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Development of Experimental Setup for Plasma Facilities At SVITS

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Abstract- Plasma is a highly conductive partially ionized gas that contains positive & negative ion Species and neutrals. It is the forth state of matter. Plasma processing is used in many areas like Subsurface Modification, Surface Activation, Plasma Enhanced Physical Vapour Deposition, Thin Film coating, Nitriding, Nanoparticles composition, microelectronic fabrication, and textile Plasma treatment. A system has been designed, fabricated and installed in SVITS, Indore for producing different Plasma through Plasma Enhanced Chemical Vapor Deposition (PE-CVD) technique and dc glow discharge for different plasma applications. The system contains a vacuum chamber, a turbo-molecular pump, two electrodes, vacuum gauges, mass analyzer, mass flow controllers and a RF & DC power supply for producing the plasma using hydrogen argon, Nitrogen, Oxygen gases. Different application can also be performed through some modification in the system like Nanoparticles composition, microelectronic fabrication. The system is integrated at SVITS and a vacuum of the order of $3*10^{-6\ mbar}$ is achieved and glow discharge plasma has been created to test all the sub-systems. The system design with all sub-system specifications and Coating by PECVD, and Plasma Textile Treatment will be broadly presented in this paper

Keywords: - Plasma, PE-CVD, DC-RF Glow Discharge, Textile plasma,

1. Plasma

Plasma is one of the four fundamental states of matter (the others being solid, liquid, and gas). When air or gas is ionized, plasma forms with similar conductive properties to that of metals. Plasma is the most abundant form of matter in the Universe, because most stars are in plasma state. Plasma comprises the major state of matter of the Sun. Heating a gas may ionize its molecules or atoms (reducing or increasing the number of electrons in them), thus turning it into plasma, which contains charged particles: positive ions and negative electrons or ions. Ionization can be induced by other means, such as strong electromagnetic field applied with a laser or microwave generator, and is accompanied by the dissociation of molecular bonds, if present. Plasma can also be created by the application of an electric field on a gas. The presence of a non-negligible number of charge carriers makes the 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, some common plasma is found in stars and neon signs. In the universe, plasma is the most common state of matter for ordinary matter, most of which is in the rarefied intergalactic plasma and in stars. Much of the understanding of plasmas has come from the pursuit of controlled nuclear fusion and fusion power, for which plasma physics provides the scientific base.

2. Plasma Enhanced Chemical Vapor Deposition (RF-PECVD)

Fractionally ionized plasmas have great interests in thin film coating and material processing. In such plasmas, the energy exchange between the electron and neutral gas is very inefficient. So, the bulk plasma is more positive than any object (substrate) present and in contact with plasma. The voltage between the plasma and substrate drops at the sheath region and the ions in the sheath feel an electrostatic force and are accelerated towards the substrate. Thus, the substrate exposed to plasma receives energetic ion bombardment. CVD performed in a plasma environment leads to increase in the nucleation, growth kinetics, and hence density of the deposited film and also plays an important role in the process of sputtering of the impurities called Plasma Enhanced Chemical Vapor Deposition (PECVD).

This process avoids typical drawbacks like requirement of high temperature, related deformations, poor adhesion etc. The plasma environment in PECVD performs mainly two basic functions; reactive chemical species are formed by cracking of relatively stable molecules via electron impact collisions and supplies energetic radiation such as positive ions, met stable species, electrons and photons. Increased ion Bombardment tends to make the film denser and cause film stress to become more compressive. PECVD performed with RF plasma is called RF-PECVD.

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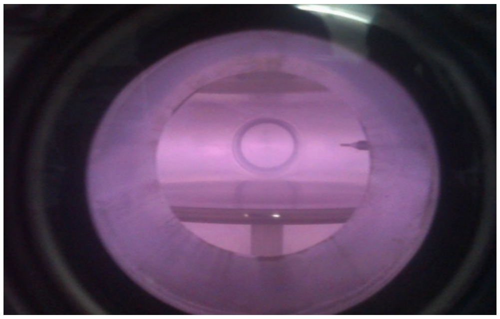

