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INSTITUTE OF ADVANCED STUDY IN SCIENCE AND TECHNOLOGY GUWAHATI 1979

UGC Sponsored National Seminar
on
"Plasma Science and Technology"

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ABSTRACTS

Organised by
Department of Physics
Nabajyoti College, Kalgachia

In collaboration with
Institute of Advanced Study in
Science & Technology, Guwahati

Welcome address

By

Principal & Chairman, Organising Committee

Seminar on

Plasma Science & Technology

Respected Chief Guest, Distinguished Resource Persons, Guests, Dignitaries, Participants, Teachers, Employees and Students.

First of all I, on behalf of Nabajyoti College, would like to extend my warm greetings to you all. It gives me immense pleasure to welcome you all to our college to this two day long UGC sponsored National Seminar on **'Plasma Science and Technology'**, organised by the Department of Physics of this college in collaboration with **Institute of Advanced Study in Science And Technology (IASST), Guwahati**. We feel very happy and fortunate enough to be a host college in welcoming you all to this seminar.

Nabajyoti College, the premier institution of higher learning in western part of Barpeta District unequivocally occupies the pride of place among the institutions of its kind in the lower part of Assam. Having contributed significantly to the academic and cultural life of the region, the institution has not only withstood the test of time but has also carved a niche for itself in the sphere of higher education in the state as well as in the country. Nabajyoti College came into existence in the year 1971 and has been rendering service by imparting higher education in both Arts and Science streams in Under Graduate level under Gauhati University and in Post Graduate level through IDOL, GU and KK Handique State Open University.

Science is a vital part of modern day life. The influence of science in our day to day life cannot be ignored. The revolutionary change that science has brought to our life, which began about 400 years ago with the work of Galileo and the technology spawned from this ongoing revolution and transformed the world. Plasma is the most common state of matter. 99% of our Universe, Stars and tenuous space between stars are comprised of plasma. Studies and research on plasma science has led to important advances in various fields and its future potential is reflected through numerous current applications in the technological areas like Electronics & Semiconductors, Metallurgy, Reactor and Isotopes, Lasers etc. And above all, plasma research provides us the prospect of abundant energy.

Hope, this seminar will highlight the future prospects of this subject, open the window for new research areas and in the minds of new researchers and students.

With these few words, I once again welcome you all to this seminar and express our gratitude to the chief guest, resource persons, and other dignitaries for your gracious presence.

Thanking you all.

Dr Shahjahan Ali Ahmed
Principal & Chairman
Organizing Committee
Nabajyoti College, Kalgachia

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THERMAL PLASMA ASSISTED MATERIALS RESEARCH FACILITIES AT CPP-IPR, PRESENT RESULTS AND FUTURE PROSPECTS

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The paper gives a small introduction of thermal plasmas which are in general produced under high pressure environment, as against the classical glow discharge plasmas produced at low pressure. Plasma torches, which produce different stabilized thermal-plasma configurations are also discussed. Thermal plasmas have been extensively used in materials research, for example in synthesis of novel materials, production of thick coatings, advanced welding-cutting, environmental engineering etc. At CPP-IPR, we have a developed a supersonic plasma jet assisted experimental reactor configuration, which was used for synthesis of different high temperature materials nanomaterial with better control and enhanced material characteristics (titanium dioxide, titanium nitride, alumina, carbon nanoparticles). Some recent results on synthesis of carbon encapsulated iron nanoparticles optimized for application in targeted drugs delivery will be presented. We have also developed a plasma assisted controlled heat source system, where a collimated plasma jet can deliver more than 10 MW/m2 power on a remote substrate (similar to the condition over the surface of the Sun). We are now in process of imposing an axial magnetic field along the plasma jet which will recreate the conditions inside the Divertor region of Tokamaks, the well known plasma fusion machine. The system may be used for basic studies on how plasma interacts with material surfaces under fusion plasma like extreme high temperature/high flux conditions and validation of novel materials developed for similar applications.

