Guest editorial: special issue on nonthermal medical/biological applications using ionized gases and electromagnetic fields

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Guest Editorial
Special Issue on Nonthermal Medical/Biological Applications Using Ionized Gases and Electromagnetic Fields

I. INTRODUCTION

THE FASCINATION of men with the interaction between electricity and biological systems can be traced back to Egyptian hieroglyphs dated in 4000 BC that describe biological electricity in catfish. In the modern era, active exploration of beneficial bioelectrical effects has witnessed a substantial increase in research activities and interests over the past three decades. This period of considerable growth is underpinned by major advances in the technologies of low-temperature ionized gases, ultrashort intense electrical pulses, and high-frequency electromagnetic waves. As a result, ionized gases and electromagnetic fields are widely and increasingly studied for their applications in medicine and biology, for example, biological decontamination, tissue engineering, environment management, cell manipulation, and tumor growth control. It is conceivable that ionized gases and electromagnetic fields will ultimately bring some applications to reality and offer real and widespread healthcare solutions. This Special Issue offers a snapshot of the current understanding and technological capabilities, as well as a reference point for future research directions.

II. HISTORICAL REVIEW

This Special Issue is the fourth of a series devoted to bioelectrical effects and published in the IEEE TRANSACTIONS ON PLASMA SCIENCE, with the first three published in February 2000, August 2002, and August 2004, respectively. The first Special Issue consists largely of papers presented at the First International Symposium on Nonthermal Medical and Biological Treatments Using Electromagnetic Fields and Ionized Gases, which was held in April 1999 in Virginia. It acted as a focal point of seminal reports on many of the most important scientific issues, as well as a critical trigger for many subsequent studies to be initiated and developed. Since then, there has been a steady growth in the number of scientific publications with varying emphases on biology and/or physical sciences. Their disseminations are also done through a variety of scientific journals and conferences—some biology-focused and some engineering-focused. To reflect this trend of growth and diversity, this Special Issue includes papers presented at the Fourth International Symposium on Nonthermal Medical/Biological Treatments Using Electromagnetic Fields and Ionized Gases (May 2005, Portland, OR) and in response to our call for papers for this Special Issue.

As shown in Table I, both the first and the fourth Special Issues include more than 30 papers. The first Special Issue contains several major historical reviews of topical issues, whereas the succeeding issues document the growth and change within these areas. To some extent, the figures also reflect the great challenge of these fields, where an equal emphasis on life science and physical science is essential, rather than just desirable. It cannot be overstated that the future of this exciting field relies on equal, interactive, and synergistic contributions from both the physical and life sciences communities. It is noteworthy that, as a result of the interdisciplinary character of this research, the numbers in Table I are representative of the great and increasing number of related papers being published in more specific journals with emphases on physics, biology, and medical or environmental applications. The overall picture of this field is particularly promising.

III. SUMMARY OF WORK PRESENTED

As in previous Special Issues, there are two distinct types of techniques used, namely: 1) ionized gases and 2) electromagnetic fields, including, in particular, pulsed electric fields.

Ionized gases considered in papers included in this Special Issue are mostly nonequilibrium gas discharges generated either in open air at atmospheric pressure or in a vacuum chamber, but also energetic electron beams that can be considered as fully ionized plasmas. Their applications include biological decontamination, sublethal modifications of cellular functions and properties, and pollution control. Evolving from those included in previous Special Issues, a majority of the biodecontamination papers included in this Special Issue focus on: 1) sublethal effects; 2) possible biological targets hit by agents of ionized gases; and 3) possible agents of ionized gases that may be responsible for the observed biodecontamination effects. The scope of biodecontamination enabled by ionized

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TABLE I

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<thead>
<tr>
<th>Year</th>
<th>2000</th>
<th>2002</th>
<th>2004</th>
<th>2006</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of papers</td>
<td>33</td>
<td>23</td>
<td>22</td>
<td>32</td>
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gases has also been expanded from bacterial inactivation to protein removal and destruction. These reflect the range of decontamination needs in healthcare facilities and industrial sectors such as food manufacture. With this expansion, more diagnostics and analytical techniques are being introduced such as fluorescence microscopy, X-ray photoelectron spectroscopy, and atomic force microscopy, as evident in some of the papers included in this Special Issue.

