Scholarly Research Journal for Interdisciplinary Studies
Online ISSN 2278-8808, SJIF 2021 = 7.380, www.srjis.com
PEER REVIEWED & REFEREED JOURNAL, MAR-APR 2023, VOL- 10/76
https://doi.org/10.5281/zenodo.7963282

CONTRIBUTIONS OF PLASMA SCIENCE AND TECHNOLOGY FOR SUSTAINABLE FUTURE

Chandan Bhowmik
Assistant Professor, Department of Mathematics, Saheed Nurul Islam Mahavidyalaya, Tentulia-743296

Abstract

We all know that matter exists in three states: solid, liquid, and gaseous. But in recent years, more and more attention has been directed to the properties of matter in a fourth and unique state, which we call plasma. It is likely that more than 99% of the matter in the visible universe is in the form of plasma. But quantum plasmas are also important in metallic and semiconductor nanostructures as well as in super-dense astrophysical environments. In recent years, plasma science and technology have gained increasing interest for synthesis, processing, nanoparticle structure, textile surfaces, alloy formation, etching, etc. A major field of plasma technology is gas conversion (including CO_2, CH4, and N_2) into value-added chemicals or renewable fuels. Moreover, plasma is generated by electric energy and is very suitable for catalyst preparation at low temperatures, as well as for requirements for sustainable agriculture. Many researchers are experimenting with plasma to make a new kind of nuclear power called fusion, which would be much better and safer than ordinary nuclear power and produce much less radioactive waste.

Keywords: *Plasma state; Gas conversion; Sustainable future.*

Introduction

The United Nations defines sustainable development as "meeting the needs of the present without compromising the ability of future generations to meet their own needs." Thus, sustainability requires us to protect both natural resources and human health while using our available resources efficiently. Recently, plasma has become very important for a sustainable future. First and foremost, the term plasma represents a macroscopically neutral gas containing many interacting charged particles (electrons and ions) and neutrals. Basically, plasma is a quasi neutral gas of charge and neutral particles that exhibits collective behavior due to long-range Coulomb forces. The quasi-neutrality of plasma implies that the electron density is approximately equal to the ion density. The collective behavior implies that the motion of species depends not only on the local conditions but also on the state of the plasma far away from the point of interest [1]. However, any ionized gas can't be called a plasma; to

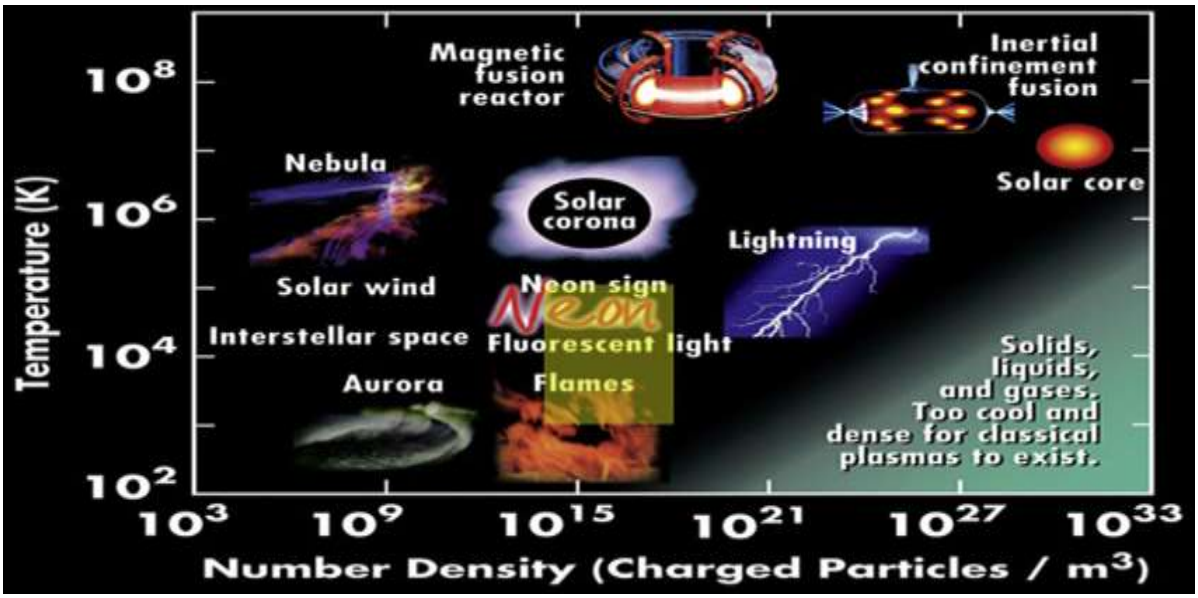
fulfill plasma criteria, gas must satisfy the quasi neutral condition and the collective behavior condition.

