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The Plasma Approximation

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ABSTRACT

In this review, we have studied literature survey on various types of plasma and their applications and also discuss the advantages and disadvantages. The presence of a significant number of charge carriers makes plasma electrically conductive so that it responds strongly to electromagnetic fields. Like gas, plasma does not have a definite shape or a definite volume unless enclosed in a container. Unlike gas, under the influence of a magnetic field, it may form structures such as filaments, beams and double layers. Sensitive applications of plasma, like subjecting human body or internal organs to plasma treatment for medical purposes, are also possible. This possibility is profoundly being investigated by research groups worldwide under the highly-interdisciplinary research field called 'plasma medicine.

Keywords : The plasma approximation, Astrophysical Plasma, Plasma medicine and Dusty plasmas.

I. INTRODUCTION

A. Plasma

The purpose of this review is to outline the definition and method of origin of the plasma that are most commonly used at present. A plasma can be created by heating a gas or subjecting it to a strong electromagnetic field, applied with a laser or microwave generator at temperatures above 5000 °C. This decreases or increases the number of electrons in the atoms or molecules, creating positive or negative charged particles called ions (Luo et al. 1998) and is accompanied by the dissociation of molecular bonds.

Plasma is the most abundant form of ordinary matter in the universe (the properties of dark matter are still mostly unknown; whether it can be equated to ordinary matter has yet to be determined), most of which is in the rarefied intergalactic regions, particularly the intracluster medium, and in stars, including the Sun (Peratt 1996). A common form of plasma on Earth is produced in neon signs. Plasma is an electrically neutral medium of unbound positive and negative particles (i.e. the overall charge of a plasma is roughly zero). It is important to note that although the particles are unbound, they are not ‘free’ in the sense of not experiencing forces. When a charged particle moves, it generates an electric current with magnetic fields; in plasma, the movement of a charged particle affects and is affected by the general field created by the movement of other charges. This governs collective behavior with many degrees of variation (Hanne 1990). Three factors are listed in the definition of a plasma stream (Dickel 1990).

B. The Plasma Approximation

Charged particles must be close enough together that each particle influences many nearby charged particles, rather than just interacting with the closest particle (these collective effects are a distinguishing feature of a plasma). The plasma approximation is valid when the number of charge carriers within the sphere of influence (called the Debye sphere whose radius is the Debye screening length) of a particular particle is higher than unity to provide collective behavior of the charged particles. The average number of particles in the Debye sphere is given by the plasma parameter.

C. Bulk Interactions

The Debye screening length (defined above) is short compared to the physical size of the plasma. This criterion means that interactions in the bulk of the plasma are more important than those at its edges, where boundary effects may take place. When this criterion is satisfied, the plasma is quasineutral.

D. Plasma Frequency

The electron plasma frequency (measuring plasma oscillations of the electrons) is large compared to the electron-neutral collision frequency (measuring frequency of collisions between electrons and neutral particles). When this condition is valid, electrostatic interactions dominate over the processes of ordinary gas kinetics.

Characteristic	Terrestrial plasmas	Cosmic plasmas
Size in meters	10^{-6} m (lab plasmas) to 10^{2} m (lightning) (~8 OOM)	10^{-6} m (spacecraft sheath) to 10^{25} m (intergalactic nebula) (~31 OOM)
Lifetime in seconds	10^{-12} s (laser-produced plasma) to 10^{7} s (fluorescent lights) (~19 OOM)	10^{1} s (solar flares) to 10^{17} s (intergalactic plasma) (~16 OOM)
Density in particles per cubic meter	10^{7} m^{-3} to 10^{32} m^{-3} (inertial confinement plasma)	1 m^{-3} (intergalactic medium) to 10^{30} m^{-3} (stellar core)
Temperature in Kelvin	~0 K (crystalline non-neutral plasma) to 10^{8} K (magnetic fusion plasma)	10^{2} K (aurora) to 10^{7} K (solar core)
Magnetic fields in teslas	10^{-4} T (lab plasma) to 10^{3} T (pulsed-power plasma)	10^{-12} T (intergalactic medium) to 10^{11} T (near neutron stars)