Fig: 1 Argon RF-PECVD for coating created at SVITS

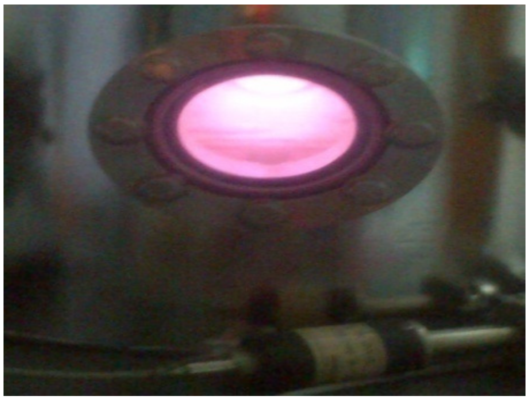

Fig: 2 Oxygen RF-PECVD for Textile Treatment created at SVITS

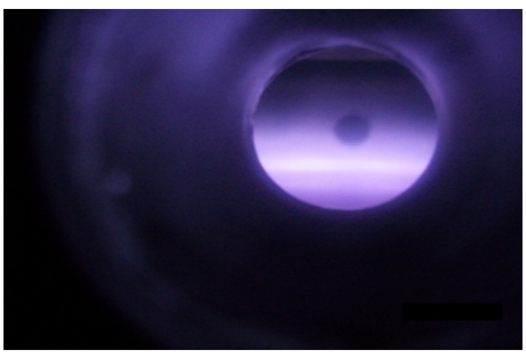

Fig: 3 DC Glow Discharge Plasma for Nitriding created at SVITS

3. Textile Plasma Treatment:

Due to increasing requirements on the finishing of textile fabrics, increasing use of technical textiles with synthetic fibers, as well as the market and society demand for textiles that have been processed by environmentally sound methods, new innovative production techniques are demanded. In this field, the plasma technology shows distinct advantages because it is environmentally friendly, and even surface properties of inert materials can be changed easily.

Plasma technology can be used not only for textile finishing, but also for the optimization of textile machines, for example, with hard coatings.

It has been known for at least 60 years that plasma could affect desirable changes in the surface properties of materials. Plasma treatments have been used to induce both surface modifications and bulk property enhancements of textile materials, resulting in improvements to textile products ranging from conventional fabrics to advanced composites. These treatments have been shown to enhance dyeing rates of polymers, to improve colorfastness and wash resistance of fabrics, to increase adhesion of coatings, and to modify the wet-ability of fibers and fabrics. Research has shown that improvements in toughness, tenacity, and shrink resistance can be achieved by subjecting various thermoplastic fibers to a plasma atmosphere. Recently, plasma treatments have produced increased moisture absorption in fibers, altered degradation rates of biomedical materials (such as sutures), and deposition of low friction coatings.

4. Systematic Diagram: For Plasma Enhanced Chemical Vapor Deposition (RF-PECVD) & Textile Plasma Treatment

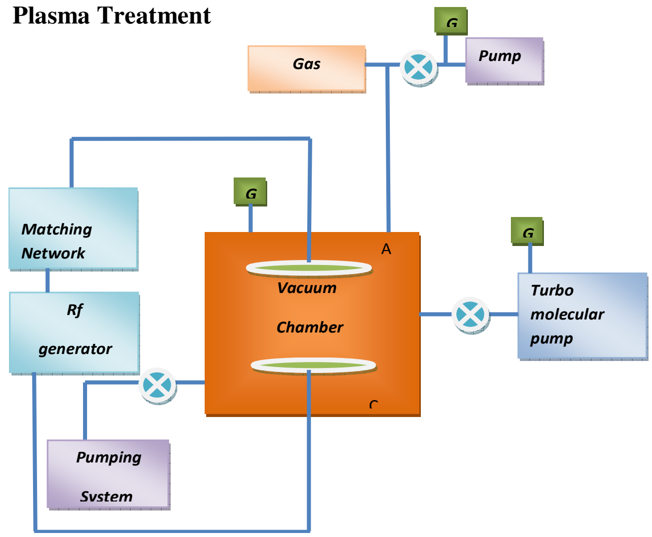

Fig: 4 Systematic Diagrams

5. Experimental Set-up:

Figure: 5 – Installation of system

A system has been designed, fabricated and installed in SVITS, Indore for producing Plasmas through Plasma Enhanced Chemical Vapor Deposition (PE-CVD) technique and dc glow discharge for different plasma applications.

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The Plasma system consist of

(1) Plasma chamber consist of a cylindrical stainless steel vacuumed chamber with Capacity 30Lit, Height (30cm) and diameter of (36cm) with cathode assembly Electrode (two circular electrodes, one of which has movable shift denoted "Anode" and fixed electrode denoted" cathode

2) RF power supply (13.56MHz, 600 Watt): For the RF electric discharge of gas

(3) Turbo Molecular Pump &Rotary Pump: inbound vacuum pumps system: For Rough Vacuum and to achieve vacuum of the order of $3*10^{-6}$ mbar

(4) Residual Gas Analyzer): For the detections of the species inside the Chamber with a range of 300 amu