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AN OVERVIEW ABOUT THE DUST CHARGING IN LOW PRESSURE FILAMENTARY PLASMA

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Dusty plasma is an ionized gas containing charged dust particles, with sizes ranging from tens of nanometers to hundreds of microns [1]. The study of dusty plasma extends beyond the realm of fundamental science. Dusty plasmas can be treated as omnipresent component of space. Dusty plasmas occur naturally, for example in interstellar space and Saturn's rings. It has a tremendous impact in astrophysics and low-temperature laboratory discharges including processing plasmas in the semiconductor industry [2]. The presence of dust particles causes a rich variety of phenomena in laboratory plasmas and changes the plasma parameters as well as effects the collective processes in such plasma systems. Due to the charging of the dust grains in plasma, the different properties of the plasma changed dramatically than the pristine plasma. A number of theoretical and experimental investigations have carried out by different researcher for understanding the charging of dust grains in various plasma environments [3-5]. An ongoing experiment [6-9] is being carried out to identify the different controlling parameters for dust charging in low-pressure filamentary plasma. Hydrogen plasma is generated by hot cathode filament discharge technique in multi-dipole dusty plasma device. From the recent experimental observation, it is seen that working pressure is one of the important factors to control the dust charging. As the working pressure decreases the charge accumulated on dust particle increases.

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DESIGN AND OPTIMIZATION OF HALL THRUSTERS BY USING COMPUTER SIMULATION

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Hall thrusters are versatile electric propulsion devices with moderate efficiency and high specific impulse. Thrust efficiencies can easily exceed 50%, and specific impulses are typically between 1200-3500s. This specific impulse range, as well as the ability to throttle the specific impulse, has been identified by NASA as very appealing for both station keeping and orbital transfer missions to the near planets. Hall thrusters adjust their thrust and specific impulse by varying the acceleration voltage and propellant flow rate. This capability makes them ideal for missions where different types of manoeuvres require different levels of thrust and specific impulse. For example, in a mission to Mars there will be a long period of low thrust during transfer from geocentric orbit to areocentric orbit where fuel economy is most important. As a spacecraft approaches Mars, a relatively rapid deceleration is necessary for Mars capture, and high thrust manoeuvre will be desired. A single Hall thrust could perform both types of manoeuvres in a single mission.

Hall thrusters have several advantages over other space propulsion systems that make them attractive options for integration with spacecraft. Their high specific impulse relative to chemical rockets allows for either significant weight savings in propellant or extended mission lifetimes. Hall thrusters are often referred to as "grid less" versions of the ion engine. Although the ion engines are functionally similar to Hall thrusters, they require alignment and careful production of delicate acceleration grids. Hall thrusters are relatively easy to build and assemble because of their simple annular geometry and use of commonly available materials. Ion engine operates in a space charge limited regime because they accelerate only ions out of the discharge chamber through the grids. The current density is therefore limited by the Child Langmuir Law for the particular grid spacing. Hall thrusters maintain quasi neutrality and thus are not charge density limited. They are also relatively simple to operate and easily throttled by adjusting the discharge voltage and mass flow rate.The main objective of our work is to design a Hall Thruster using computer simulation and optimize its performance by understanding the physical processes of its operation and validate our Hall thruster simulation model and to generate sufficient data for making a physical laboratory model that can be used for long distance planetary missions.

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EFFECTS OF ION TEMPERATURE AND POSITRON DENSITY ON THE EXACT AMPLITUDE, SPEED AND SHAPE OF ION-ACOUSTIC SOLITARY WAVES IN ELECTRON-POSITRON-ION PLASMA

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An electron-positron plasma is usually characterized as a fully ionized gas consisting of electrons and positrons, the masses of which are equal. It is widely believed that electron-positron plasmas form the major constituents of the several astrophysical situations[1,2,3]. However, most of the astrophysical plasmas usually contain ions as well in addition to electrons and positrons. Taking into account of ion temperature and positron density effects, existence conditions of exaction-acoustic solitary waves are investigated in collision less electron-positron-ion plasma by a direct analysis of the field equations [Ref.1]. The Sagdeev's potential in terms of u (ion fluid speed) instead of, φ the usual electrical potential, is derived. It is found that there exists a critical value of ion speed $u_0 (\neq 0)$ beyond which the solitary waves cease to exist for a given set of parameters. Both ion temperature and positron density play an important role in determining this critical value and have significant effects on the amplitude of solitary waves. These results reproduce the results of Johnston and Epstein [Phys. Plasmas.7, 906 (2000)] when the effects ion temperature and positron density are neglected.

