PLASMA

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Editor's note

Mr. Vishal Jain explains about the recent development of power supply and a new roller DBD discharge system for high density DBD plasma generation in air. He also discuss about the advantages of the generated plasma with various examples.

Mr. M.L.Choudhary, et.al. cites about the measurement of electron energy distribution function after formation of solitary electron hole in plasma. The experiments conducted and the results were discussed briefly with graphical representations.

Solar energy is a renewable and green energy. Various Industries and Research centres were showing keen interest on the renewable energy to meet the energy requirements. Photovoltaic system has recently attracted due to its in borne advantages. Mr. Vivek Beladiya discuss about the advantages of Photovoltaic system and scope of CZTS solar cell. He also gives a glimpse of initiative taken at FCIPT on solar cell development.

Editor: Dr. S. Mukherjee

Co-Editor: P.Vadivel Murugan

ABOUT FCIPT

Facilitation Centre for Industrial Plasma Technologies

The Institute for Plasma Research (IPR) is exclusively devoted to research in plasma science, technology and applications. It has a broad charter to carry out experimental and Theoretical research in plasma sciences and emphasis on the physics of magnetically confined plasmas and certain aspects of nonlinear phenomena. The Institute also has a mandate to stimulate plasma research activities in the universities and to develop plasma-based technologies for the industries. It also contributes to the training of plasma physicists and technologists in the country. IPR has been declared as the domestic agency responsible in INDIA to design, build and deliver advanced systems to ITER (International Thermonuclear Experimental Reactor) to develop nuclear fusion as a viable long term energy option.

The Facilitation Centre for Industrial Plasma Technologies (FCIPT) links the Institute with the Indian industries and commercially exploits the IPR knowledgebase. FCIPT interacts closely with entrepreneurs through the phases of development, incubation, demonstration and delivery of technologies. Complete package of a broad spectrum of plasma-based industrial technologies and facilitation services is offered. Some of the important areas in which FCIPT has been working on include Plasma Surface Engineering, Plasma Pyrolysis/ Gasification/ Energy Recovery, Plasma Diagnostics, Plasma Based Nano Patterning and Nano Synthesis, Textile Engineering, Solar Cell Development, etc. The Centre has process development laboratories, jobshops and advanced material characterisation facilities like Scanning Electron Microscopy, Microhardness Testing facilities, which are open to users from industry, research establishments and universities. For further information, please visit our website.

This newsletter is designed to update the readers with the latest developments in the important field of plasma processing and plasma based technology development and to look for new industrial opportunities.

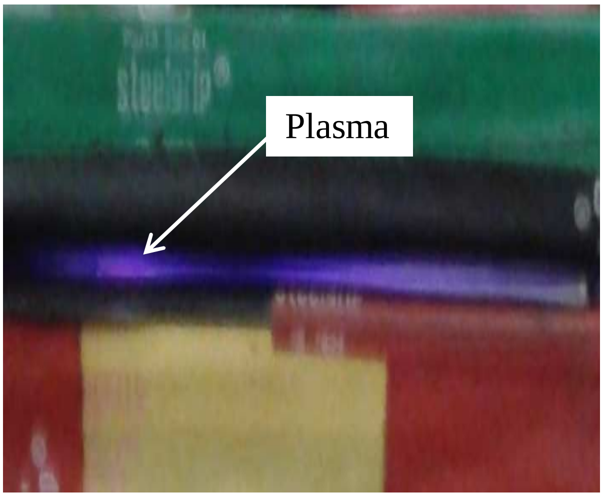
Please visit our website:
http://www.plasmaindia.com

