Salahaddin University- Erbil

زانكۆی سه لاحه ددين-هه ولێر

Plasma the Fourth state of matter as well as brief summary application of cold plasma and its uses in medical fields

Research project

the Submitted to department of physics in partial fulfillment of the requirements for the degree of B.Sc. in physics

By:

Gazang Rasool Salee

Supervised by:

M.Gullala Yaseen Baker **2023-2024**

بِسْمِ اللَّهِ الرَّحْمَٰنِ الرَّحِيمِ

قَالُوا سُبْحَانَكَ لَا عِلْمَ لَنَا إِلَّا مَا عَلَّمْتَنَا ۖ إِنَّكَ أَنتَ الْعَلِيمُ الْحَكِيم

صدق الله العظيم

سورة البقرة - الآية 32

Supervisor Certificate

This research project has been written under my supervision and has been submitted for the award of the degree of BSc. in (Bittencourt).

Signature

Name: Gulala Yasien Baker

Date / 4 /2024

I confirm that all requirements have been completed.

Signature:

Name: prof. Dr . Asaad Hamid Ismail

Head of the Department of Physics

Date : 8 / 4 /2024

ACKNOWLEDGEMENT

First and foremost, I must acknowledge my limitless thanks to Allah, the Ever Magnificent; the Ever-Thankful, for His help and bless. I owe a deep debt of gratitude to the physics department and Salahaddin university for giving us an opportunity to complete this work. I am very appreciative to my colleagues in the physics department. I am grateful to some people, who worked hard with me from the beginning till the completion of the present research particularly my supervisor M. Gullala Yassin Bakr who has been always generous during all phases of the research. I would like to take this opportunity to say warm thanks to all my beloved friends, who have been so supportive along the way of doing my thesis. I also would like to express my wholehearted thanks to my family for the generous support they provided me throughout my entire life and particularly through the process of pursuing the thesis. Last but not least, deepest thanks go to all people who took part in making this thesis real.

LIST OF FIGURES Figure

CONTENTS

Abstract:

Plasma is considered 4th state of matter despite solids , liquids ,and gases. it is one of the fundamental states of mater Technically it is an ionized gas consisting of positive ions and free electrons typically at low pressures (as in the upper atmosphere and in fluorescent lamps) or at very high temperatures (as in stars and nuclear fusion reactors) Because so much of the universe is made of plasma, its behavior and properties are of intense interest to scientists in many disciplines. Importantly, at the temperatures required for the goal of practical fusion energy, all matter is in the form of plasma. Researchers have used the properties of plasma as a charged gas to confine it with magnetic fields and to heat it to temperatures hotter than the core of the sun. Other researchers pursue plasmas for making computer chips, rocket propulsion, cleaning the environment, destroying biological hazards, healing wounds and other exciting applications and Cold plasma technology (CPT) is considered as one of the emerging alternative techniques for preserving food commodities, extending shelf life, and retaining bioactive compounds in foods. Due to non-thermal nature, CPT is a useful technology for the sterilization process, especially for heat-sensitive foods.

Chapter one

Introduction:

Plasma is the fourth state of matter. It is essentially very hot , ionized gas. It is what makes up the sun and most of the universe. Plasma is so hot (millions of Kelvin) that is cannot be contained by physically. Instead magnetic confinement is frequently used. Because so much of the universe is made of plasma , its behavior and properties are of intense interest to scientists in many disciplines .There are so many applications of plasma . It is used for making computer chips , rocket propulsion , cleaning the environment , destroying biological hazards , healing wounds and other exciting applications . The most important application of plasma is in Fusion Test Reactor (FTR) Scientists have developed modern plasma theory to achieve the demand of Fusion energy for humankind(Goldston, 2020).