Plasma is generally associated with a hot gas of charged particles, which became classical. Research shows that plasma constitutes 99% of the visible universe. We belong to the rest of the 1% of the matter on earth, which is something different. from plasma. Plasmas are found in and around the earth, in lightning. channels of the ionosphere, in the aurora, and in the earth's magnetosphere.
Plasmas are also found in the solar wind, in the magnetosphere, and in comets. Around Jupiter and Saturn, we have plasma in the form of gigantic plasma toroids. The sun and the other stars are nothing but enormous plasma balls. Not only the stars but also the nebulae within the galaxies are also composed. of plasma, and so on.

It is interesting to note that our solar system is dominated by plasma, as the sun is in a plasma state. Solar energy comes from the sun. It has a positive effect on sustainable development. The use of solar energy produces an increase in the level of sustainable development. Also, it can be used in sustainable development in different ways, such as to generate electricity, heat water or air in homes and buildings, or produce solar fuels. It can also help reduce greenhouse gas emissions. Solar energy is a renewable resource, but it is not always available. The amount of solar radiation that reaches the Earth's surface depends on the time of day, the season, and the weather. It can also be more costly than other forms of energy but more affordable and accessible.

Recently, the field of quantum plasmas, where the dominated wave nature of electrons gives rise to collective effects, has become an intense field of investigation, having applications in quantum dots and quantum wires [2], microelectronics [3], nonlinear optics [4], quantum wells, carbon nanotubes, and quantum diodes [5], as well as, in laser plasma experiments [6–8]. On the other hand, quantum plasmas are of great importance in dense astrophysical environments such as those in white dwarf stars and magnetars [9–11].
We know that plasma is always hot, but it is interesting to note that plasma can exist in different ranges of temperature and density, as shown in Fig. 1.

Fig. 1: Existence of plasma in diverse ranges of temperature and density.



Because of this diverse nature it has found application in various fields. Apart from naturally occurring plasmas in the universe, artificial plasma may be created in the laboratory in a variety of ways.

Applications of plasma

Because of its diverse nature plasma finds application in various fields such as surface treatments, biomedical applications, lightning, medicine, electronics, space propulsion, gas lasers, cold plasma treatment, gas conversion and agriculture etc.. Some of the important and interesting applications of plasma in various fields are discussed here.

Usually plasma can be classified on the basis of several parameters out of which temperature is the major ones, giving it quantitative description. There are two types of plasma that can be divided on the basis of temperature such as hot plasma, also known as 'Thermal plasma' and cold plasma also known as 'Non thermal plasma':

- **Thermal or hot plasma**: Thermal or hot plasma is a type of plasma mainly includes radio frequency, torch and arc discharges. This plasma can be used for treating solid waste and processing.
- **Non thermal or cold plasma**: Earlier, discharges of cold plasma were produced by alternating(AC) and stationary(DC) electric fields and for producing such discharges different types of electric power supplies. But nowadays, atmospheric pressure plasma jets discharge, corona discharge, radio frequency, microwaves induce plasma etc. are widely implemented for producing cold plasma discharges. This non-thermal cold plasma is energy efficient and provides high selectivity in resulting chemical reactions.

Therefore, considering all these reasons, application of cold plasma technology is attracting the interest of technologists for waste water treatment purposes. Cold plasma is a novel nonthermal food processing technology that uses energetic, reactive gasses to inactivate contaminating microbes on meats, poultry, fruits and vegetables.

- **Gas conversion**: Plasmas are finding increasing interest for various environmental and energy applications. A major field of interest is gas conversion [12,13], such as CO_2 conversion into value-added chemicals or renewable fuels and N_2 fixation from the air, to be used for the production of small building blocks for e. g., mineral fertilizers.
- **Agriculture**: The plasma generated reactive oxygen and nitrogen species (RONS) and change in solution properties pH, electrical conducting and oxidation reduction potential. These solutions affect the rate of seed germination, enhancement in plant growth as well as an increase in agricultural yields. Finally, because protection of the environment and natural resources are also requirements for sustainable agriculture for a sustainable future, the programme also includes research on agriculture, food and water-treatment, plasma treatment of seeds, plasma-enhance plant growth as well as the production of fertilizers by nitrogen fixation.
- **Nuclear fusion:** Fusion is the process occurring within the plasma core of our Sun in which the nuclei of lighter atoms link to form a heavier atom. When hydrogen nuclei clash, they can fuse into heavier helium nuclei and release huge amounts of energy in the process. Nuclear fusion occurs naturally in stars including the sun where hydrogen nuclei fuse and create helium while releasing the energy that lights and heats the Earth. Nuclear fusion has also been used in nuclear weapons, but research to harness fusion power for electricity generation is still ongoing.