Atmospheric pressure high power density DBD plasma in air

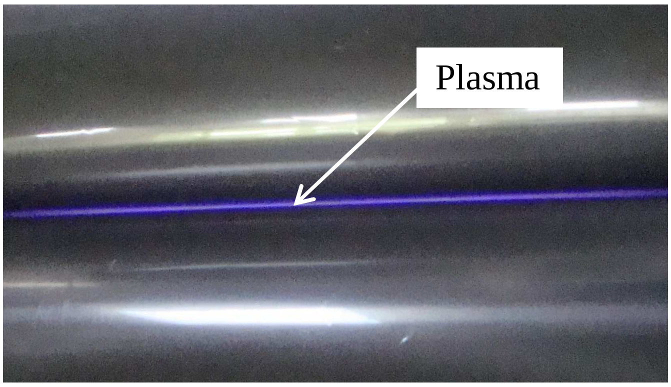
Mr. Vishal Jain

FCIPT had earlier developed a prototype system for treatment of Angora fibre with DBD plasma at atmospheric pressure in air. These systems have been installed at Kullu, Ranichauri, WRA (Wool Research Association, Bombay). The speed of treatment is nearly 2 to 4 meters per minute.

In the recent development, FCIPT has successfully developed power supply and a new roller DBD discharge system for the higher density DBD plasma generation in air to meet the higher speed demand for various industrial In-line applications. The DBD plasma discharge with plate and roller electrode configurations are shown in the figure below.



Plasma Discharge in Plate Electrodes



Plasma Discharge in Cylindrical Electrodes

FCIPT successfully generated the blue coloured plasma discharge between the two electrodes as shown in the above figure. This plasma was exposed to various materials for example paper, cotton, polyethylene film to verify the plasma induced surface modification. We observed that there was no sign of damage on the surface of any of these materials during plasma treatment. In fact, there was significant improvement in the surface wettability which is confirmed by contact angle measurement technique. The cylindrical electrodes showed better uniformity of the discharge than the plate electrodes. However, the discharge area in case of plate electrode is better. The contact angle for polyethylene film just after few seconds of treatment was reduced from 103 degree to 45 degree which is shown in the figure below.

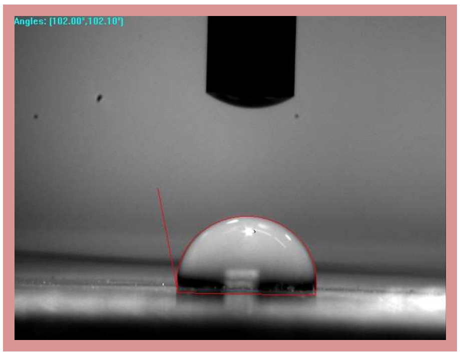
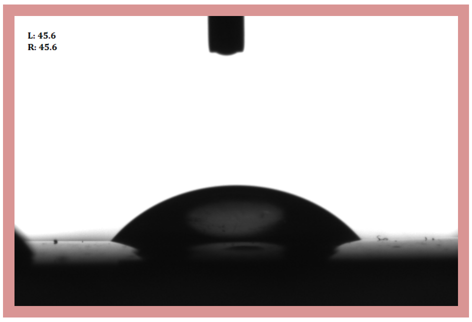


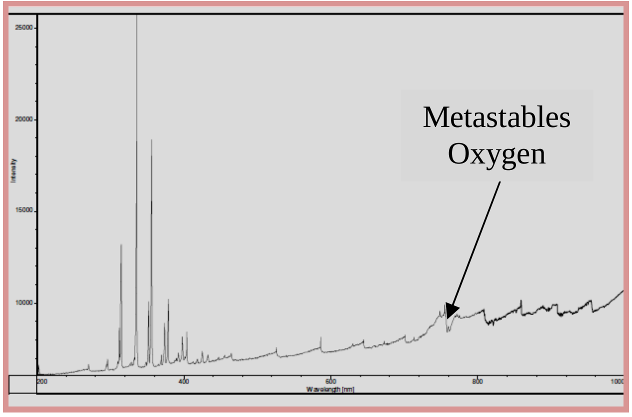
Figure: Water contact angle measurement of Untreated sample by goniometer



(B)

Figure: Water contact angle measurement of Plasma Treated sample by goniometer

The OES (Optical Emission Spectroscopy) measurement of the DBD plasma is shown in the figure below. This spectrum shows the molecular oxygen in metastable states with a peak at 768 nm. This is responsible for forming oxygen containing functional group on the surface. There are also peaks in the range of 380nm – 400nm from molecular nitrogen in UV region. These peaks give idea about the bulk temperature of the plasma discharge.