Definition of a Plasma :

Plasma is superheated matter – so hot that the electrons are ripped away from the atoms forming an ionized gas. It comprises over 99% of the visible universe. In the night sky, plasma glows in the form of stars, nebulas, and even the auroras that sometimes ripple above the north and south poles. Plasma is often called "the fourth state of matter," along with solid, liquid and gas. Just as a liquid will boil, changing into a gas when energy is added, heating a gas will form a plasma – a soup of positively charged particles (ions) and negatively charged particles (electrons). The word plasma comes from the Greek and means something molded. It was applied for the first time by Tons and Langmuir, in 1929, to describe the inner region, remote from the boundaries, of a glowing ionized gas produced by electric discharge in a tube, the ionized gas as a whole remaining electrically neutral(Bittencourt, 2013).

History plasma :

Plasma was first identified by Sir William Crookes in 1879 using an assembly that Is today know as "Cokes tube" and he called "radiant matter" an experimental electrical discharge tube in which air is ionized by the application of a high voltage through a voltage coil. A Crookes tube is an early experimental electrical discharged tube , with partial vacuum , invented by English physicist William Crookes (on the left side)and others around 1869-1875 , in which cathode rays ,streams of electrons , were discovered.[4] And latter in 1927 Irving Langmuir ,the Nobel laureate who pioneered the scientific , study of ionized gas , gave this new sate of matter the name "Plasma" (Bittencourt, 2013).

Plasma as the 4th state of matter :

As far as we know, matter generally exists in three states in nature. These are: $(i)\, Solid$ $(ii)\, Liquid$ and structure apart, usually a liquid is formed. When a liquid is heated enough that atoms vaporize off the surface faster than they recondense , a gas is formed. Now what happens to a matter just after that gaseous state? When a gas is heated enough ($> 100{,}000°C$) that the atoms collide with each other and knock their electrons off in the process, a plasma is formed: The so-called "fourth state of matter". The important point is that an ionized gas has unique properties. The word "plasma" comes from the Greek and means "moldable substance" or "jelly". It is used to describe a wide variety of macroscopically neutral substances containing many interacting free electrons and ionized atoms or molecules. As far as we know , matter generally exists in three states in nature . These are : (1) Solid (2) Liquid and (3) Gas . Now when a solid is heated sufficiently that the Thermal motion of the atoms break the crystal lattice structure apart , usually a Liquid is formed . Now what happens to a matter just after that gaseous state ? When a gas is heated enough (T> 100,000 ^{0}C) that the atoms collide with each other and knock their electrons off in the process , a plasma is formed : the so-called "Fourth state of matter" (Gu, 2011).

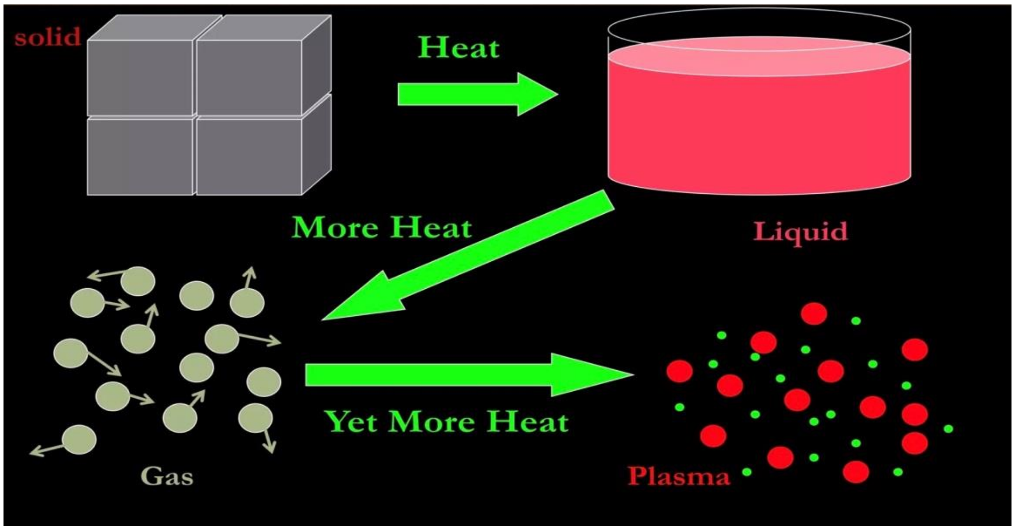

Figure (1-1) Fourth state matter

Type of Plasma:

1-Cold plasma: A cold plasma is one in which the thermal motion of the ions Can be ignored . Consequently there is no pressure force , the magnetic force can Be ignored , and only the electric force is considered to act on the particles Example of cold plasma include the earth's ionosphere (about 1000K compared To the Earth's ring current temperature of about 10^8K)(Chu and Lu, 2013).