E. Degree of Ionization

For plasma to exist, ionization is necessary. The term "plasma density" by itself usually refers to the "electron density", that is, the number of free electrons per unit volume. The degree of ionization of a plasma is the proportion of atoms that have lost or gained electrons, and is controlled mostly by the temperature. Even a partially ionized gas in which as little as 1% of the particles are ionized can have the characteristics of a plasma (i.e., response to magnetic fields and high electrical conductivity). The degree of ionization, is defined as, where is the number density of ions and is the number density of neutral atoms. The electron density is related to this by the average charge state of the ions through, where is the number density of electrons.

F. Plasma Temperatures

Plasma temperature is normally measured in kelvins or electron volts and is, informally, a measure of the thermal kinetic energy per particle. High temperatures are usually needed to sustain ionization, which is a defining feature of plasma. The degree of plasma ionization is determined by the electron temperature relative to the ionization energy. At low temperatures, ions and electrons tend to recombine into bound states atoms (Doherty et al. 1965) and the plasma will eventually become a gas.

In most cases the electrons are close enough to thermal equilibrium that their temperature is relatively well-defined, even when there is a significant deviation from a Maxwellian energy distribution function, for example, due to UV radiation, energetic particles, or strong electric fields. Because of the large difference in mass, the electrons come to thermodynamic equilibrium amongst themselves much faster than they come into equilibrium with the ions or neutral atoms. For this reason, the ion temperature may be very different from (usually lower than) the electron temperature. This is especially common in weakly ionized technological plasmas, where the ions are often near the ambient temperature.

Since plasmas are very good electrical conductors, electric potentials play an important role. The potential as it exists on average in the space between charged particles, independent of the question of how it can be measured, is called the "plasma potential", or the "space potential". If an electrode is inserted into a plasma, its potential will generally lie considerably below the plasma potential due to what is termed a Debye sheath. The good electrical conductivity of plasmas makes their electric fields very small. This results in the important concept of "quasineutrality", which says the density of negative charges is approximately equal to the density of positive charges over large volumes of the plasma but on the scale of the Debye length there can be charge imbalance (Zhang et al. 2002). In the special case that double layers are formed, the charge separation can extend some tens of Debye lengths.

Plasma Potential

Lightning is an example of plasma present at Earth's surface. Typically, lightning discharges 30,000 amperes at up to 100 million volts, and emits light, radio waves, X-rays and even gamma rays (Boeuf et al. 2010). Plasma temperatures in lightning can approach 28,000 K (28,000 °C; 50,000 °F) and electron densities may exceed 10^{24} m^{-3}.

Magnetization

Plasma with a magnetic field strong enough to influence the motion of the charged particles is said to be magnetized. A common quantitative criterion is that a particle on average completes at least one gyration around the magnetic field before making a collision, i.e., where is the "electron gyrofrequency" and is the "electron collision rate". It is often the case that the electrons are magnetized while the ions are not. Magnetized plasmas are anisotropic, meaning that their properties in the direction parallel to the magnetic field are different from perpendicular to it. While electric fields in plasmas are usually small due to the high conductivity, the electric field associated with a plasma moving in a magnetic field is given by (where is the electric field, is the velocity, and is the magnetic field), and is not affected by Debye shielding (Chin 2006).

Common Plasmas

Plasmas are by far the most common phase of ordinary matter in the universe, both by mass and by volume (Braams 1966). Essentially, all of the visible light from space comes from stars, which are plasmas with a temperature such that they radiate strongly at visible wavelengths. Most of the ordinary (or baryonic) matter in the universe, however, is found in the intergalactic medium, which is also a plasma, but much hotter, so that it radiates primarily as X-rays.

