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EDITORIAL

PLASMA PROCESSES AND POLYMERS

Industrial plasma applications

Perhaps only a minority of readers of this journal, *Plasma Processes and Polymers* (PPaP), realize just how rich, going back in time, is the history of plasma-based technologies that we now tend to take for granted. The purpose of this special issue (S.I.) on *Industrial Plasma Applications* is to illustrate the current highly advanced and sophisticated state that some of those technologies have now attained. It is useful to point out here that this current S.I. in many ways complements an earlier one on *The Future of Plasma Science* (*PPaP Vol. 16, Issue 1, January 2019*), to which we shall occasionally refer below: its purpose and background were eloquently summarized in a Consensus Paper of similar title by K.-D. Weltmann et al.,[1] followed by a series of "White papers" on various themes like those in this present S.I. Not unrelated is yet another recent S.I., *Plasmas for Microfabrication (PPaP Volume 16, Issue 9, September 2019)* which contained numerous papers on that particular "hot" subject.

1) Probably, the earliest large-scale use of plasma chemistry was ozone generation, starting with the ozonizer patent to Werner von Siemens in 1857,[2] an invention that was implemented for municipal drinking water treatment in 1906, with the first full-scale ozone plant in Nice, France.[3] In this S.I., the article by Nau-Hix et al.[4] presents a modern adaptation of water treatment relating to specific types of present-day organic contaminants, while that of Kim et al.[5] illustrates, among numerous other examples, how drinking water in remote locations can be purified by small-scale, solar-powered atmospheric pressure plasma devices.
2) With the advent of large-scale commercial use of synthetic and natural polymers (plastics) during and after World War II, the low surface energy of these materials rapidly became apparent as a limitation for many applications. This led the Danish engineer Verner Eisby to invent the corona treatment process in 1951, after being challenged to find a way to print on plastic. This eventually led to the present world-wide application of modern-day variants in the converting industry, whereby the surface of plastic sheets many meters in width are plasma-treated at astonishing line speeds. This is beautifully illustrated in the article by F. Foerster.[6] A White Paper by Cvelbar et al. had earlier addressed this same subject, the future of plasma treatment for plastics and textiles.[7]
3) Many readers are probably familiar with the so-called "Moore's Law," an empirical relationship first noted by Gordon Moore, cofounder and CEO of Intel Corporation. As early as 1965 he stated that the number of transistors in integrated circuits doubled roughly every year and would continue to do so for many years; in 1975 he revised his observation to say that this would occur every 2 years, indefinitely. That bold forecast has indeed been held so far, in large part due to plasma-based etching, deposition, and advanced lithography techniques,[8] which facilitated the multiplication of transistors on microchips from a few thousand in 1970 to roughly 50 billion currently. The article by Oehr et al.[9] describes some modern industrial plasma equipment, mostly related to thin film deposition processes, developed for micro-device fabrication. It also analyses cost-breakdowns of various factors that contribute to production (and therefore single-device) pricing, analyses that yield some surprising conclusions. The article by Kim et al.,[5] too, describes microplasma-based devices and systems currently being manufactured for applications in photolithography, photopatterning, and other nanofabrication processes such as atomic layer deposition (ALD). Finally, in PPaP 16(9), 2019, two review papers dealt with the topic of MEMS fabrication (micro electro mechanical systems),[10,11] now ubiquitous in many devices for daily use.
4) An area of practical use for low-temperature plasmas that is growing rapidly after emerging from modest beginnings is their application in health sciences[12]; more generally, this now includes biology, agriculture, and the environment.[13] Of course, it is not illogical to include the special case of drinking water decontamination from microbiological pathological agents, already discussed in item (1) above. Another overlap with earlier-mentioned plasma technology exists in the field of roll-to-roll surface treatment of flexible synthetic polymer webs, where the article by Borek-Donten et al.[14] presents antiviral mask textiles that constitute a special case of the

("corona") theme of item (2) above. But health-related examples are also found in that of Kim et al.,[5] where disinfection of air and surfaces in public spaces by UV-C radiation from highly efficient KrCl lamps is described, along with several other more specialized medical applications.

5) A final area being addressed is that of advanced functional thin film coatings for various "high-tech" industries. An excellent example is the automotive sector, where plasma processing has also become ubiquitous: The article by Hosenfeldt[15] describes hard coatings that systematically reduce frictional losses in engines and powertrains to improve energy efficiency and thus cut CO_2 emissions. Because the transport sector accounts for ca. 28% of annual energy consumption, plasma surface technology offers outstanding potential for the optimization of highly stressed tribological systems. However, as also illustrated by Oehr et al.[9] and in the earlier White Paper by Šimek et al.,[16] the optical coatings sector (architectural glass, for example, but also for communications and data storage applications) is also benefiting greatly (and ever increasingly) from plasma-based processes.

To summarize, this S.I. (and the earlier ones from 2019 identified above) bears witness to the immense progress that low-temperature plasma processing technology has been making to our everyday experience, be it in health, communications, transport, shelter, leisure, or any of the other vital sectors that influence our quality of life.

Christian Oehr[1]
Michael R. Wertheimer[2]

[1]*Herrenberg, Germany*
[2]*Polytechnique Montréal, Québec, Canada*

Correspondence
Michael R. Wertheimer, Professor Emeritus, Department of Engineering Physics, Polytechnique Montréal, Montreal, Québec, Canada.

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