2- Hot Plasma : A hot plasma in one which approaches a state of local Thermodynamic equilibrium (LTE) . A hot plasma is also called a thermal Plasma , but in Russian literature , a "low temperature " plasma in order to Distinguish it from a thermonuclear fusion plasma such plasma can be produced By atmospheric arcs , sparks and flames.

3- Ultra cold Plasma : An ultra cold plasma is one which occurs at Temperature as low as 1K . And may be formed by photo ionizing laser-cooled Atoms . Ultra cold plasma tend to be rather delicate , experiments being Carried out in vacuum(Killian et al., 2007).

Properties of Plasma:

(1)Plasma is state of matter in which an ionized gaseous substance becomes highly electrically conductive to the point that long-range electric and magnetic fields dominate the behavior of the matter.

(2) the plasma state can be contrasted with the other state : solid , liquid , and gas.

(3) plasma is an electrically neutral medium of unbound positive and negative particles (the overall charge of a plasma is roughly zero).

(4) Moving charged particles generate an electric current within a magnetic field and any movement of a charged plasma particle affects and is affected by the fields created but the other charges. In turn this governs collective behavior with many degrees of variation(Bittencourt, 2013).

Plasma in Nature: Though naturally occurring plasma is rare on earth , it is the most plentiful from Of matter in the universe.

Plasma in Space:

1-Stars

2-Coronas

3-Solar wind

4-Star nurseries

5-interstellar Nebulae

6-In the magnetic fields of many planets

7-Interplanetary , Interstellar and Intergalactic mediums

8-The accretion disks and accretion disk jets of black holes

9-sun exists in 99.9% plasma state. The sun in 1.5 million Km ball of plasma heated by Nuclear Fusion.

10-Spaceis not empty vacuum. It is actually filled with plasma that conducts our

EM wave signals. Our universe is 99.9% plasma.

Terrestrial Plasma:

1-Fire (when hotter than 1500 ^{0}C).

2-Lightning

3-The magnetosphere

4-The ionosphere

5-The plasma sphere

6-The polar aurorae

7-The polar wind

Chapter Two

Collision :

Collision **,** in physics, the sudden, forceful coming together in direct contact of two bodies, such as, for example, two billiard balls, a golf club and a ball, a hammer and a nail head, two railroad cars when being coupled together, or a Falling object and a floor. Apart from the properties of the materials of the two objects, two factors affect the result of impact: the force and the time during which the objects are in contact(Bellan, 2008).

Types of collision:

1-Elastic collision.

2-Inelastic collision.

3- Superplastic collision

1-Elastic collision:

In an elastic collision, the system's kinetic energy is conserved. That is, the total kinetic energy of the two objects after the collision is equal to the total kinetic energy of the two objects before the collision. This is called conservation of kinetic energy. The term elastic can help you understand how and why a collision affects the kinetic energy. An elastic collision is one where the objects involved bounce off of each other, with no net loss of energy(Bellan, 2008).

2- Inelastic collision:

In contrast to elastic collisions, inelastic collisions are collisions in which some kinetic energy is lost. The kinetic energy is transformed into other forms, such as thermal energy or sound energy. Consider a collision involving a ball composed of soft putty or clay. In contrast, an inelastic collision is one where the objects become deformed or fused together, and there is a net loss of energy.