***Keywords**: Electron-positron-ion plasma, ion-acoustic wave, Solitary wave, Sagdeev's potential, Speed & shape of ion-acoustic solitary waves.*

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BASIC PLASMA PHYSICS

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Plasma is one of the fourth fundamental states of matter (the other beings of solid, liquid and gas). Hannes Alfven is the father of plasma physics. As we increase the heat added to a solid, it will eventually make phase transitions to the liquid state, become gaseous and then finally the bonds binding electrons and ions are broken and the gas becomes electrically conducting plasma. As a loose definition we may regard plasma as matter whose behavior is dominated by electric and magnetic forces.

Plasma are widely used in industries such as automotive, aerospace, batteries, electrical, food packing, electronics, fuel cells, glass, optics, packaging, space, textile etc. Here I will studies the basic of the plasma, its importance and various uses of plasma in various purpose.

Keywords: *Plasma, matter, electric and magnetic force.*

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CONCEPT OF PLASMA

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The Properties of matter in a fourth unique state is called plasma. Plasma is an isonised state of matter in the solied, liquid and gaseous form but the gaseous form is most studied. Sir William Crooks an English physicist identified a fourth state of matter now called plasma in 1879. The term plasma was first used by two American physicists, Langmuir and Tonks in 1923.Plasma contains mostly charge particles and partly neutral particles, the charged particles are electrons and singly or multiply- charged ions, in such a number as to make the total charge zero. So that the plasma is electrically neutral.

The electrons and ions in a plasma are completely free to move and hence can give rise to current.Al though a plasma is electrically neutral, it is electrically conducting. It is an electrically neutral conductor capable of interacting with electric and magnetic fields. Plasma is a gaseous conductor and also conducting gas. The basic difference between a neutral gas and a plasma arises due to the different character of the antiparticles forces in them. In a neutral gas this force is of Vander Waals type, that is, short range and strong. Whereas in a plasma this force is of the Coulomb type, that is long range and weak at very large distances. As a result each particle of plasma can simultaneously interact in many ways with its innumerable immediate and distant neighbors. That is why plasma physics, is rich with information but complex in character and so a rather hard nut to crack.

Plasma is the most natural state of matter, most matter in the universe is in this state. Plasma temperatures and densities range from relatively cool and tenuous (like aurora) to very hot and dense (like the central core of a star.), ordinary solides, liqudies and gases are both electrically neutral and two cool or dense to be in a plasma state. The study and research about the properties of plasma has been immensely aroused mainly due to two causes. One is space physics and the other is controlled thermonuclear fusion. Although the ionised gas is up till now the principal medium used for research, some solids and liquids also are considered as plasma. The average kinetic energy of the neutral atoms in a gas is the same, whereas the average kinetic energy and hence their temperature of electrons, ions and neutral particles of a plasma are generally different. The average kinetic energy of electrons is much greater than that of ions and the latter may be greater than that of the neutrals. Hence, it is quite interesting that plasma is a mixture of its constituents at different temperature at the same time. Electric and magnetic fields do not affect and ordinary gas, while they are the sole agents that control the behaviour of the plasma.

In a plasma even a small applied electric field can produce a large electric current due to its high electrical conductivity. This current in turn interacts with its own magnetic field. In an external magnetic field plasma behaves like a diamagnetic substance. Plasma strongly reacts with electromagnetic waves because it behaves like a dielectric medium with a high dielectric constant. Radio waves below a certain frequency determined by the parameters of the particular plasma are disallowed transmission. As a whole plasma is quasineutral that is almost neutral. Which means that there can not be any significant excess positive or negative charge accumulated at any point in it.

(Ref. book by S.N. Goswami and other.)