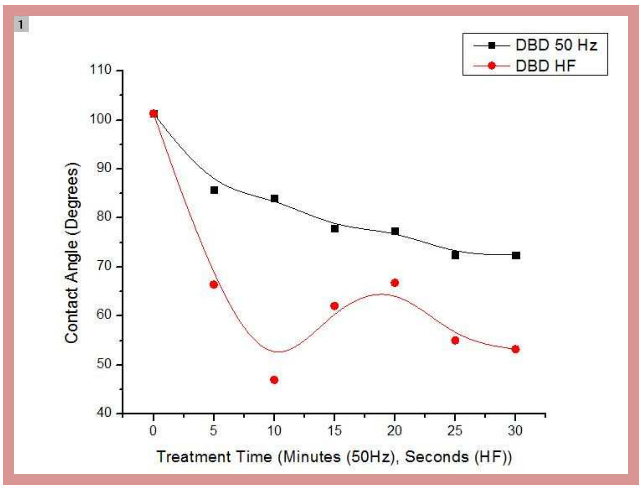


Figure: The contact angle measurement vs exposure to plasma

The above figure shows that even 30 minutes treatment of polyethylene film in conventional high voltage 50Hz supply reduces the contact angle up to nearly 75 degree. On the other hand, the contact angle was significantly reduced with high frequency rider current DBD plasma treatment. As shown in the above figure, the effective plasma treatment time for rider power supply is in the order of seconds and for conventional 50Hz DBD supply is in the order of minutes.

The FTIR (Fourier Transform Infrared) spectroscopy analysis of the polyethylene film after plasma treatment with rider supply is shown in the figure below. It is evident from the IR spectra that polar groups such as C=O, COOH, C-O-C are formed during plasma treatment that are responsible for wettability improvement on the surface.

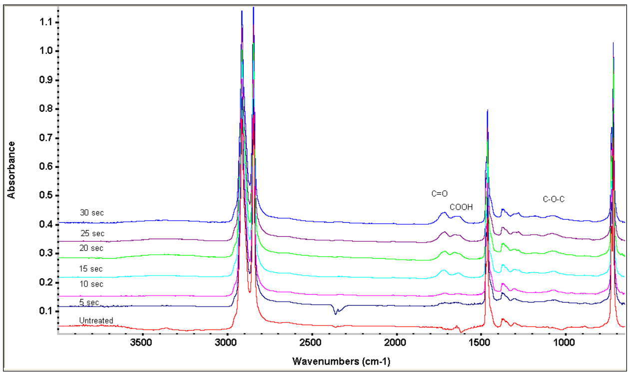


Figure: FTIR of the rider current DBD plasma treated polyethylene film

Measurement of electron energy distribution function after formation of solitary electron hole in plasma

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M.L. Choudhary, S. Kar and Dr. S. Mukherjee

Introduction

In plasma, there exist various types of electrostatic localized structures. Nonlinear landau damping of electrostatic wave in collision less electron – ion plasma gives stationary BGK

[1] like state instead of asymptotic behavior .these states were characterized as solitary electron hole, gives vortex like distribution in phase space [2]. It was described by the stationary state solution of Vlasov – Poisson's system of equations. EH structure consists of a positive potential hump that moves near electron thermal velocity. Trapping of electrons in the potential structure of electrostatic wave gives such types structures in phase space [2-5]. Distribution of trapped particles is decided by potential profile of EH. Theoretical work on study of EH has been goings-on since 1979 [5]. Holes were found in computer runs simulation of two stream instability [6]. Experimentally, an electron hole was discovered in collision less plasma of Q – machine [7]. For excitation of EH, applied potential should be above a critical value $\varphi_c = \frac{m}{2e}(\omega_p\, \alpha)^2$ [7]. Where m is the electron mass, ω_p is the angular electron plasma frequency, and α is the plasma column radius. Coalescence of EH has been observed in numerical investigation [5] and experimentally [7].

