

Low Temperature Plasmas: a bridge between Chemistry and Physics.

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A Low-Temperature Plasma (LTP) is a partially ionized gas in which electron energies are of the order of the ionisation potential of atoms and molecules, typically of a few eV, while the ions and the neutral are at low energy, close to room temperature. Essentially, this plasma represents a *non-equilibrium system*, with the electron temperature being higher than the ion temperature, even of orders of magnitude. In this kind of plasma, the interactions of neutrals with each other and with the wall play a particular role in the redistribution of energy, thus modifying, ultimately, the energy distribution function of the electrons. LTP are present in natural phenomena such as the interstellar medium and the aurora borealis, while laboratory and industrial LTP are of interest in various applied fields such as biomedicine, agriculture and food systems, energy, aerospace, electronics, materials science, environmental remediation and, more recently, plasma-catalysis.

Dusty Plasma (DP) and Non-Neutral Plasma (NNP) constitute two special classes of LTP deserving a dedicated discussion. DP is a complex LTP plasma that also contains charged micro- or nano-particles, which led to more complex dynamics and processes that are not found in LTP.

For DP the field of interest spans from the synthesis of functional nanoparticles, environmental monitoring, semiconductor fabrication, and understanding planetary formation processes.

In NNP the net charge creates an electric field large enough to play an important or even dominant role in the plasma dynamics. In the last years, these plasmas have attracted attention for the applications that can be derived for sophisticated devices, like free electron lasers, gyrotrons, or other electromagnetic wave generators.

LTP plasmas are characterised by multiple and complex physico-chemical processes occurring within them, which can be highlighted and studied through experimental setups equipped with appropriate diagnostic systems.

Furthermore, nowadays the need to create a synergy between experiments and theory is increasingly evident, and LTP are studied using multi-scale models (both on time and length) in which the result of the previous step becomes the input of the next step. These models are based on very accurate theoretical-computational methods, also due to the notable advances in HPC (High-performance computing). Of particular relevance in the study of LTP plasmas is the interplay between chemistry and physics, so that the introduction of the former can help to understand the occurrence of processes that would not otherwise occur. In this regard, it is worth mentioning a method, introduced in the 70s, which for many decades has been unique in the international scenario, this is the *state-to-state* approach used to study the kinetics, thermodynamic and transport properties of LTP (see [1] and references therein).

In this contribution, we will provide an overview of the key characteristics of LTP, with a specific focus on DP and NNP. We will highlight the chemical and physical processes that occur within these systems, as well as the theoretical modelling methodologies and

experimental techniques used for their study and characterization. Additionally, we will emphasise the various applications of LTP. In this context, we will try to provide a comprehensive framework of the various Italian research groups that deal with the different aspects in the field of LTP.

Reference:

- [1] M. Capitelli, et al. Plasma Sources Sci. Technol. , **16**, S30 (2007).