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INSTABILITY OF DRIFT ACOUSTIC WAVE IN A MULT-ICOMPONENT PLASMA IN PRESENCE OF SHEARED FLOW

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The study of drift wave is one of the most important issues of active, especially in the study of the nuclear fusion and other magnetically confined plasma systems. Generation of flow shear or zonal flow are believed to be responsible for suppressing of fluctuation and inhibiting transport properties of plasma. The presence of multi-species ions can have significant effects on equilibrium and inhibiting transport properties of plasma. The stability of drift acoustic modes inhibiting transport properties of plasma by sheared flow in a multi-species plasma is studied. By considering adiabatic response for electrons expressed by Boltzmann relation and the fluid ions that are determined by equation of continuity and momentum conservation an eigenmode equation is derived. The perpendicular flow shear has a prominent effect on the nature of the eigenmode equation. The eigenmode equation is solved in the limit of vanishing perpendicular flow shear and finite perpendicular flow shear. The dispersion relation is thus derived for vanishing flow shear and the growth rate.

Keywords: *Drift wave, Sheared flow, Doppler shift, Weber equation, Shear length.*

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INFLUENCE OF PLASMA DENSITY ON ASSOCIATED ELECTRICAL ELEMENTS OF AN ION SHEATH

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The electrical elements such as capacitance and resistance associated with an ion sheath as an equivalent series LCR circuit have been estimated for real experimental plasma parameters. Quantitative estimations of the C and R components with density variation are analyzed and required parameters are taken from a low frequency instability experiment. The ion sheath under consideration is formed by a negatively biased mesh grid.

***Keywords**: Ion sheath, Ion transit time, Instability.*

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MEASUREMENT OF PLASMA POTENTIAL BY AN EMISSIVE PROBE IN AN INDUCTIVELY COUPLED 13.56 MHz RF PLASMA

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An Electron emitting probe is constructed and used in a13.56 MHz Inductively Coupled RF plasma to measure the plasma potential by adopting the saturated floating potential method. The floating potential of the hot Emissive probe is observed in an oscilloscope having very high internal impedance. The results from the Floating potential method of the Emissive probe is cross-checked by measuring the plasma potential by determining the point of separation of the hot and the cold probe characteristics and this technique also shows the same value of plasma potential at the same plasma condition.

Keywords: *Longmuir Probe, plasma potential, floating potential.*

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DUST ACOUSTIC WAVES IN H IGHER ORDER NONLINEARITY WITH DUST CHARGE VARIATION

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The effects of higher order nonlinearity on dust acoustic waves are studied with dust charge variation. Using the reductive perturbation techniques K-dV and mK-dV equations are derived. Applying the analytical and numerical methods for the higher order nonlinear equation studied the effects of amplitude and width of soliton in dusty plasma. The effects of dust charge fluctuation are also discussed in terms of higher order higher order nonlinearity. The model of charge fluctuation, taken here when the charge equilibrium occurs, i.e. of the form $I_e + I_i = 0, I_e$ and I_e being the currents of electron and ion.

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DUST ACOUSTIC SHOCK WAVES IN WARM DUSTY PLASMAS

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The nonlinear propagation of dust acoustic waves in warm dusty plasma system containing Boltzmann distributed of electrons and ions, arbitrary charged dust grains has been investigated by employing the reductive perturbation method. The nonlinear waves have been observed in the case of negative charged dust grains from the stationary solution of the Korteweg-de Vries (KdV) equation, Burgers equation and Korteweg-de Vries-Burgers (KdVBurgers) equation. The analytical solution of KdV-Burgers and Burgers equation are numerically analyzed and DA shock waves propagation is reported. It is shown and theoretically discussed about the critical dust density *dc n*. It is found that the solution of KdV equation represent a rarefactive (compressive) solitary waves if *nd* < *ndc* (*nd* > *ndc*), where *d n* is the dust density and the strength of dispersion term, the Burgers equation represent a negative (positive) shock waves when ( ) *d dc d dc n* < *n n* > *n* but with the combination of dispersion and dissipation term, the KdVBurgers equation represent a positive (negative) shock waves when ( ) *d dc d dc n* < *n n* > *n*. We observed the difference of shock wave profile of Burgers equation and KdV-Burgers equation with same parameter.