Manuscripts submitted to this Special Issue show the continuing strong interest in the interaction of cells with electromagnetic fields. Different aspects of current research efforts are reflected in the selected articles. The topics include research on the cytotoxicity of millimeter-wave and microwave irradiations. In other studies, the possibility of interactions with subcellular structures via nonthermal resonant effects were investigated with the potential for future selective modifications of cell functions. Papers presented on the application of electromagnetic fields in the even shorter range of the electromagnetic spectrum—the ultraviolet—show how these technologies have matured into effective decontamination alternatives. Several manuscripts are dedicated to the effects of pulsed electric fields. New results demonstrate their successful use in the processing of water or liquid food. Beyond the scope of decontamination, the articles show how the research is moving toward exposures with very short pulsed exposures of mere nanoseconds but of high field strength. The interest lies, in particular, in the way in which these stimuli interact with organelles and promote cell modifications that may ultimately be exploited in biological and medical applications. The effort to understand these interactions goes along with new and improved modeling and simulation studies.

ACKNOWLEDGMENT

The authors, as the Guest Editors, would like to thank Dr. S. J. Gitomer, Editor-in-Chief of the IEEE TRANSACTIONS ON PLASMA SCIENCE, for his agreement to host this Special Issue and for his guidance and support. They would like to express their great appreciation to all the reviewers. Their evaluation of the scientific merit of the manuscripts and their expert advice have helped improve the quality of the accepted manuscripts. The Guest Editors are particularly grateful for the willingness of the reviewers to respond quickly on sometimes multiple reviews of manuscripts.

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Juergen F. Kolb (M’02) received the Dr.rer.nat. degree in physics from the University of Erlangen, Germany, in 1999.

After holding research positions at the University of Erlangen and the Technische Hochschule Darmstadt, Germany, he joined Old Dominion University, Norfolk, VA, in 2002. Here, he transitioned from the Physical Electronics Research Institute to the Frank Reidy Research Center for Bioelectrics in 2003 and is currently an Assistant Professor in the Frank Batten Department of Electrical and Computer Engineering. His current research interests are focused on the study of subcellular effects using nanosecond pulsed electric fields, atmospheric pressure air plasmas, and pulsed power physics and technologies.
Michael G. Kong (M’94–SM’98) received the B.Sc. and M.Sc. degrees in electronics engineering from Zhejiang University, Hangzhou, China, in 1984 and 1987, respectively, and the Ph.D. degree in electrical engineering from Liverpool University, Liverpool, U.K., in 1992.

After research and faculty positions at Liverpool University and Nottingham University, Nottingham, U.K., he joined Loughborough University, Loughborough, U.K., in 1999, where he holds a Chair in bioelectrical engineering and leads the Plasma and Pulsed Power Group. At Loughborough University, he is also the Head of the Energy Research Division whose research encompasses gas plasmas, pulsed power, and renewable energy. His current research interests include atmospheric pressure glow discharges, ultrashort electric pulses, and their biomedical applications. In these areas and others, he has published some 150 papers in scientific journals and peer-reviewed conference proceedings.

Peter F. Blackmore received the B.Sc. and Ph.D. degrees in biochemistry from the University of New South Wales, Sydney, Australia, in 1971 and 1976, respectively.

From 1978 to 1988, he was an Assistant Professor with the Department of Molecular Physiology and Biophysics, Vanderbilt University School of Medicine, Nashville, TN. From 1980 to 1998, he was also an Associate Investigator with the Howard Hughes Medical Institute. He is currently a Professor with the Department of Physiological Sciences, Eastern Virginia Medical School, Norfolk, VA. One of his current research interests focuses on investigating how steroids act via nongenomic mechanisms to promote calcium influx in human platelets and sperm. In addition, he is studying the effects of nanosecond pulsed electric fields on calcium fluxes in a variety of cell types.

Dr. Blackmore was a Member of the Editorial Board of the Journal of Biological Chemistry from 1987 to 1993 and the American Journal of Physiology: Endocrinology and Metabolism from 1985 to 2001. He is currently on the Editorial Board of Steroids.