In real space, EH are 1 – 2 % electron density depressed region. These electron density depressed regions produced hollow vortices in the electron phase space. Existence of a hole in the resonance region of the electron distribution function is remark of the EH in phase space. Recently, experimental excitation of EH in the laboratory plasma by high voltage electrostatic pulses with time duration $\tau_p > 3\tau_i$ and $\tau_p < 3\tau_i$ was observed [8]. Distribution of electrons in the Hole potential structure is not observed experimentally in 1-D, collision less, unmagnetized plasma.

Initially, plasma is in thermally equilibrium.in thermal equilibrium electrons obey Maxwellian distribution. During the excitation of EH, beam of electrons is extracted from the plasma by exciter. Creation of EH in phase space increases the plasma potential and plasma goes to non-thermally equilibrium so electron distribution is changed with time. After long time, perturbed part of distribution vanishes and plasma turn into thermal equilibrium.

The studies of the plasma, after excitation of EH [8] has been investigated in our experiment. EHs have been excited by a sudden extracts the electrons beam by metal plate inside plate at high positive potential. Perturbed current was measured by help of plane probe with different biasing at particular distance. Temporal current signals were used to obtain current – voltage (I – V) characteristic of probe at given time. Temporal perturbed EEDF was measured by first derivative of I – V curves [9] i.e.

$$f(E) = \frac{m_e}{Ae^2}\frac{dI_p}{dV_p}$$

Where, A is probe area, m_e is mass of electron, e is electron charge

Let, f_0 an equilibrium electron energy distribution function is. If we perturbed the plasma then distribution function becomes –

$$f_t = f_0 + f_1$$

here f_1 is perturbed part of EEDF at a given time. If $f_1 << f_0$ then we get $f_t \approx f_0$. For looking at the perturbing EEDF, $f_1$we need to measure the time varying part of EEDF i.e. f_1. After long time of perturbation, $f_1$goes to vanish and ft goes to f_0

Experimental Setup

Experiment was carried out in a device with 50 cm Length and 29 cm diameter. For vacuum, system was attached with pumping assembly. Rotary pump and diffusion pump was used for base pressure less than 5 x 10^{-5} mbar. And the flow rate of the Ar gas was maintained at (20 SCCM). System consists two SS rings of diameter 20 cm. both rings were apart 20 cm to each other. Four thoreated tungsten filaments were mounted on those SS rings. a metal disk of diameter 10 cm is used as a exciter. Plane probe with radius 4 mm was used for measuring I – V characteristic.

Schematic diagram of setup is given in Figure below.

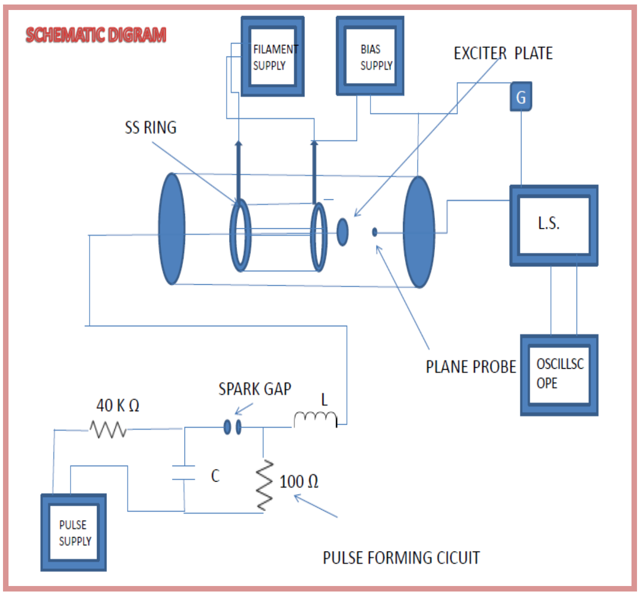

Figure: Schematic diagram of experimental system

Experimental procedure and results

During the experiment base pressure was kept at 5 x10^{-5} mbar, Ar gas kept at 3 x 10^{-3} mbar. Thermionic field emission method was used for plasma formation.