Keywords: *Dusty plasma, Solitary Wave, Shock Wave and Viscosity.*

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BIDIRECTIONAL REFLECTANCE OF REGOLITHS CONTAINING ALUMINA

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Bidirectional reflectance of a surface is defined as the ratio of the scattered radiation at the detector to the incident irradiance as a function of geometry. The accurate knowledge of the bidirectional reflectance function (BRF) of layers composed of discrete randomly positioned scattering particles is very essential for many remote sensing, engineering and biophysical applications in different areas of Astrophysics. The planetary bodies which have no atmosphere are covered by layers of finely grained dust particles which are known as regolith layers. In planetary remote sensing, the chief aim is to retrieve the information about the nature of the regolith layers by studying the phase curves.

In this work we present our Assam University Laboratory based data of bidirectional reflectance of alumina sample at different phase angles with two different particle sizes. We also fit those data with some established theoretical models viz using Mie theory and Heney-Greenstein phase function.

Keywords: *BRF, Regolith, phase curves, Mie theory, Heney-Greenstein phase function.*

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INTERPRETING THE CHEMICAL EVOLUTION OF FLUORINE IN THE EVOLVED STARS OF GLOBULAR CLUSTER M4 AND M22

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The origin of the abundance pattern present among the elements found in stars of globular cluster (hereafter GC) remains unclear till date. The proton-capture reactions are presently recognised as one of the important candidates for that kind of an observed behaviour. We propose a reaction networks of a nuclear cycle at evolved stellar condition namely Carbon-Nitrogen-Oxygen-Fluorine (hereafter CNOF) since fluorine (F^{19}) one element which gets affected by proton captures. The stellar temperature considered here ranges from 2×10^7 to 10×10^7 K and density being 10^2 gm/cc and 10^3 gm/cc. Such kinds of temperature density condition are likely to be prevailing in the H-burning shell of red giant stars. The estimated abundances of F^{19} are then matched with the data which is observed for some metal-poor giants of GC M4 as well as M22. As far as the comparison between the observed and calculated abundances is concerned it is found that the F^{19}'s abundances have shown a fairly good agreement with the observed abundances, supporting the occurrence of that nuclear cycle at adopted temperature density conditions.

***Keywords**: Globular cluster, metal-poor stars, abundances, nucleosynthesis.*

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COHERENT SCATTERING IN ACCORDANCE WITH POMRANING PHASE FUNCTION

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Most of the observable matter in the universe is in the plasma state [2]. The interplanetary medium, the interstellar medium, the intergalactic medium, the Comets, the Cosmic Rays (galactic and extra-galactic energetic particles), the Pulsars and their magnetosphere etc. all are mostly comprised of plasma [6].

The most resourceful of plasma is the coherent sources of electromagnetic radiation. According to space plasma pioneers Hannes Alfvın and Carl-Gunne Fδlthammar [1], space plasma density is medium and low according as $\lambda << \rho << l_c$ and $l_c << \lambda$ with λ= Mean free path. ρ= Larmor radius (gyroradius) of electron. λ_D=Debye length. l_c= Characteristic length.. In such cases the diffusion is found to be anisotropic. The plasma is very small so a high spatial resolution is required to study the effect of the penetration of air molecules into the plasma. The scattering signal has three overlapping contributions: Rayleigh scattering from heavy particles, Thomson scattering from free electrons and Raman scattering from molecules.[7]

Viik [9] considered the Rayleigh like phase function introduced by Pomraning [8] to derive the intensities in a homogeneous plane-parallel optically semi-infinite atmosphere where there are sources of radiation infinitely deep in the atmosphere. Basak and Karanjai [3,4] obtained the diffusely reflected intensity and emergent intensity $I(0,\mu)$ for coherent anisotropically scattering medium with planetary and Rayleigh phase functions by solving a radiative transfer equation in the form of Woolly and Stibbs [10] by using discrete ordinate method of Chandrasekhar [5]

Here attempt has been made to derive the diffusely reflected intensity, and emergent intensity $I(0,\mu)$ for the case of a coherent anisotropic scattering atmosphere with Rayleigh like Pomraning phase function.