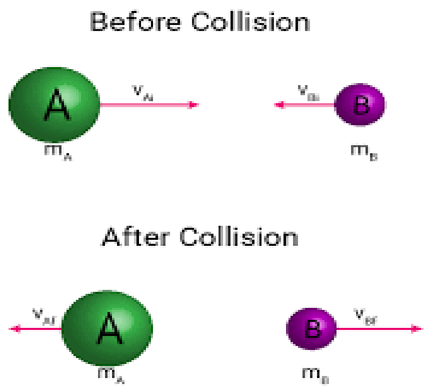

Figure (2-1): Elastic Collision

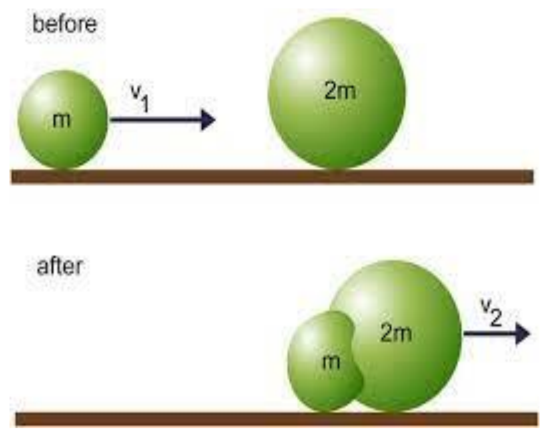

Figure (2-2): Inelastic collision

4- Superplastic Collision:

A superplastic collision is one where there is actually an increase in kinetic energy during the collision. This can happen when two objects collide and become joined together (such as two pieces of putty), or when an object bounces off a surface (such as a basketball bouncing off a floor).

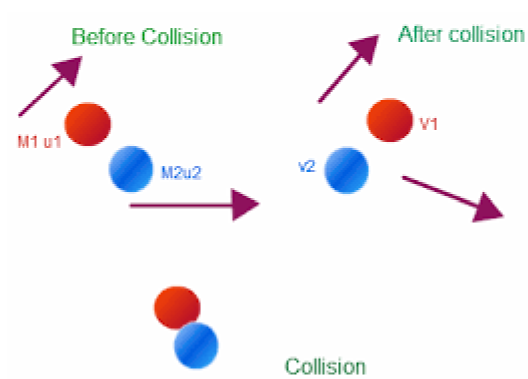

Figure (2-3): Superplastic Collision

Cold atmospheric pressure plasma(CAPP)

Cold plasma generated in an open environment with a temperature nearly around room temperature has recently been a topic of great importance. It has unlocked the door of plasma application in a new direction: biomedical applications. Cold atmospheric pressure (CAP) plasma comprises various neutral and charged reactive species, UV radiations, electric current/fields etc., which have several impactful effects on biological matter. Some of the significant biological effects of CAP plasma are inactivation of microorganism, stimulation of cell proliferation and tissue regeneration, destruction of cells by initializing apoptosis etc. Although the detailed mechanism of action of plasma on biomaterials is still not completely understood, some basic principles are known. Studies have indicated that the reactive oxygen species and nitrogen species (ROS, RNS) play a crucial role in the observed biological effects(Khanikar et al., 2021).

