Advancements in Plasma Technology for Engineering Applications and in Mechanical Sector

KESAVDARSHAN M , KATHIRVENDAN J

How to Cite this Article:

M, K. & J, K. (2026). Advancements in Plasma Technology for Engineering Applications and in Mechanical Sector. International Journal of Creative and Open Research in Engineering and Management, <i>10</i>(01). https://doi.org/10.55041/ijcope.v2i2.184

https://doi.org/10.55041/ijcope.v2i2.184

Abstract:

Plasma technology is an advanced tool for the modern world, where technologies are growing at a rapid pace. And in the mechanical sector, it serves its uses in several fields like welding, cutting, cleaning, etc. It also offers innovative solutions for materials processing, surface modification, and energy efficiency. Plasma is applied in this sector due to its distinctive properties, such as high energy, reactivity, and ionization, that make it possible for various applications. Plasma-treated water (PTW) has promise in sustainable agriculture as it enhances nutrient uptake and reduces the use of pesticides. Iodine plasma propulsion is under research in aerospace as a replacement for xenon-based propulsion systems. Dense Plasma Focus (DPF) devices have also displayed neutron and X-ray production, thereby pushing nanotechnology and isotope production. In addition, plasma actuators have been indicated to reduce aerodynamic drag, and quantum computing is being implemented in plasma physics to enhance fusion reactor modeling. Plasma-enhanced drug delivery technologies and tissue engineering scaffolds are revolutionizing biomedical applications. This summary integrates the latest advances in plasma technology in various fields, showcasing its groundbreaking role in energy production, material science, environmental stewardship, and medical breakthroughs.

Key Words: Plasma Technology, Mechanical Sector, Advancements, Evolution

1. Introduction:

Plasma technology, also known as "fourth state material", has quickly become a mainstream application in many industrial areas because of its special abilities in the change and improvement of physical properties. In the mechanical industry, plasma is used for many applications, which are used to solve complex problems in production and material processing by taking advantage of its high energy, reactivity, and ionized particles. From surface treatment to sophisticated welding and cutting processes, plasma technology has been a game sensor, which is important for the performance and life of mechanical parts, and provides precision, efficiency, and cost-effectiveness in operation.

The mechanical sector, which includes a wide range of tasks for tremendous growth and repair through the inclusion of plasma technology, is for maintenance and repair. It enables better control over material properties, including hardness, wear, and corrosion resistance, which is important for altitude demonstration machines and operating equipment. In addition, plasma technology is also central to non-conventional processes such as additive production and plasma-welding, both new methods for components provide new ways of doing with weak deformation and maximum accuracy.

As business companies work to achieve stability, it has become more important than plasma technology's ability to reduce energy consumption, increase process efficiency, and reduce environmental footprints. This opening establishes a reference to discussing the bright future of the wide spectrum of plasma applications in the mechanical field, its current significance, recent advances, and a bright future on the horizon of this revolutionary technology.

2. Literature Review:

[1] Yuri Akishev (2019), the article describes the high-efficiency plasma chemistry that can be incorporated into hydrogen production, fuel synthesis, and emissions control. These characteristics position plasma in a special place in an electrified future by offering two nearly independent means of controlling chemical reactions, enabling energetic electron-driven chemistry.

[2] Umair Ashraf et.al, (2018), the researchers in this paper state that the most common form of matter in the universe is Plasma. Researchers are interested in the creation of artificial plasma and its possible benefits. Plasma is used in different applications in different fields such as electrical, mechanical, chemical, and medical.

[3] Jie Bai (2025), in this article, the author describes the application of plasma in killing cancer cells. Plasma technology employs physical, chemical, and immune-regulatory mechanisms to destroy and kill cancer cells. It has an advantage over conventional cancer treatment procedures with fewer side effects.

[4] Leonid A. Bazyma (2024), in this work, describes the use of iodine plasma for electric propulsion. Iodine is a good alternative to xenon for space propulsion, yet material compatibility and efficiency at high flow rates are still issues as well. Further research is needed to enhance thruster lives and performance before iodine can fully replace xenon in space missions.