In equilibrium state, n ≈ 3 x 10^9 cm^{-3}, T_e ≈ 2eV, T_i ≈ 0.5eV. These plasma parameters are measured by help of I – V characteristic of plane. Figure below is equilibrium EEDF at d = 4 cm from exciter.

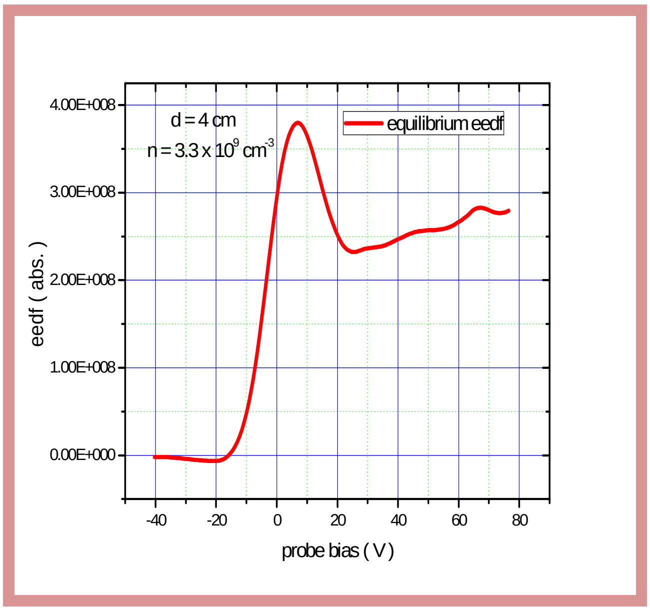

Figure: Equilibrium EEDF at d = 4 cm

Single hump profile is indication of one type electrons Population in the system

Figure below shows the temporal current variation of probe at 4 cm far away from exciter. A positive pulse of 1020 V and pulse width 10 µs was applied to the exciter at t = 0.

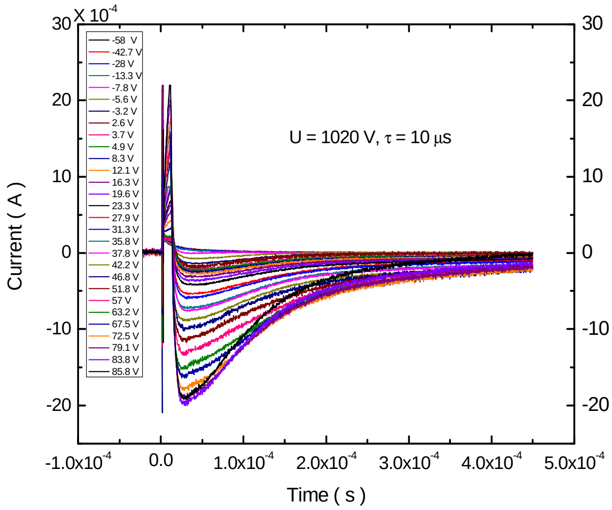

Figure: Temporal current at 4 cm from exciter for different probe bias.

These results are showing the excess Population of electrons after Pulse Off time. Using these results; we can get temporal Current variation of probe with probe bias at a given distance and time. The temporal variation of electron current as a function of probe bias at 4 cm is mentioned in the below figure and the next figure shows smooth temporal I – V curve after subtracting the ion current.

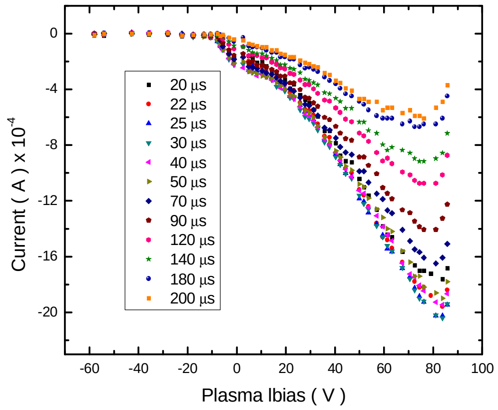

Figure: Electron current variation with probe bias at d = 4 cm for different times