Keywords: *Radiative transfer equation, coherent scattering, anisotropically scattering medium.*

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PLASMA FOCUS ASSISTED ION IRRADIATION ON GRAPHITE

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The response of graphite/carbon to harsh fusion condition namely energetic ions is currently a subject of thorough investigations because of their usage in next generation fusion reactors. In the present work, a low cost and simple helium ion source, namely Plasma Focus (PF), is employed to assess the response of graphite to ion irradiations. Graphite samples were irradiated to helium ions of varying doses by keeping them at different angular positions and at a fixed height from the central electrode of PF device. The irradiated and reference samples were characterized by employing various analytical treatments such as Optical Microscope (OM), Transmission Electron Microscope (TEM) and X-Ray diffraction (XRD). Optical micrographs of ion the irradiated samples mostly show rounded microstructure with sparsely layered type structure in higher resolution (100×). When viewed under TEM at very high resolution, the reference and irradiated sample (20 shots, axial position) illustrate layered type two dimensional sheaths and rounded structure with mean diameter ~10 nm, respectively. XRD spectrum of reference sample matches with hexagonal phase whereas spectrum of irradiated sample (20 shots, axial position) indicates mixed phases. Detailed results will be discussed in the paper.

Kewwords: *Plasma focus, helium ions, graphite, TEM, XRD.*

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THE STRUCTURAL AND MECHANICAL PROPERTIES OF TiN FILM DEPOSITED ON PLASMA NITRIDED SUBSTRATE

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TiN films were prepared by DC magnetron sputtering a Ti target in an Argon(Ar)+Nitrogen(N_2) atmosphere with N_2 partial pressure at $3.0x10^{-2}$ Pa on bare and pulsed DC plasma nitrided AISI M2 High speed steel(AISI M2) substrate. The deposition rate and Vicker's micro-hardness of the films were measured and the microstructure of the films were characterized by X ray diffraction (X.R.D), scanning electron microscope(SEM) and roughness of the coated substrates were characterized using surface roughness tester. X.R.D reveals that the growth of TiN on bare AISI M2 substrate is different from the plasma nitrided AISI M2 substrate. The preferred orientation of TiN was along (111) direction on bare substrate and it changes to (200) direction on plasma nitrided substrate. The surface hardness of composite surface is found to be greater than bare TiN coated substrate.

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PERIOD DOUBLING BIFURCATION AND FEIGENBAUM UNIVERSALITY OF A DISCRETE DYNAMICAL SYSTEM

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The Dynamical System is that branch of mathematics which attempts to understand processes in motion. In other words a Dynamical System is a system whose state changes with time (t). Such processes occur in all branches of science. For example, the motion of stars and galaxies in the heavens, the change of chemicals, the rise and fall of populations and the motion of simple pendulum are Dynamical Systems. The three important directions of Dynamical Systems are (i) Identification of deterministic chaos, (ii) Control of chaos and (iii) Application of Dynamical Systems in modeling theory like population models, economic models chemical models, biological models etc. In this paper I study about period doubling bifurcation and Feigenbaum universality on the map $f(x,\mu)=\mu x(1-x^2)$ where μ is a parameter.

Keywords: *Fixed point, Stable, Unstable, Bifurcation, Period doubling bifurcation and Feigenbaum universality.*

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NUMERICAL COMPUTATION OF DUST CHARGING AND PLASMA SHEATH

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Numerical computations and its developments have added a complete new dimension to the field of research. The game of numbers have been evolved so much today that, sometime it is an alter ego of the experiments. Our endeavor is to understand some basic concepts of plasma physics especially in the field of dusty plasma and plasma sheath, with the help of numerical techniques. Dust when inside a plasma is treated as a third species beside the electrons and ions. It, in most of the cases is negatively charged and thus, to understand its behavior inside, the study of dust charging is an important phenomena in the field of dusty plasma [1]. The charging mechanism is provided by OLM (Orbit-limited motion) theory. However its validity is limited to the region of low collisionality [2]. Again, beside the continuous charging OLM theory, the discrete charging theory based on the concepts of probability exists [3]. Surrounding the dust there exists a region of space charges called the sheath which is responsible for the directed ion flux on to the dust [4-6]. We attempt to understand the dust charging by understanding the sheath around.