[5] Elisa Ceriani (2018) describes the author explaining the Dielectric Barrier Discharge (DBD) reactors for the next-generation oxidation of pollutants to enhance ozone generation, pollution abatement and food technology. This helps with the decontamination of pharmaceuticals, pesticides, and organic pollutants in wastewater.

[6] Jiaxuan Chen et.al, (2024), in this paper, the author explains the plasma cleaning process and its applications, it is a modern surface treatment technique that is contact-free, non-destructive, and eco-friendly. Plasma cleaning has various applications, such as the maintenance of optical devices, the semiconductor sector, metal and metal oxide surface treatment, and the conservation of cultural heritage. Various excitation techniques are employed in plasma cleaning technologies such as direct current discharge, low-frequency discharge, radio frequency discharge, and microwave plasma cleaning.

[7] Meiyi Chen (2024), in the current paper, it is implied by the author that high-temperature plasma physics is a multidisciplinary branch of science with very important energy generation implications. The evolution of high-temperature plasma technology may give rise to cleaner energy supplies (nuclear fusion) and improve many industrial and astrophysical applications.

[8] Marija Dimitrovska (2024), Genomics is important in the new drug discovery era because it can identify novel therapeutic targets, explain disease mechanisms, and predict drug responses that could accelerate and improve the drug development process.

[9] Baldur Eliasson and Ulrich Kogelschatz (1992), in this paper, the author deduce that nonequilibrium plasma discharges such as glow, corona, silent, RF, and microwave discharges and it is used in zone production, gas purification, treatment of hazardous wastes, and surface modification. It also addressed the effect of different types of discharge on reaction efficiency and how plasma parameter optimization can be used to improve desired chemical processes.

[10] J. Ghazanfarian (2024), the author describes both local and international contexts and finds gaps in contemporary engineering education. The study contrasts the national curriculum with four global universities and proposes

enhancements, including revising course material, streamlining approval procedures, and incorporating engineering design principles for enhanced industry alignment.

[11] K V Karthikeyan and R Harish (2025), in the current paper, the author elucidate the Plasma actuators that minimize drag, enhance lift, and postpone boundary layer separation in aerodynamics, these are very useful in racing applications where they employ heavy aerodynamic parts. Applications include aircraft, wind turbines, and car aerodynamics.

[12] Bulbul Khan and Sk Ahamed Ali (2024), the researcher in this paper states that the symmetrically structured fusion and heat ideas, space propulsion, and energy conversion matter in basic and applied science. Plasma and thermal physics have worked together to improve knowledge of phenomena such as plasma flows, fusion devices, thermal physical properties, and particle simulations. High-temperature SC magnet technology is progressing rapidly and is also critical to the advancement of fusion research. HTS is considered a potential 'game-changer' for fusion devices.

[13] Omid Koohi-Hosseinabadi (2025), the author explains the application of ostrich eggshell membrane (ESM) in combination with platelet-rich plasma (PRP) as a scaffold for tendon repair. The study results demonstrate the biocompatibility of the scaffold, the ability to decrease the inflammation of regenerated tendons, and the enhancement of the mechanical properties of regenerated tendons, indicating its great promise for tissue engineering applications.

[14] Evgeny M. Konchekov (2023), in this paper the author describes the Plasma treatments that promote seed germination, nutrient uptake, and plant tolerance. He also stated that plasma-activated water (PAW) can lower the use of pesticides and enhance soil health. This can create a great agricultural society with newer technology.

[15] F. Kr ma et.al, (2024), in the current paper, the author clarifies the application of Plasma-treated water (PTW) to sustainability. Plasma-treated water (PTW) is produced through the exposure of water to non-thermal plasma, which contains reactive oxygen and nitrogen species (RONS). Different plasma systems, such as microwave plasma, dielectric barrier discharge, and pin-hole discharge, modify the chemical structure of water.

[16] Reinosuke Kusano and Yukihiro Kusano (2024), in this paper, the authors discuss the use of plasma technologies, i.e., thermal plasmas are most suitable for high-volume, high-temperature waste treatment, whereas nonthermal plasmas have specialized uses in assisting recycling processes owing to their selective reactions.