In 1937, Hannes Alfvén argued that if plasma pervaded the universe, it could then carry electric currents capable of generating a galactic magnetic field (Leal and Edbertho 2004). After winning the Nobel Prize, he emphasized that to understand the phenomena in a certain plasma region, it is necessary to map not only the magnetic but also the electric field and the electric currents. Space is filled with a network of currents which transfer energy and momentum over large or very large distances. The currents often pinch to filamentary or surface currents. The latter are likely to give space, as also interstellar and intergalactic space, a cellular structure (Nemchinsky and Severance 2006).

By contrast the current scientific consensus is that about 96% of the total energy density in the universe is not plasma or any other form of ordinary matter, but a combination of cold dark matter and dark energy. Our Sun, and all of the other stars, are made of plasma, much of interstellar space is filled with a plasma, albeit a very sparse one, and intergalactic space too. Even black holes, which are not directly visible, are thought to be fuelled by accreting ionising matter (Sobolewski et al. 1997), and they are associated with astrophysical jets of luminous ejected plasma (Park et al. 2001) such as M87's jet that extends 5,000 light-years (Leroux et al 2008).

In our solar system, interplanetary space is filled with the plasma of the Solar Wind that extends from the Sun out to the heliopause. However, the density of ordinary matter is much higher than average and much higher than that of either dark matter or dark energy. The planet Jupiter accounts for most of the non-plasma within the orbit of Pluto (about 0.1% by mass, or 10−15% by volume).

Dust and small grains within a plasma will also pick up a net negative charge, so that they in turn may act like a very heavy negative ion component of the plasma.

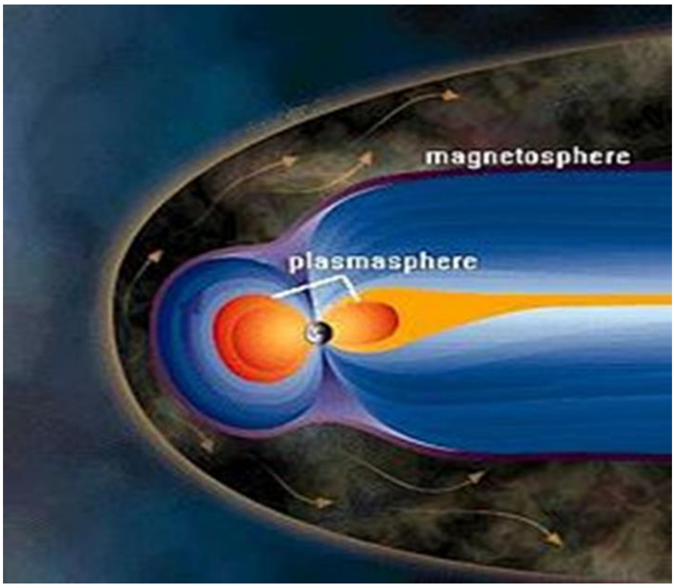
II. METHODS AND MATERIAL

1) Astrophysical Plasma

Lagoon Nebula is a large, low-density cloud of partially ionized gas.

An astrophysical plasma is a plasma (a highly ionized gas) whose physical properties are studied as part of astrophysics. Much of the baryonic matter of the universe is thought to consist of plasma, a state of matter in which atoms and molecules are so hot, that they have ionized by breaking up into their constituent parts, negatively charged electrons and positively charged ions. Because the particles are charged, they are strongly influenced by electromagnetic forces, that is, by magnetic and electric fields. All astrophysical plasmas are likely influenced by magnetic fields.