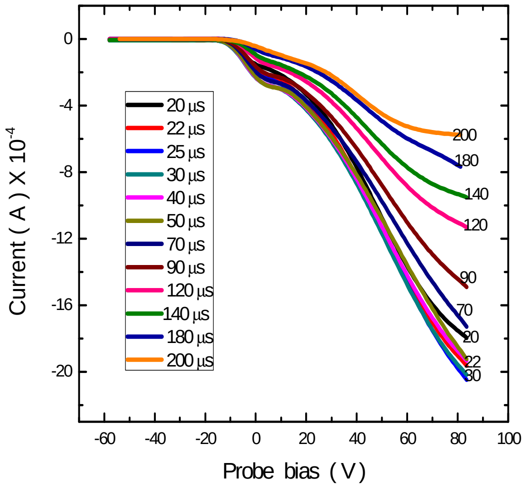

Figure: Smooth electron current variation with probe bias at d = 4 cm for different times.

Taking the first derivative of smooth temporal I – V curves, gives temporal perturbing EEDF at 4 cm for given time. Figure below shows the results for longer pulse width (10µs). Double hump profile of EEDF is observed after 20 - 25µs. It is due to arise of a beam component in the system. Beam component gets saturates and then goes toward vanishing mode.

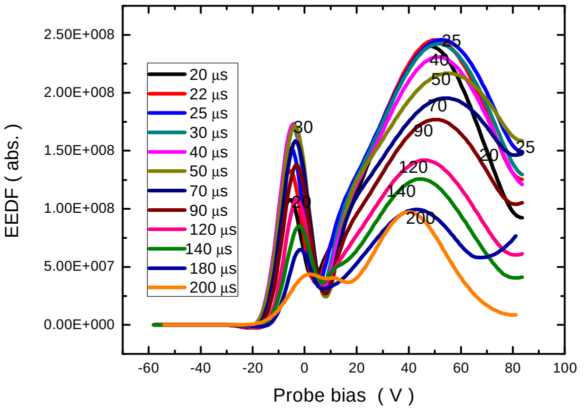

Figure: Temporal perturbing EEDF at 4 cm for different time, pulse width 10µs, U = 1020 V.

In the case of shorter pulse width 900 ns, we got double hump profile of EEDF with lower value than formal case. Plot below shows the temporal perturbing part of EEDF at 3 cm for pulse width 900 ns. Other plasma parameters are same as in the case of longer pulse width.

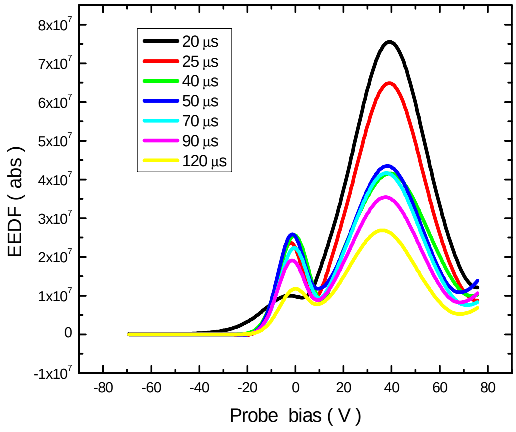

Figure: Temporal perturbing EEDF at 3 cm for different time, pulse width 900 ns, U = 1020 V

Discussion

EEDF measurements for shorter and longer pulse width tell about the life time of SEH in the phase space. EH potential may be responsible for the beam component as well as hot electron population in the system after pulse off time. These results also indicate the relaxation time of low pressure plasma in presence of SEH in the system.

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Scope of CZTS solar cell

Mr. Vivek Beladiya

At present mankind is facing the problem related to pollution and energy shortage which gradually have gained attention to the researchers to find the alternative to non renewable energy. In order to keep sustainable development, Government, Industries and Research centres have started working on problems caused by the shortage of available energy sources. The best way to overcome the problem is to make use of Renewable energy sources. Solar energy is the pre-eminent alternative to the problem, thereby providing most economic and effective option comparable to other renewable energy sources. It in inexhaustible energy sources and do not pollute earth.