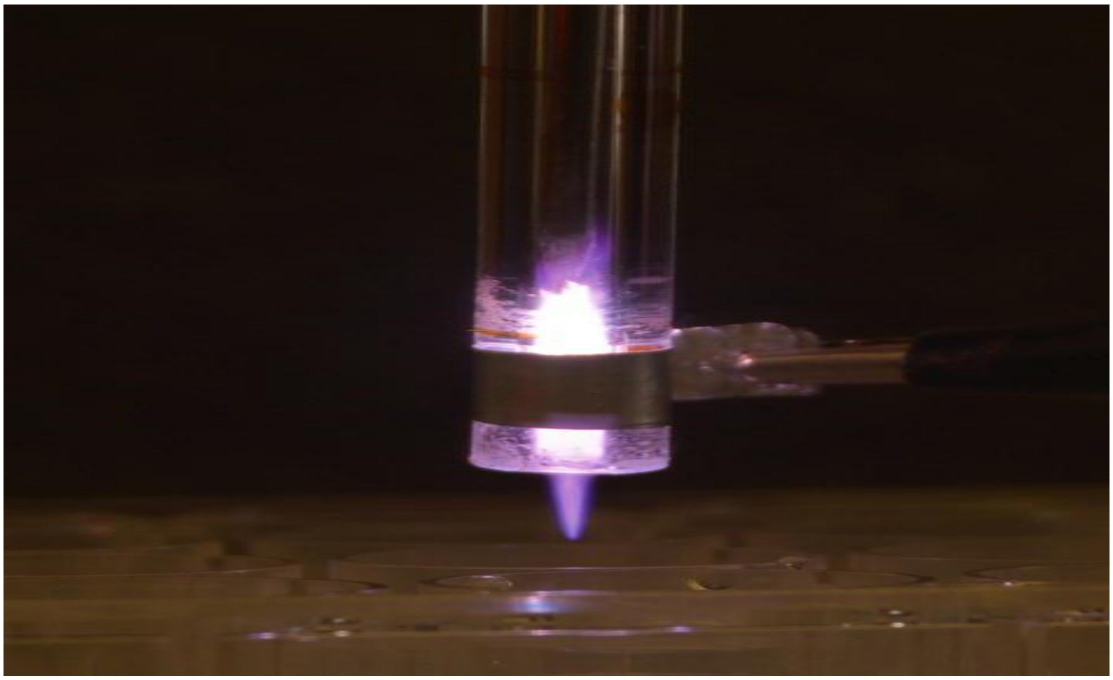

Figure (2-4)**.** Photograph of a CAP plasma jet.

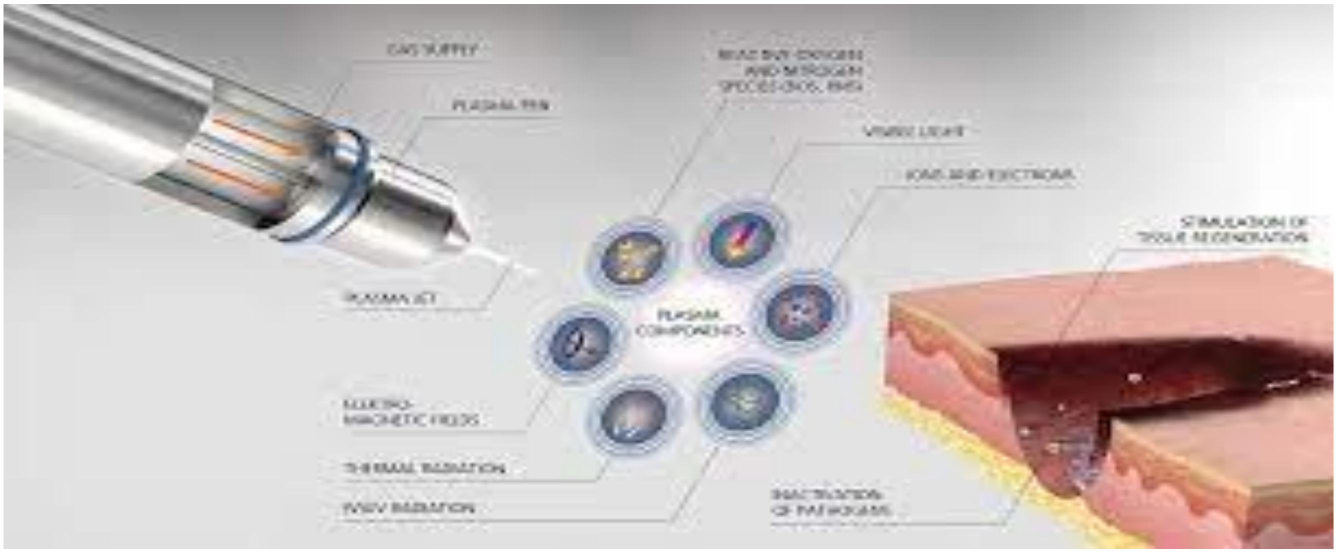

Figure (2-5) : With cold atmospheric plasma (CAP) a mixture of reactive components dominated by reactive oxygen and nitrogen species (ROS, RNS) is working on living tissue, e.g. a wound. Wound healing by plasma is a combination of inactivation of bacteria and stimulation of tissue regeneration.