2) Plasmasphere



The plasmasphere, or inner magnetosphere, is a region of the Earth's magnetosphere consisting of low energy (cool) plasma. It is located above the ionosphere. The outer boundary of the plasmasphere is known as the plasmapause, which is defined by an order of magnitude drop in plasma density. The plasmasphere was discovered in 1963 by Don Carpenter from the analysis of VLF whistler wave data. Traditionally, the plasmasphere has been regarded as a well behaved cold plasma with particle motion dominated entirely by the geomagnetic field and hence corotating with the Earth. In contrast, recent satellite observations have shown that density irregularities such as plumes or biteouts may form. It has also been shown that the plasmasphere does not always co-rotate with the Earth. The plasma of the magnetosphere has many different levels of temperature and concentration (Singh et al. 2012, Singh and Mishra 2015). The coldest magnetospheric plasma is most often found in the plasmasphere, a donut-shaped region surrounding the Earth. But plasma from the plasmasphere can be detected throughout the magnetosphere because it gets blown around by electric and magnetic field. Data gathered by the twin Van Allen Probes show that the plasmasphere also limits highly energetic ultrarelativistic electrons from cosmic and solar origin from reaching low earth orbits and the surface of the planet.(Grydeland 2003, Singh and Mishra 2016).

3) History

Space physics can be traced back to the ancient Chinese, who recorded sun spots. The Chinese also discovered the principle of the compass, but did not understand how it worked. During the 16th century, in De Magnete, William Gilbert gave the first description of the Earth's magnetic field, showing that the Earth itself is a great magnet, which explained why a compass needle points north. Deviations of the compass needle magnetic declination were recorded on navigation charts, and a detailed study of the declination near London by watchmaker George Graham resulted in the discovery of irregular magnetic fluctuations that we now call magnetic storms, so named by Alexander Von Humboldt. Gauss and William Weber made very careful measurements of Earth's magnetic field which showed systematic variations and random fluctuations. This suggested that the Earth was not an isolated body, but was influenced by external forces. A relationship between individual aurora and accompanying geomagnetic disturbances was noticed by Anders Celsius and Peter Hiorter in 1747. In 1860, Elias Loomis.

In the late 1870s, Henri Becquerel offered the first physical explanation for the statistical correlations that had been recorded: sunspots must be a source of fast protons. They are guided to the poles by the Earth's magnetic field. In the early twentieth century, these ideas led Kristian Birkeland to build a terella, or laboratory device which simulates the Earth's magnetic field in a vacuum chamber, and which uses a cathode ray tube to simulate the energetic particles which compose the solar wind. A theory began to be formulated about the interaction between the Earth's magnetic field and the solar wind.

4) Plasma Medicine

Medicine plasma is an innovative and emerging field combining plasma physics, life sciences and clinical medicine to use physical plasma for therapeutic applications. Initial experiments confirm that plasma can be effective in in vivo antiseptics without affecting surrounding tissue and, moreover, stimulating tissue regeneration. Based on sophisticated basic research on plasma-tissue interaction, first therapeutic applications in wound healing, dermatology and dentistry will be opened.

Plasma, described as the fourth state of matter, comprises charged species, active molecules and atoms and is also a source of UV-photons. These plasma-generated active species are useful for several bio-medical applications suclants and surgical instruments as well as modifying biomaterial surface properties (Vandamme et al. 2011). Sensitive applications of plasma, like subjecting human body or internal organs to plasma treatment for medical purposes, are also possible. This possibility is profoundly being investigated by research groups worldwide under the highly-interdisciplinary research field called 'plasma medicine'.

5) Non-thermal atmospheric-pressure plasma for medical therapy

Recently, one of challenges is the application of non-thermal plasmas directly on the surface of human body or on internal organs. Whereas for surface modification and biological decontamination both low-pressure and atmospheric pressure plasmas can be used, for direct therapeutic applications only atmospheric pressure plasma sources are applicable.

