PiAI Seminar Series: Physics informed AI in Plasma Science
7:00-8:00, 20 November 2023(EST)
13:00-14:00, 20 November 2023 (CET)
21:00-22:00, 20 November 2023 (JST)
Web Seminar

From Physics-Informed Plasma Chemistry to Plasma-Based Intelligence

Li Lin and Michael Keidar

The George Washington University, USA

The inelastic collisions are the key feature of the plasmas and they also represent the plasma chemistry as the key feature of many applications such as material processing (etching, atomic layer deposition, chemical vapor deposition, and surface modifications), biomedicine (cancer therapy, wound treatment, and sterilizations), environmental engineering (CO_2 conversion, NOx conversion, and water purifications), etc. However, many of these plasmas work under atmospheric pressure, making the collisions at a sub-nanosecond scale during a full treatment process of several minutes or even longer. In other words, the plasma chemistry is a multi-scale problem. Moreover, for those air plasmas, hundreds of species and thousands of reactions can occur simultaneously with each having a unique and dynamic rate coefficient as a function of the reactant temperatures. Therefore, considering such complex problems lay in the high-pressure and low-temperature plasma chemistry, we are not surprised when machine learning techniques are involved in both the diagnostic results analysis and the optimization controls on the plasma generators. We developed self-adaptive plasmas that the plasma generator can adjust itself to maintain the optimized plasma parameters according to the dynamic environment, such as the target condition and the external disturbance during plasma processing. The adaptive system contains artificial neural networks that can predict and control the chemical composition based on the limited information of optical emission spectroscopy (OES). Later, a physics-informed neural network (PINN) is trained using physical laws and the results of Fourier-transform infrared spectroscopy (FTIR) to predict the composition based on the control parameters rather than a real-time observation. However, these are not the full potential of merging the concepts of machine learning and plasma chemistry. Actually, a complex chemical pathway network (CPN) itself is an artificial neural network, leading the plasma to a programmable intelligent material. We proposed the concept of intelligent plasma based on a strict mathematical definition of training and using the CPN of plasma as a neural network. This is a revolutionary idea that not only leads to plasma without an external machine learning executor but also all chemical systems with enough complexity can achieve a substantial material intelligence, programmable at the molecular scale.