Adventures in Plasma Chemistry

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Abstract: Plasma chemistry is a remarkably diverse field that spans many areas of fundamental and applied science and industrial technology. Over more than a century of study and application, the field has grown in multiple directions and continues to redefine itself and expand its impact. Some promising new directions are identified in quantitative methods, material processing, and applications to living systems.

1. Introduction

Plasma chemistry is a diverse field with its scientific foundations in plasma and gas discharge physics, thermodynamics and transport phenomena, electricity and magnetism, chemical kinetics, and quantum and statistical mechanics. Applications in material and chemical processing, biotechnology, agriculture and medicine, and a multitude of others, broaden the field still further. This diversity in both fundamentals and applications is the most important feature of plasma chemistry.

Ionized gas plasma can exist in a state of thermal non-equilibrium, and this sets it apart from conventional non-isothermal reacting flows. Non-equilibrium plasma is a special form of matter, rather than a separate 'phase,' and the infinitely adjustable degree of non-equilibrium is at the heart of its remarkable range and diversity of applications.

There are many scientists that could be cited as seminal in the history of plasma chemistry, but my favorite is Irving Langmuir. It is well known that Langmuir is responsible for choosing the term 'plasma' for ionized gas collective dynamics.[1] It could be argued that Langmuir did not focus much on plasma chemistry per se, but his collected works reflect his energy, curiosity, range of interests, and ability to see to the heart of the matter. [2] On balance, I think our plasma chemistry field can claim him as 'patron saint!'

I outline part of my history in this field, not as a model, but to illustrate a finite subset of this infinite dimensional space of intellectual diversity. I benefitted enormously from my colleagues and students. I stress, even though it is obvious, that the only way I could have been involved in so many different aspects of the field is by working with an extraordinarily talented and capable group of colleagues, including of course students at all levels.

2. Quantitative methods

I began my research in plasma chemistry (with my PhD advisor Klavs Jensen at the University of Minnesota) by trying to improve models of gas discharges with the aim of applying these models to studies of thin film plasma chemical processes.[3] Later, I benefited from colleagues at UC Berkeley in extending fluid models to particle-in-cell models.[4] Still later, I was aided by pioneering colleagues in applying molecular dynamics simulations to better understand plasma-surface interactions.[5] I propose some new challenges in this area.

3. Material Processing

Studying plasma to better understand and control material processing – and especially in the context of thin film microelectronic device fabrication – has been a consistent theme. A recent group of colleagues helped identify some priority research opportunities.[6]

4. Applications to living systems

Few sub-fields in plasma chemistry challenge our ability to digest and couple diverse fields than plasma applications to living systems. I offer one vision for biomedical applications. [7]

5. Conclusions

I am most grateful for the good fortune of working in this remarkable and rewarding field. I sincerely thank my collaborators and colleagues who have made this work an absolute joy and privilege.

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