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EDITORIAL

Special Issue on "Dielectric Barrier Discharges and their Applications" in Commemoration of the 20th Anniversary of Dr. Ulrich Kogelschatz's Work

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Twenty years ago, Dr. Ulrich Kogelschatz wrote a seminal review paper, "Dielectric-barrier Discharges: Their History, Discharge Physics, and Industrial Applications", which was published in *Plasma Chem. Plasma Process.* in March 2003 [1]. Although Ulrich sadly passed away much too early (June 25, 2016), his work has inspired the entire low-temperature atmospheric pressure plasma community. This is demonstrated by the impressive number of citations of the above-mentioned "must read" review paper (over 4000 according to Google Scholar, and it continues to receive over 150 citations each year), but also several other of his papers have received more than 1000 citations. Hence, we decided to publish a special issue on DBDs and their wide range of applications, 20 years after his seminal review paper in the same journal, to celebrate Dr. Kogelschatz's inspiring work. We invited all leading authors working with DBD, and the response was overwhelming, highlighting how indeed Dr. Kogelschatz has inspired so many of us.

The SI contains 36 research papers (most of them upon invitation, but some are also unsolicited, as the special issue was open to all authors), one invited review paper, as well as three tribute articles. The latter are written by Mounir Laroussi (Old Dominion University) [2], Michael Wertheimer (Polytechnique Montréal) [3] and by Ronny Brandenburg (INP-Greifswald), Kurt Becker (New York University) and Klaus-Dieter Weltmann (INP-Greifswald) [4], who all have collaborated with Ulrich (or Uli, to his friends) and also personally knew him very well. Laroussi wrote that he learned a lot from Ulrich, both from his writings and from personal interaction. He considered Ulrich as his mentor and dear friend for many years. Wertheimer was also a close friend for many years, and explicitly wrote about his so-much appreciated humility, kindness, generosity and openness in the practice of scientific research. Brandenburg, Becker and Weltmann wrote that Ulrich had such great scientific insight, and was aware of nearly every publication in the field. He was very good at combining fundamental research and applications. They also praise his humour and humanity. They combined their personal tribute with a review that can be considered as a follow-up of Ulrich's 2003 paper, summarizing the research and applications of DBDs

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in the last decades, focusing especially on O_3 generation, radiation sources, environmental applications, surface treatment, but also on topics which have gained increasing interest after 2003, such as plasma medicine, CO_2 conversion, liquid treatment and airflow control.

The applications of DBDs have indeed expanded greatly in the past 20 years, including now also plasma catalysis, plasma medicine, plasma agriculture, etc., in addition to O_3 generation, pollution control, surface treatment, high-power CO_2 lasers, UV excimer lamps, and plasma TVs, which were all discussed in the original review paper. As Ulrich was both a pioneer in fundamental studies and applications, we are happy that the papers published in this special issue also cover both fundamental studies of DBDs, as well as their broad range of applications.

Indeed, several papers report fundamental studies on DBDs, such as on the production of gas species with multi-hollow surface DBD [5], the study of successive multi-microdischarges in a pin-to-line DBD geometry [6], temperature-dependent kinetics in an O_2 DBD for O_3 production [7], the generation of multiple jet capillaries in DBDs for large scale plasma jets [8], the study of random bullets vs. self-triggered short discharges in plasma jets [9], the interaction between flow fields induced by surface DBD arrays [10], streamer-based discharge on water-air interface for producing plasma-activated water [11], gas-liquid chemical reactions with nanosecond pulses [12], the characterization of a portable air floating-electrode DBD [13], and the characterization of such a DBD for treating either plastic well plates or skin surface [14] both for plasma medicine applications, as well as modelling the impact of residual surface charges on energy coupling in packed-bed DBD [15], and characterization of surface-DBD for flow control in plasma conversion [16].

As mentioned above, DBDs find a wide range of applications, as also demonstrated in this special issue, such as for the treatment of volatile organic compounds and O_3 [17], vanadium redox flow batteries [18], dye treatment [19], and plasma treatment and ozonization of binary mixtures, such as maleic and fumaric acids [20]. Some papers also report on the material (thin film) application of DBDs, i.e., on immobilized microdischarges for localized deposition and patterning of polymer-like films [21], and on the synthesis of thin films containing Au nanoparticles from metal salt injection in DBDs [22].

Many novel applications of DBDs are situated in the fields of plasma medicine and plasma agriculture, and several of these applications are also reported in this special issue, including testing the antimicrobial efficacy of large-scale DBD on food contact surfaces [23], and large surface decontamination [24], as well as studying the effect of volume DBD on phytopathogenic fungi [25], accelerating the germination and nutrient composition of foxtail millet [26], and seed treatment [27, 28].

Last but not least, one of the fastest-growing application fields of DBDs is in gas conversion (green chemistry), where DBDs are the most convenient plasma types for combining with catalysts, in so-called plasma catalysis. Hence, it is not surprising that our special issue contains many papers in this application field, for DBDs with and without catalysts, such as for nitrogen fixation, both for NO_x synthesis [29] and NH_3 synthesis [30], dry reforming of CH_4 in a nanosecond-pulsed DBD [31] and in plasma catalysis [32, 33], direct oxidation of CH_4 [34], pure CH_4 conversion (studying the effect of temperature inhibition) [35], CO_2 splitting with pyramid-shaped electrodes [36] and at elevated pressures in barrier corona discharges [37], non-oxidative C_2H_6 dehydrogenation [38], H_2S decomposition in the presence of low alkanes [39] and H_2 production from NH_3 cracking [40], and finally an invited review paper on plasma-assisted CO_2 methanation, by Ullah and coworkers [41].

The full list of contributions can be found on the page of this collection.

As Laroussi wrote, "the pioneering work of Dr. Ulrich Kogelschatz and his team on the physics and chemistry of the dielectric barrier discharge was foundational and remains of great relevance to the present day". This is not only clear from the large number of citations to his work, but also from the many interesting contributions in this special issue, of which many indeed do refer to Ulrich's work. His 2003 paper can safely be called a seminal paper, and we do hope that this special issue will also become seminal!

I wish to thank all authors who contributed to this special issue, as well as Bruce Locke and Tony Murphy for the careful editorial work, and the publisher, Christiane Brox, for her kind support. Finally, I wish to dedicate this editorial and the entire special issue to Dagmar Kogelschatz, who often accompanied her husband at conferences, making her also well-known in our community. Dagmar, I hope this special issue demonstrates again how Uli was inspiring for our entire community.

Annemie Bogaerts, guest editor.

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