The role of plasma physics in medicine

Plasma medicine is an innovative and emerging field combining plasma physics, life science and clinical medicine. In a more general perspective, medical application of physical plasma can be subdivided into two principal approaches. (i) “Indirect” use of plasma-based or plasma-supplemented techniques to treat surfaces, materials or devices to realize specific qualities for subsequent special medical applications, and (ii) application of physical plasma on or in the human (or animal) body to realize therapeutic effects based on direct interaction of plasma with living tissue. The field of plasma applications for the treatment of medical materials or devices is intensively researched and partially well established for several years. However, plasma medicine in the sense of its actual definition as a new field of research focuses on the use of plasma technology in the treatment of living cells, tissues, and organs(Von Woedtke et al., 2013). Therefore, the aim of the new research field of plasma medicine is the exploitation of a much more differentiated interaction of specific plasma components with specific structural as well as functional elements or functionalities of living cells. This interaction can possibly lead either to stimulation or inhibition of cellular function and be finally used for therapeutic purposes. During recent years a broad spectrum of different plasma sources with various names dedicated for biomedical applications has been reported. So far, research activities were mainly focused on barrier discharges and plasma jets working at atmospheric pressure(Chu and Lu, 2013).

Figure (2-6): TDK's compact plasma generator CeraPlas (left), and the cold plasma generator piezobrush

Chapter Three

Plasma medicine:

comprises of Cold Atmospheric Plasma (CAP) to produce specific amounts of reactive species which are focused on biological surfaces (tissues/cells). Plasmas have been used for a long time for sterilization of medical equipment, packaging in the food industry, implants, blood coagulation, dentistry, biofilm treatment . These applications are possible due to inherent benefits of CAP such as scalability, portability and disinfection effectiveness in small and confined spaces. Currently there are numerous CAP based devices that are employed for treatment of tissues and cells. CAP is implemented for rapid sterilization. There are also new research possibilities for drugs delivery through tissues and biofilms [The results of these specific experiments could translate into plasma based drug delivery techniques However, this would rely on factors such as conceptual design of plasma sources (whose chemical reactivity could be controlled), application of plasma physically, and most importantly in vivo and in vitro experiments. The CAP is generated through several mechanisms that include microwave frequencies, Radiofrequency (RF), high voltage (DC/AC). Since, these CAP are non equilibrium plasmas, they consist of both reactive species (electrons and ions) as well as excited species that has immense potential in plasma based medicine as well as drug delivery . Plasma medicine is an evolving field of research that is based fundamentally on plasma physics which governs the physical and chemical properties of CAP(Laroussi, 2020).

Figure (3-1): Schematic illustration of selected applications of CAPP treatment in medicine, agriculture and food industry

Application of cold plasma and it uses in medical fields:

In recent years, cold atmospheric pressure plasma (CAPP) technology has received substantial attention due to its valuable properties including operational simplicity, low running cost, and environmental friendliness. Several different gases (air, nitrogen, helium, argon) and techniques (corona discharge, dielectric barrier discharge, plasma jet) can be used to generate plasma at atmospheric pressure and low temperature. Plasma treatment is routinely used in materials science to modify the surface properties (e.g., wettability, chemical composition, adhesion) of a wide range of materials (e.g., polymers, textiles, metals, glasses). Moreover, CAPP seems to be a powerful tool for the inactivation of various pathogens (e.g., bacteria, fungi, viruses) in the food industry (e.g., food and packing material decontamination, shelf life extension), agriculture (e.g., disinfection of seeds, fertilizer, water, soil) and medicine (e.g., sterilization of medical equipment, implants). Plasma medicine also holds great promise for direct therapeutic treatments in dentistry (tooth bleaching), dermatology (atopic eczema, wound healing) and oncology (melanoma, glioblastoma). Overall, CAPP technology is an innovative, powerful and effective tool offering a broad application potential. However, its limitations and negative impacts need to be determined in order to receive regulatory approval and consumer acceptance.

Plasma is regularly alluded to as the fourth form of matter. Its bounty presence in nature along with its potential antibacterial properties has made it a widely utilized disinfectant in clinical sciences(Domonkos et al., 2021).