Photovoltaic (PV) systems have recently attracted much attention due to their inborn advantages.

i) Direct conversion of sunlight into energy. The theoretical conversion efficiency of PV systems is relatively higher than other power generators.

ii) PV systems do not necessarily contain movable parts. System wear induced by mechanical movement is avoided. Therefore, PV systems can work continuously free from maintenance longer than other power generation technologies.

c-Si solar cell module has dominated the market but due to high cost and energy input in manufacturing have decreased market share of c-Si technology while that of thin photovoltaic technology have increased.

The three main PV technologies include CdTe, CIGS and Thin film Si solar cell. Thin film Silicon solar cells are facing challenge related to its stability from Staebler–Wronski effect. The problem faced by CdTe and CIGS solar cells development is the earth shortage material such as In, Te and limitation to use of Cd due to its toxicity. Moreover In is used in abundant in LCDs; Plasma displays Touch panels etc which adds to the increase and fluctuations in its price. Hence CZTS comes to be the most prominent and finest alternative to the CdTe and CIGS technologies. The reason why CIGS can be replaced by CZTS is.

1) The similarity in the structure where every two group III (In or Ga) atoms in chalcopyrite structure are replaced by a Zn (group II) and Sn atom (group IV), thus maintaining the octet rule.
2) Similarity in material property.
3) Use of Materials such as Zn and Sn which is relatively abundant.

CZTS is a compound semiconductor of I)$_2$(II)(IV)(VI)$_4$. With a high absorption coefficient (>104cm^{-1}) and a desirable bandgap(~1.45 eV), CZTS thin film has been considered an excellent PV material. Theoretical calculation has shown that conversion efficiency of about 32% is possible with a CZTS layer of several micrometers thick.

At FCIPT we have initiated the study of CZTS solar cell with literature survey. We are investigating the method researchers have deployed for the development and characterization of CZTS solar cell previously.

We have planned to develop CZTS solar cell using magnetron sputtering.

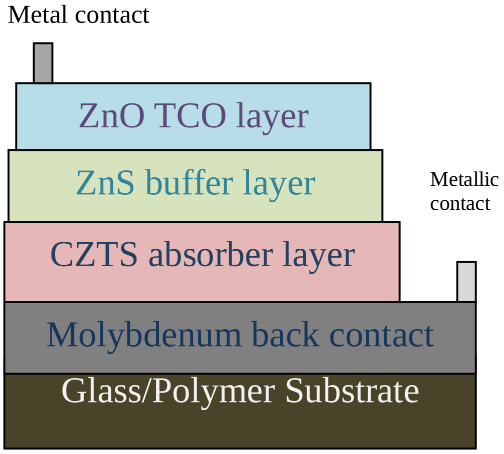


Figure : Block diagram of thin film Solar cell

We will deposit CZTS absorber layer from single CZTS sputtering target on molybdenum coated Glass substrate following ZnS as buffer layer, ZnO as TCO layer. Wadia et al. have shown raw material cost for existing PV technologies, which is shown below.