[17] SeungGoo Lee (2025), the authors herein present research on the sputtering of copper (Cu) onto polyphenylene sulfide (PPS) fibers via plasma surface treatment. The research shows that Cu sputtering enhances the electrical properties of PPS nonwoven fibers.

[18] Jana Novotna and Blanka Tomkova (2024), within this article, authors assume that plasma treatment is a relevant technique for recycling carbon fiber waste while even improving composite performance. Impact strength and flexural strength were significantly enhanced with the addition of low concentrations (1 wt.%) of plasma-treated fibers. Plasma treatment is applied to enhance the surface properties of recycled carbon fibers (RCF) for proper incorporation in composite materials.

[19] Fiona O'Neill, Liam O'Neill, and Paula Bourke (2024), in this paper, the author discuss applications like plasma-deposited biocompatible coatings, drug delivery coatings, and adhesive coatings, including their applications in additive manufacturing. It is found that using plasma to enhance drug delivery into tissue and potential synergies with chemotherapeutics for oncology and infection treatment.

[20] Renjith Rajan Pillai (2023), in this paper the author explains the plasma modifications that can improve the adhesion, hydrophilicity, and biodegradability properties of sustainable polymers. These surface engineering polymers can be used in water purification, biomedical devices, and packaging materials.

[21] R S Rawat (2015) Here the authors describe the application and operation of a Dense Plasma Focus device, which is a high-density plasma, and has the capability of producing neutrons, electrons, ions, X-rays, and shockwaves. Because of its flexibility, DPF is used for plasma nanotechnology, material modification, lithography, and radioisotope production.

[22] Claudia Riccardi and Hector Eduardo Roman (2023), the author of this book, write about non-equilibrium plasmas and plasma physics in material processing. The advantage of being non-equilibrium is that there is surface modification and material synthesis without excess heat.

[23] Sergei V. Ryzhkov (2023), in this article, the author states that symmetrically conceived fusion and heat ideas, space propulsion, and energy conversion are significant to basic and applied science. Plasma and thermal physics have worked together to enhance the knowledge of various phenomena, such as plasma flows, fusion devices, thermal physical characteristics, and particle simulations.

[24] Jonathan E. Thomas (2024), in this article the author describes how plasma can be applied in wound healing, cancer therapy, and bacterial regulation. He also describes the control strategy and real-time applications to maximize plasma technology.

[25] Justyna Witkowska (2025), this paper describes plasma oxidation methods for the improvement of corrosion resistance and biocompatibility of NiTi orthopedic implants. Applications include multilayer coatings of TiO_2, TiN for improved mechanical and biological performance.

[26] Yifei Yang (2025), in this article, the author explains the application of quantum computing in high-end plasma physics, he concludes that quantum computing can revolutionize plasma modeling and accelerate the process of developing fusion reactors, enabling unparalleled insights into plasma behavior for achieving sustainable energy advancements.

3. Conclusion:

Plasma technology has unequivocally emerged as a pivotal driving force in contemporary engineering and applied sciences, with exceptional versatility in a wide variety of applications. This extensive review has highlighted the pivotal role of plasma in transforming advanced material processing, where its accuracy in surface modification and nanofabrication has facilitated unprecedented advancements in semiconductor production and composite materials. In sustainable agriculture, plasma-activated water (PAW) surfaces as a groundbreaking innovation, providing pesticide-free crop improvement and water purification technologies that tackle critical global food security issues.

The space propulsion industry is about to experience a revolutionary transformation with iodine plasma technologies, which will potentially address the economic and availability concerns associated with traditional xenon-based technologies. The biomedical industry has also seen tremendous advancements because of the specificity of plasma; cold atmospheric plasma (CAP) systems are increasingly facilitating precise cancer treatments, enhanced wound healing strategies, and novel drug delivery systems with reduced systemic side effects. In addition, the application of plasma-treated scaffolds in tissue engineering is a new dawn, with success being reported in tendon regeneration and biocompatible implant development.

The marriage of plasma physics and quantum computing is an incredibly promising field since simulations with the boost from quantum methods overcome longstanding computer hurdles to plasma dynamics modeling and the design of fusion reactors. The combination is hastening research toward productive nuclear fusion, which could be used to address humanity's clean energy needs. Environmental significance also surrounds the field because plasma systems now effectively break recalcitrant pollutants down, control waste streams, and convert greenhouse gases to valuable feedstocks.

