Adaptive Plasmas for Health, Food, and Environmental Applications

Cold atmospheric plasma (CAP), which, in its simplest form, consists of a partially ionized gas sustained in an air mixture with gases like argon and helium, produces reactive oxygen and nitrogen species (RONS). The CAP can send fluxes of RONS and, in some cases, electric fields and photons, to nearby living cells, tissue, plants, or media.

The plasma's reactivity induces physiological changes in cells ranging from death to immune responses. For example, researchers have shown that CAP selectively eradicates cancer cells *in vitro* while preserving normal cells, and it significantly reduces tumor size *in vivo*. This preferential killing of cancer cells is one of the most intriguing aspects of the interaction of plasma with cells.

Plasmas can also self-organize to form coherent structures that modulate the electric field, adding another level of control and engineering capability.

Compared to other forms of matter, plasma is unique in its ability to change its composition and key parameters *in situ* and on demand, depending on specific requirements and environmental conditions. However, so far, the unique abilities of plasmas have not been fully explored.

To address this issue, various CAP applications are under development by researchers at the Center for High Pressure Plasma Energy, Agriculture, and Biomedical Technologies (PEAB) at George Washington Univ. (GWU). PEAB is an Industry-University Cooperative Research Center funded by the National Science Foundation (NSF).

At GWU, Michael Keidar's lab focuses on the interaction of CAP with soft biological matter (*e.g.,* liquids, cells, tissues, bacteria, viruses, and agricultural products). Assembling ionized gas species and reactive vectors (*i.e.,* electric fields and photons) in various combinations within CAP systems provides unprecedented opportunities to activate specific cellular signaling pathways in living organisms.

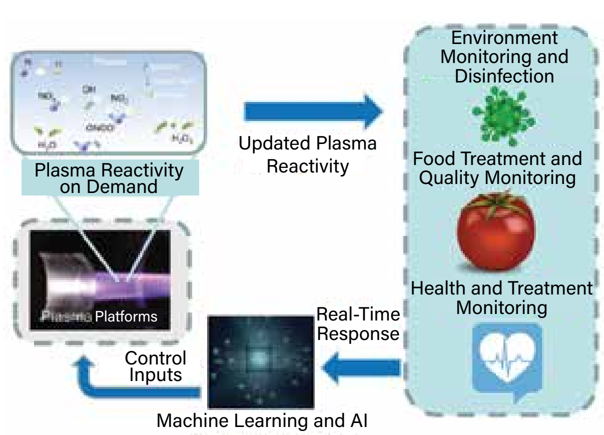
Researchers at GWU, Drexel Univ., and the Univ. of Michigan are collaborating on one such plasma-based system for disinfection. This system is capable of rapidly scanning for viral colonies on a surface and simultaneously directing the CAP beam to kill them. A handheld prototype of the system, under development by GWU, will be used to treat SARS-CoV-2 on various metal and plastic surfaces.

GWU researchers are also using artificial intelligence (AI) and machine learning — powerful tools that already benefit many disease diagnostics and therapies — to realize the unique potential of plasmas. For example, they have developed an electrochemical impedance spectroscopy (EIS) method to detect cell response that provides a real-time feedback signal for model predictive control aided by machine learning.

The team also developed a computation method to construct the plasma composition from spontaneous spectra using a novel gradual-mutation artificial neural network (ANN). Such ANN-based systems allow real-time determination of plasma chemical composition, assisting plasma adaptation in real time.

The GWU team then created a system to optimize plasma treatment of cancer cells by combining EIS for real-time feedback of cell response and an ANN for plasma species control. Preclinical animal trials are underway for further assessment of this system.

These technological developments were made in conjunction with one of the industry members of the PEAB center that is also involved in transitioning this technology into commercial products. "Real-time feedback is key to improving performance of dynamic systems like a plasma device, and the recent progress in economical AI-enabled computers will revolutionize this approach," says Jagadishwar Sirigiri, lead investigator and President and Founder of Bridge12 Technologies. CEP



◀ Researchers have developed plasma systems that can harness machine learning for real-time adaptation in disinfection, food treatment, health monitoring, and various disease treatment applications.

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