The high reactivity of plasma is a result of different plasma components, electromagnetic radiation (UV/VUV, visible light, IR, high-frequency electromagnetic fields, etc.) on the one hand and ions, electrons and reactive chemical species, primarily radicals, on the other. Besides surgical plasma application like argon plasma coagulation (APC), (Langmuir 1928). Which is based on high-intensity lethal plasma effects, first and sporadic non-thermal therapeutic plasma applications are documented in literature (Weber 2006). However, the basic understanding of mechanisms of plasma effects on different components of living systems is in the early beginning. Especially for the field of direct therapeutic plasma application, a fundamental knowledge of the mechanisms of plasma interaction with living cells and tissue is essential as a scientific basis.

Direct Plasmas

In direct plasmas the tissue/skin itself serves as an electrode so that in this form current flows through the body. A common example of this is the “dielectric barrier discharge” device (DBD). A conventional DBD device comprises two planar electrodes with at least one of them covered with a dielectric material and the electrodes are separated by a small gap which is called the discharge gap. However, for medical application of DBD devices, the human body itself can serve as one of the two electrodes making it sufficient to devise plasma sources that consist of only one electrode covered with a dielectric such as alumina or quartz. DBD for medical applications (*Kallenrode 2004*) such as for treatment of skin diseases and wounds, tumor treatment and disinfection of skin surface are currently under investigation.

Indirect Plasmas

Indirect plasmas are produced between two electrodes and then transported to the target area by a gas flow. The individual discharge can be markedly stronger here (there is no hindrance by a barrier), the transport of the charge carriers (and the pro- duced molecules) away from the dis- charge region results simply from the gas flow and from diffusion. Most devices of this type produce thin (mm diameter) plasma jets, larger surfaces can be treated simultaneously by joining many such jets or by multielectrode systems. Significantly larger surfaces can be treated than with direct plasmas. Further, the distance between the device and the skin is to a certain degree variable, as the skin is not needed as a plasma electrode, significantly simplifying use on the patient (Fridman et al. 2008).

Hybrid Plasmas

Hybrid plasmas also termed as barrier coronal discharges, combine both techniques discussed above. They are produced just as direct plasmas, but due to a grounded mesh electrode no current flows through tissue anymore.

6) First therapeutic approaches of plasma medicine

Initial experiments confirm the fact that infectious agents can be killed without adverse reactions on surrounding healthy body cells. Furthermore, it is possible to stimulate physiological and biochemical processes in living tissues by plasma treatment under special conditions. This opens the possibility to use plasma to support wound healing as well as to treat several skin diseases. Therefore, application-oriented research is directed to develop an integrated concept of plasma-based wound treatment comprising both superficial wound cleaning and antiseptics and stimulation of tissue regeneration in deeper tissue layers. On a solid scientific basis, further therapeutic plasma applications as in dentistry, or surgery, will be opened during the next years (Kuchenbecker et al. 2009).

7) Plasma-assisted modification of bio-relevant surfaces

Plasma-assisted modification of bio-relevant materials is an established technique to optimize the biofunctionality of implants or to qualify polymer surfaces for cell culturing and tissue engineering. Plasma-based methods and processes for sterilization, decontamination or reprocessing of medical and diagnostic devices, pharmaceutical products or packaging materials are under development worldwide. Both fields are more or less indirect medical plasma applications.

8) Interdisciplinary basic research on plasma interaction with living matter

Based on knowledge about mechanisms of antimicrobial plasma activity, current research in plasma medicine is mainly focused on the selective inactivation of infectious agents in the close presence of living tissue. Direct interaction of active plasma components with biochemical and physiological processes influencing growth and vitality of cells and tissue. Indirect influencing of cells and tissue via changes of the vital environment (physiological liquids) of cells and tissue through physical plasma.

Combination of plasma technology and plasma diagnostics with cell biological, biochemical and chemical analytical techniques based on in vitro models using microorganisms as well as cell and tissue cultures, will facilitate a sophisticated evaluation of biological plasma effects.

To achieve sustained success of plasma medicine, for any potential therapeutic application optimal plasma composition (radicals, irradiation, temperature, etc.), useful application rate and acceptable relation between desired therapeutic effects and adverse reactions have to be found. This can be realized only in close collaboration between plasma physicists, life scientists and clinical physicians.