Moreover, as plasma is generated by electric energy and is easily switched on/off, it is very suitable to be combined with renewable energy. Plasma also appears very suitable for catalyst preparation at low temperature. Plasma can be used for reduction, oxidation, etching, coating, alloy formation, nano-particle or nano-porous structures, textile and surface treatment of catalysts. Moreover, plasma can be used for clean and eco-friendly techniques which minimizes waste.

Conclusion

The materials in our encompassing are mostly solid, liquid and gas, however, the fourth state of matter dominates in our universe. In the future, it will likely be the stuff of electric power generated from fusion. Nuclear fusion provides one of the major options for

the sustainable or long term energy source. The fusion fuels are virtually inexhaustible and readily available throughout the world. Fusion power plant operation is safe and has no risk of long lived radioactive waste. Science and technology for a sustainable future help us understand our environment and our impact on it, which is essential for smart decisions about how to use our resources. It can also help us find solutions to problems, such as climate change and pollution, and improve the quality of life for all people. The sustainable future that we envision will need to be driven by new materials and advanced energy sources. The advances in plasmas for a sustainable future programme aims at highlighting the recent achievements, as well as remaining limitations and corresponding possible solutions in all of the application field. Work is in progress in this area.

References

[1] Eddington, A. S. (1926), The Internal constitution of stars, Cambridge University Press.

[2] Shpatakovskaya, G.V. (2006). Semiclassical model of a one-dimensional quantum dot**,** Journal of Experimental and Theoretical Physics, 102, 466–474.

[3] Markowich, A., Ringhofer, C., Schmeiser, C. (1990). Semiconductor Equations, Springer, Vienna.

[4] Leontovich, Izv. Akad. Nauk Arm. SSR Fiz. 8 (1994) 16.

[5] Ang, L.K., Zhang, P. (2007). Ultrashort-Pulse Child-Langmuir Law in the Quantum and Relativistic Regimes, Phys. Rev. Lett. 98 ,164802.

[6] Glenzer, S.H., Gregori, G., Lee, R.W., Rogers, F.J., Pollaine, S.W., Landen, O.L. (2003). Demonstration of spectrally resolved x-ray scattering in dense plasmas, Phys. Rev. Lett. 90 ,175002. DOI: 10.1103/PhysRevLett.90.175002

[7] Saiz, E.G., Gregori, G. et al.(2008). Probing warm dense lithium by inelastic X-ray scattering ,Nature Physics. 4, 940.

[8] Glenzer, S.H., Redmer, R. (2009) Rev. Modern Phys. 81 ,1625.

[9] Chabler, G., Douchin, F., Potekhin, Y. (2002). .J. Phys : Condens. Matter 14, 133.

[10] Jung, Y. F. (2001), Quantum-mechanical effects on electron–electron scattering in dense high-temperature plasmas, Phys. Plasma 8, 3842-3844. https://doi.org/10.1063/1.1386430

[11] Bhowmik ,C., Misra, A. P. , Shukla, P. K., (2007). Oblique modulation of electron-acoustic waves in a Fermi electron-ion plasma, Phys. Plasmas 14, 122107. .https://doi.org/10.1063/1.2822158

[12] Fridman, A. , (2008) Plasma Chemistry; Cambridge University Press: Cambridge, UK, 2008

[13]Snoeckx, R., Bogaerts, A. (2017), Plasma technology – a novel solution for CO2 conversion? Chem. Soc. Rev. 46, 5805-5863. DOI: 10.1039/C6CS00066E .

Cite Your Article as: Chandan Bhowmik. (2023). CONTRIBUTIONS OF PLASMA SCIENCE AND TECHNOLOGY FOR SUSTAINABLE FUTURE. Scholarly Research Journal for Interdisciplinary Studies, 10(76), 18546–18550. https://doi.org/10.5281/zenodo.7963282