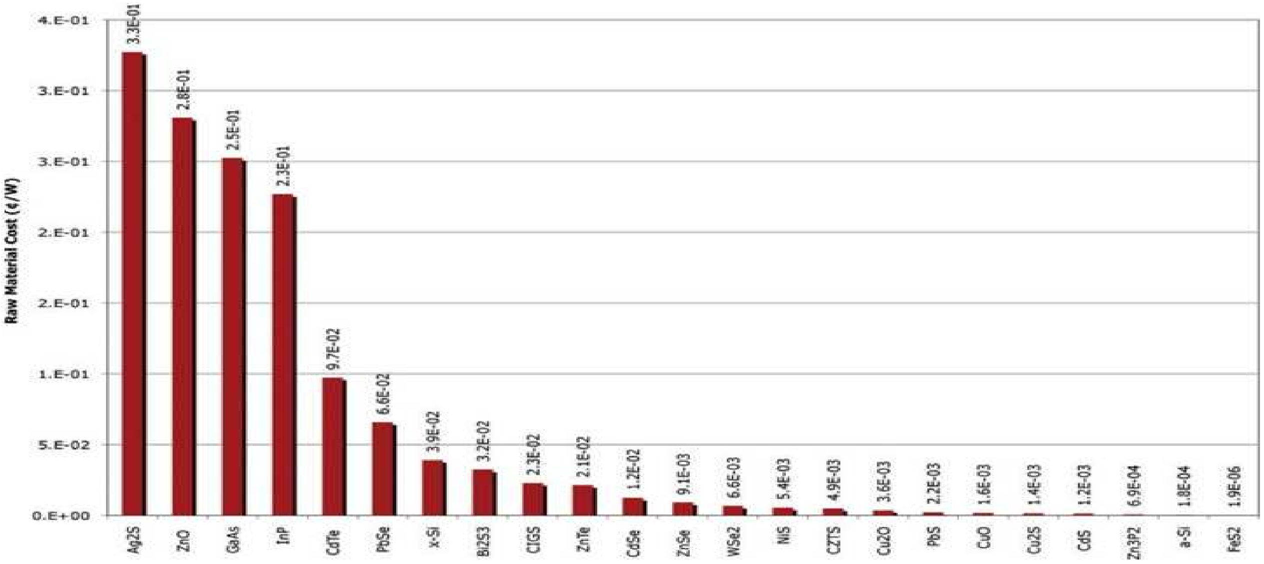


Figure: Existing PV technologies vs Raw material cost

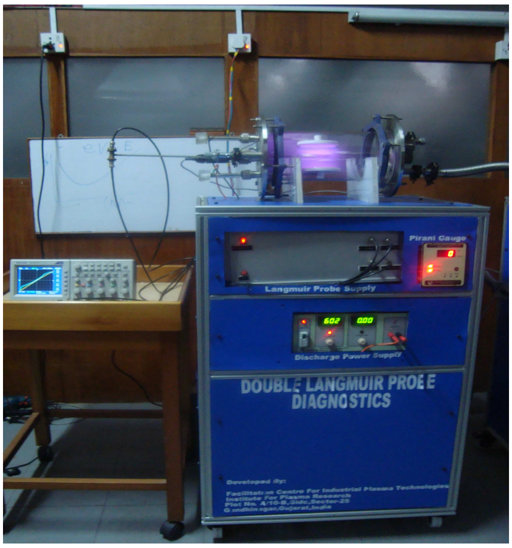
Reference: Environ. Sci. Technol. ***2009,*** *43, 2072–2077.*

Other news

Installation of two experimental systems at Kathmandu University, Nepal

Two experimental systems, Paschen Curve system and Double Langmuir Probe system were developed and successfully installed & commissioned at Kathmandu University, Nepal in January 2013 by FCIPT. The images below are the actual systems installed at Kathmandu University

Photograph of Paschen Curve system



Photograph of Double Langmuir Probe Diagnostics system

Installation of Plasma Pyrolysis system at Government Medical College, Srinagar for demonstration of Biomedical waste disposal

A prototype plasma pyrolysis system for demonstration of Biomedical waste disposal with disposal rate of 15 kg/hr was installed and commissioned at Government Medical College, Srinagar in the month of May 2013. This system was funded by Department if Science and Technology (DST), New Delhi and the fabrication was done by M/s. Bhagwati Pyrotech Pvt Ltd. along with FCIPT, IPR. The photograph of the actual system installed is shown below.

Photograph of Plasma Pyrolysis system installed in Srinagar

MoU with CSIR-CSMCRI, Bhavnagar

A project for developing a prototype plasma pyrolysis/gasification system for disposal of solvent mixture and solid waste was sanctioned by CSIR-CSMCRI, Bhavnagar, Gujarat.

Experimental systems developed by FCIPT and installed & commissioned at Kathmandu University, Nepal

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