Dusty Plasma

A dusty plasma is a plasma containing millimeter (10^{-3}) to nanometer (10^{-9}) sized particles suspended in it. Dust particles are charged and the plasma and particles behave as a plasma.(*Mendis 1979*) Dust particles may form larger particles resulting in "grain plasmas". Due to the additional complexity of studying plasmas with charged dust particles, dusty plasmas are also known as Complex Plasmas.

Dusty plasmas are interesting because the presence of particles significantly alters the charged particle equilibrium leading to different phenomena *(Hill 1979).* It is a field of current research. Electrostatic coupling between the grains can vary over a wide range so that the states of the dusty plasma can change from weakly coupled (gaseous) to crystalline. Such plasmas are of interest as a non-Hamiltonian system of interacting particles and as a means to study generic fundamental physics of self-organization, pattern formation, phase transitions, and scaling.

Laboratory Dusty Plasmas

Dusty plasmas are often studied in laboratory setups. The dust particles can be grown inside the plasma, or microparticles can be inserted. Usually, a low temperature plasma with a low degree of ionization is used. The microparticles then become the dominant component regarding the energy and momentum transport, and they can essentially be regarded as single-species system. This system can exist in all three classical phases, solid, liquid and gaseous, and can be used to study effects such as crystallization, wave and shock propagation, defect propagation, etc.

When particles of micrometer-size are used, it is possible to observe the individual particles. Their movement is slow enough to be able to be observed with ordinary cameras, and the kinetics of the system can be studied. However, for micrometer-sized particles, gravity is a dominant force that disturbs the system (*Shukla 2002*). Thus, experiments are sometimes performed under microgravity conditions during parabolic flights or on board a space station.

9) General Characteristics

Plasma displays are bright (1,000 lux or higher for the module), have a wide color range, and can be produced in fairly large sizes—up to 3.8 metres (150 in) diagonally. They had a very low-luminance "dark-room" black level compared with the lighter grey of the unilluminated parts of an LCD screen at least in the early history of the competing technologies (in the early history of plasma panels the blacks were blacker on plasmas and greyer on LCDs) (Myers 2002). LED-backlit LCD televisions have been developed to reduce this distinction. The display panel itself is about 6 cm (2.4 in) thick, generally allowing the device's total thickness (including electronics) to be less than 10 cm (3.9 in). Power consumption varies greatly with picture content, with bright scenes drawing significantly more power than darker ones – this is also true for CRTs as well as modern LCDs where LED backlight brightness is adjusted dynamically. The plasma that illuminates the screen can reach a temperature of at least 1200 °C (2200 °F). Typical power consumption is 400 watts for a 127 cm (50 in) screen. 200 to 310 watts for a 127 cm (50 in) display when set to cinema mode. Most screens are set to "shop" mode by default, which draws at least twice the power (around 500–700 watts) of a "home" setting of less extreme brightness. Panasonic has greatly reduced power consumption ("1/3 of 2007 models") (Weber 2006). Panasonic states that PDPs will consume only half the power of their previous series of plasma sets to achieve the same overall brightness for a given display size. The lifetime of the latest generation of plasma displays is estimated at 100,000 hours of actual display time, or 27 years at 10 hours per day. This is the estimated time over which maximum picture brightness degrades to half the original value.

Plasma screens are made out of glass.This may causes glare from reflected objects in the viewing area. Companies such as Panasonic coat their newer plasma screens with an anti-glare filter material. Currently, plasma panels cannot be economically manufactured in screen sizes smaller than 82 centimetres (32 in). Although a few companies have been able to make plasma enhanced-definition televisions (EDTV) this small, even fewer have made 32 inch plasma HDTVs. With the trend toward large-screen television technology, the 32 inch screen size is rapidly disappearing. Though considered bulky and thick compared with their LCD counterparts, some sets such as Panasonic's Z1 and Samsung's B860 series are as slim as 2.5 cm (1 in) thick making them comparable to LCDs in this respect.