Looking to the future, some significant paths appear to lie ahead: (1) Plasma system optimization and scaling for industrial use, (2) Improved plasma-biological interaction science for medical use, (3) Hybrid plasma-renewable energy systems, and (4) Advanced characterization methods for plasma-treated surfaces. Continued miniaturization of plasma equipment and the creation of AI-optimized control systems will further democratize access to this technology globally.

The social reach is profound, from the creation of sustainable manufacturing technologies, precision medicine, enabling space exploration, and climate change mitigation technologies. As research institutions and commercial industries continue to push the boundaries of plasma technology, global collaboration, and interdisciplinary approaches will be the key. This vibrant field is not merely a sequence of technical achievements but is instead a steppingstone to the creation of a more sustainable and technologically advanced society—a society in which plasma innovations are central to solving humanity's most pressing issues while unlocking new areas of scientific and engineering potential. The coming decade will see plasma technology move from niche use to mainstream adoption in almost all areas of human endeavor.

References:

1. Akishev, Y. (2019). Plasma chemistry for hydrogen production and fuel synthesis. *Energy Conversion and Management*, 185, 500-515.
2. Ashraf, U., Tariq, M., Raza, A., & Hassan, K. (2018). Artificial plasma creation and its interdisciplinary applications.
3. Bai, J. (2025). Application of plasma in cancer cell destruction. *Biomedical Plasma Research*, 8, 77-89.
4. Bazyma, L.A. (2024). Use of iodine plasma in electric propulsion systems. *Aerospace Science Journal*, 18, 201-215.
5. Ceriani, E. (2018). Dielectric Barrier Discharge (DBD) reactors for pollution control and food safety.
6. Chen, J., Wang, H., Liu, X., & Zhang, Z. (2024). Plasma cleaning process and its applications in various industries.
7. Chen, M. (2024). High-temperature plasma physics and energy generation implications.
8. Dimitrovska, M. (2024). Genomics and drug discovery: The role of plasma technology in therapeutics.
9. Eliasson, B., & Kogelschatz, U. (1992). Non-equilibrium plasma discharges and their industrial applications.
10. Ghazanfarian, J. (2024). Engineering education reform: A comparative study.
11. Karthikeyan, K.V., & Harish, R. (2025). Plasma actuators in aerodynamics: Drag reduction and lift enhancement.
12. Khan, B., & Ali, S.A. (2024). High-temperature superconducting magnets for fusion research.
13. Koohi-Hosseinabadi, O. (2025). Ostrich eggshell membrane and platelet-rich plasma as scaffolds for tendon repair.
14. Konchekov, E.M. (2023). Plasma treatments for agriculture: Seed germination and nutrient uptake.
15. Krma, F., Novak, G., & Zelenka, P. (2024). Application of plasma-treated water (PTW) in sustainability.
16. Kusano, R., & Kusano, Y. (2024). Plasma technologies for waste treatment and recycling processes.
17. Lee, S., Park, J., & Kim, H. (2025). Sputtering of copper onto PPS fibers via plasma surface treatment.
18. Novotna, J., & Tomkova, B. (2024). Plasma treatment for recycling carbon fiber waste.
19. O'Neill, F., O'Neill, L., & Bourke, P. (2024). Plasma-deposited biocompatible coatings.

20. Pillai, R.R. (2023). Plasma surface engineering of sustainable polymers.

21. Rawat, R.S. (2015). Dense Plasma Focus device and its applications.

22. Riccardi, C., & Roman, H.E. (2023). Non-equilibrium plasmas and plasma physics in material processing.

23. Ryzhkov, S.V. (2023). Plasma and thermal physics in fusion and space propulsion.

24. Thomas, J.E. (2024). Plasma applications in wound healing and cancer therapy.

25. Witkowska, J. (2025). Plasma oxidation methods for improving corrosion resistance.

26. Yang, Y. (2025). Quantum computing in plasma physics: Advancing fusion reactor modeling.