The main field of plasma medicine :

Is the direct application of cold atmospheric plasma (CAP) on or in the human body for therapeutic purposes. CAP is effective both to inactivate a broad spectrum of microorganisms including multiple drug resistant ones and to stimulate proliferation of mammalian cells. Clinical application has started in the field of wound healing and treatment of infective skin diseases(Bernhardt et al., 2019). Below are some pictures of the use of plasma in medical fields.

Figure (3-2): Cold plasma can be used to bond disparate materials or to color dentures.

Chapter Four

Conclusion

Over the past two decades, advances in CAP reaserch have resulted in many promising and exciting scientific discoveries as well as the development of new technologies and applications. Most notably, CAP can produce a chemically rich environment at close to atmospheric pressure and room temperature, a unique condition that can deliver highly reactive species in a beneficial and non-destructive manner. The multidisciplinary field of plasma medicine focuses on the therapeutic uses of plasma, or ionized gas, including wound healing, cancer treatment, and disinfection. These applications can be broadly categorized into three groups: Plasma-assisted preparation of biocompatible surfaces. CAP has been tentatively used in inflammatory or pruritic skin disorders such as psoriasis, pruritus, and ichthyoids. Increasing data suggest that CAP can attack the microbial structure due to its unique effects, such as heat, ultraviolet radiation, and free radicals, resulting in its inactivation.

Cold plasma treatment offers distinct advantages over traditional methods such as heat treatment, chemical treatment, and irradiation. It effectively eliminates pathogenic microbes from food surfaces while preserving the quality, flavor, and nutritional content of the food.

CAP has been shown to be a promising and inexpensive treatment for a variety of different diseases. While CAP already reached standard medical care status for wound treatment, only preliminary data for its effects in oncology are available. Continuing efforts in this emerging and highly dynamic field of plasma medicine will be necessary to further explore the full therapeutic potential of CAP and to fully understand its mechanisms of action.

Unique advantages of plasma application for therapeutic purposes are:

1. Active components are generated locally and only for the required duration of the application on-site primarily by a physical process.

2. Biologically active plasma components (above all reactive oxygen and nitrogen species) are the same as occur in regular physiological and biochemical processes in the body but cannot be supported adequately by drugs.

3. Because of its localized and short-term generation by local plasma treatment these substances can be detoxified by processes of regular cell metabolism, i.e. there is no increased risk of plasma application.

BELLAN, P. M. 2008. *Fundamentals of plasma physics*, Cambridge university press.

BERNHARDT, T., SEMMLER, M. L., SCHÄFER, M., BEKESCHUS, S., EMMERT, S. & BOECKMANN, L. 2019. Plasma medicine: Applications of cold atmospheric pressure plasma in dermatology. *Oxidative medicine and cellular longevity,* 2019.

BITTENCOURT, J. A. 2013. *Fundamentals of plasma physics*, Springer Science & Business Media.

CHU, P. K. & LU, X. 2013. *Low temperature plasma technology: methods and applications*, CRC press.

DOMONKOS, M., TICHÁ, P., TREJBAL, J. & DEMO, P. 2021. Applications of cold atmospheric pressure plasma technology in medicine, agriculture and food industry. *Applied Sciences,* 11**,** 4809.

GOLDSTON, R. J. 2020. *Introduction to plasma physics*, CRC Press.

GU, Z. 2011. Brief Introduction. *Peking oJ http://www. ciccc. com/english_ciccc/about_npcpi/about_npcpi_brief. htm [Abruf am 04.04. 2011]*.

KHANIKAR, R. R., BAILUNG, H., KHANIKAR, R. & BAILUNG, H. 2021. Cold atmospheric pressure plasma technology for biomedical application. *Plasma Sci. Technol*.

KILLIAN, T. C., PATTARD, T., POHL, T. & ROST, J. 2007. Ultracold neutral plasmas. *Physics reports,* 449**,** 77-130.

LAROUSSI, M. 2020. Cold plasma in medicine and healthcare: The new frontier in low temperature plasma applications. *Frontiers in Physics,* 8**,** 74.

VON WOEDTKE, T., REUTER, S., MASUR, K. & WELTMANN, K.-D. 2013. Plasmas for medicine. *Physics Reports,* 530**,** 291-320.