III. RESULTS AND DISCUSSION

Advantages

- ✓ Capable of producing deeper blacks allowing for superior contrast ratio
- ✓ Wider viewing angles than those of LCD; images do not suffer from degradation at less than straight ahead angles like LCDs. LCDs using IPS technology have the widest angles, but they do not equal the range of plasma primarily due to "IPS glow", a generally whitish haze that appears due to the nature of the IPS pixel design.
- ✓ Less visible motion blur, thanks in large part to very high refresh rates and a faster response time, contributing to superior performance when displaying content with significant amounts of rapid motion.
- ✓ Superior uniformity. LCD panel backlights nearly always produce uneven brightness levels, although this is not always noticeable. High-end computer monitors have technologies to try to compensate for the uniformity problem.
- ✓ Unaffected by clouding from the polishing process. Some LCD panel types, like IPS, require a polishing process that can introduce a haze usually referred to as "clouding".
- ✓ Less expensive for the buyer per square inch than LCD, particularly when equivalent performance is considered.

Disadvantages

- ✓ Earlier generation displays were more susceptible to screen burn-in and image retention. Recent models have a pixel orbiter that moves the entire picture slower than is noticeable to the human eye, which reduces the effect of burn-in but does not prevent it.
- ✓ Due to the bistable nature of the colour and intensity generating method, some people will notice that plasma displays have a shimmering or flickering effect with a number of hues, intensities and dither patterns.
- ✓ Earlier generation displays (circa 2006 and prior) had phosphors that lost luminosity over time, resulting in gradual decline of absolute image brightness.
- ✓ Uses more electrical power, on average, than an LCD TV using an LED backlight. Older CCFL backlights for LCD panels used quite a bit more power, and older plasma TVs used quite a bit more power than recent models.
- ✓ Does not work as well at high altitudes above 6,500 feet (2,000 metres) due to pressure differential between the gases inside the screen and the air pressure at altitude. It may cause a buzzing noise. Manufacturers rate their screens to indicate the altitude parameters.
- ✓ For those who wish to listen to AM radio, or are amateur radio operators (hams) or shortwave listeners (SWL), the radio frequency interference (RFI) from these devices can be irritating or disabling.
- ✓ Plasma displays are generally heavier than LCD, and may require more careful handling such as being kept upright.

IV. CONCLUSION

In this review we have compared various types of plasma. It is concluded that plasma display typically comprises millions of tiny compartments in between two panels of glass. These compartments, or "bulbs" or "cells", hold a mixture of noble gases and a minuscule amount of another gas (mercury vapor). Just as in the fluorescent lamps over an office desk, when a high voltage is applied across the cell, the gas in the cells forms a plasma. With flow of electricity (electrons), some of the electrons strike mercury particles as the electrons move through the plasma, momentarily increasing the energy level of the atom until the excess energy is shed. Mercury sheds the energy as ultraviolet (UV) photons. The UV photons then strike phosphor that is painted on the inside of the cell. When the UV photon strikes a phosphor molecule, it momentarily raises the energy level of an outer orbit electron in the phosphor molecule, moving the electron from a stable to an unstable state; the electron then sheds the excess energy as a photon at a lower energy level than UV light; the lower energy photons are mostly in the infrared range but about 40% are in the visible light range. Thus the input energy is converted to mostly infrared but also as visible light. The screen heats up to between 30 and 41 °C (86 and 106 °F) during operation. In plasmas potential, plasma are very good electrical conductors, electric potentials play an important role. The potential as it exists on average in the space between charged particles. Based on sophisticated basic research on plasma-tissue interaction, first therapeutic applications in wound healing, dermatology and dentistry will be opened. Dust particles may form larger particles resulting in "grain plasmas". Due to the additional complexity of studying plasmas with charged dust particles or dusty plasmas.

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