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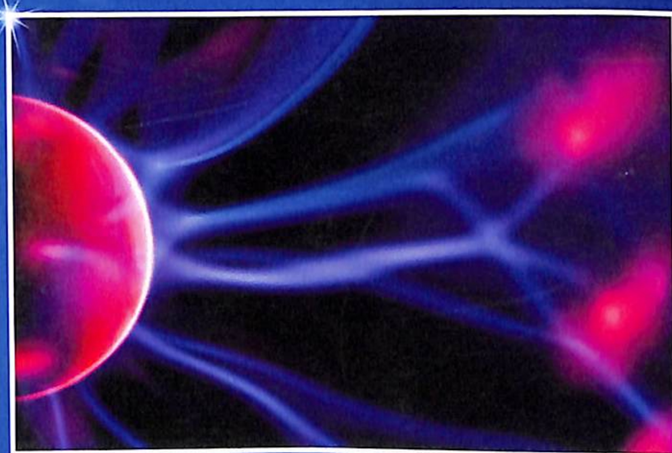

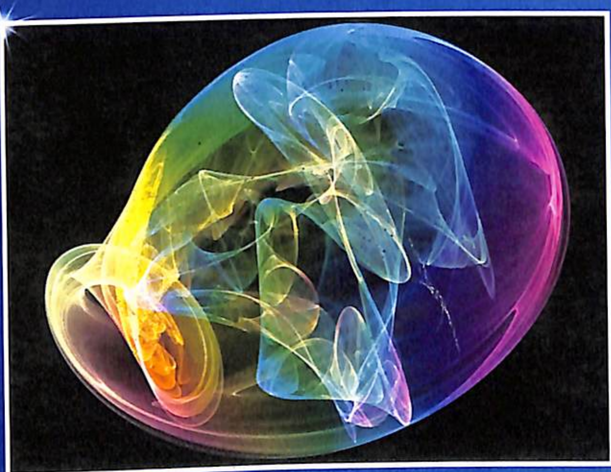

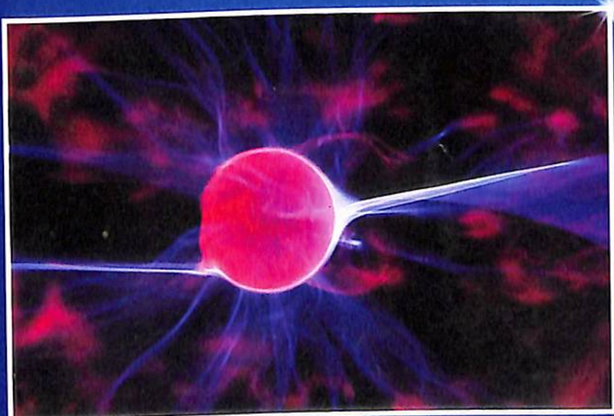

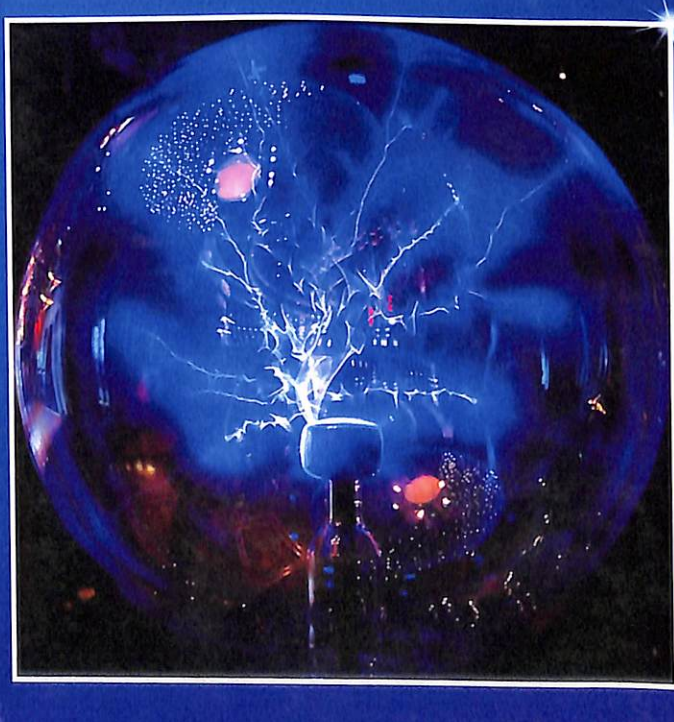

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