization front. EF components have a few kV/cm in amplitude in the case of helium or neon plasmas and almost constant along a few tens of cm long capillary. These measurements are in excellent agreement with the previous calculations.

Evaluation of efficacy of the plasma-activated media on cancer cells was described by \textit{Mohades et al.}. It was observed that the chemistry induced by plasma in the aequous state becomes crucial and usually determines the biological response. They report on the measurements of concentrations of the hydrogen peroxide, a species known to have strong biological effects. \textit{Yang et al.} presented a study of atmospheric pressure cold plasma effect on chemotherapeutic drug-resistant cells. Incubation with plasma-treated medium for 20 s induced more than 85% death rate in Bel7402 cells, while the same death ratio was achieved when Bel7402/5FU cells were treated for as long as 300 s. They established that the hydrogen peroxide in the medium played a leading role in the cytotoxicity effects. \textit{Miller et al.} addressed an important problem of atmospheric plasma effect on angiogenesis, which is the process of formation of new blood vessels from pre-existing vessels. Stimulation of angiogenesis is a promising and an important step in treatment of peripheral artery disease. They demonstrated that atmospheric plasma treatment stimulates the production of VEGF, MMP-9, and CXCL1 that, in turn, induces angiogenesis in mouse aortic rings. \textit{Ishaq et al.} described biological mechanisms that underpin plasma-induced death in cancer cells. In particular, they focused on effect of the plasma treatment dose on the expression of tumour suppressor protein TP73. They found that the plasma treatment induces dose-dependent up-regulation of TP73 gene expression, resulting in significantly

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elevated levels of TP73 RNA and protein in the plasma-treated melanoma cells. These results confirm the role of TP73 protein in dose-dependent regulation of anticancer activity of atmospheric-pressure plasmas. Jablonowski et al. investigated the role of ultraviolet (UV) and, in particular, vacuum UV (VUV) radiation generated by an atmospheric pressure argon plasma jet in plasma medicine. They concluded that a considerable amount of radicals are generated by the plasma-generated photoemission. Tanaka et al. presented a mini review describing the interaction of non-thermal atmospheric pressure plasma with cancer cells. They outlined recent innovative studies suggesting that the cold atmospheric plasma can affect cells both directly and indirectly. They stated that a new academic field that combines plasma science, biology of free radicals, and system biology is establishing.