(5) Ion gauge heads and readers: For the measurement of vacuum inside the chamber From atmosphere pressure to $3*10^{-9}$ mbar

(6) High Voltage DC- power supply (2 KV, 1 amp): For the DC electric discharge of Gas

(7) Mass flow controller: To control the flow of gas with preciseness

(8) Digital pirani gauge head and redder: For the measurement of vacuum inside the Chamber up to $3*10^{-3}{}_{mbar}$

(9) Langmuir probes (wire of tungsten, it surface covered by ceramic and inserted From the side of chamber with RF filter): For the basic Characterization of plasma

(10) Argon, H_2 & O_2 gas for test all the sub-systems

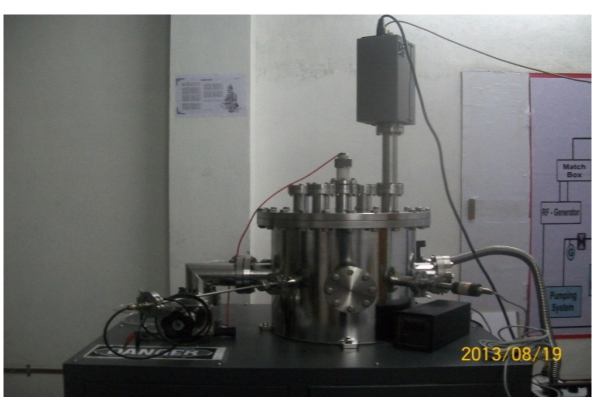
6. Details Specification of Equipments:

6.1. Vacuum Chamber

Vacuum chamber material: SS 304 Height of Vacuum chamber = 300mm

Diameter of vacuum chamber =360mm, Volume of vacuum chamber = 33 lit.

Distance B/W Electrode = 80mm, Diameter of electrode = 201mm.All port extensions are 75 mm minimum. Ports on the top and bottom flange are 35 CF std. Ports on the body is 63 CF std. All weld joints are being Ar tig welding. System leak rate is <10^-7 mbar ltr/sec with He leak detector. Support structure is being Al Sq. Bar as required to carry the dead load of the system. All 35 CF & 63 CF flanges for each port is included

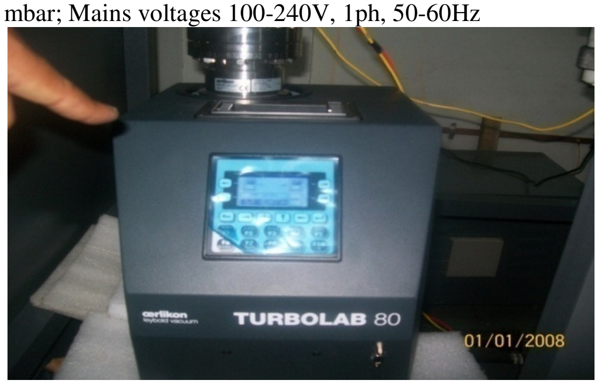


6.2. RF Power Supply

Frequency-13.56 MHz, Power Output-600 Watts, Input Power-95-125, VAC or 190-250 VAC, 47-63 Hz, Output Connector-Type "N" Harmonics; -50 dBc,Pulsing;10 KHz, 50 Micro Sec. / Min. Pulse, Cooling; Forced Air,110 C.F.M.(52 L/sec.)

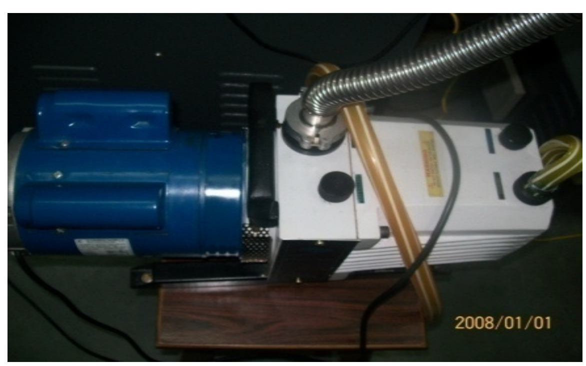
6.3. Turbo Molecular Pump

Pumping speed for N2 60 l/s ;Attainable ultimate pressure range 10-7 mbar ;* Run-up time for the turbo molecular pump 1.5 minutes; Pumping speed of the diaphragm pump 0.7 m³/h ;Ultimate pressure of the diaphragm pump 3 mbar; Mains voltages 100-240V, 1ph, 50-60Hz



Rotary Vacuum Pump:

Free Air Displacement 250 Lts/Min 8.85 CFM 15 M^2/H 0.50 HP ;Motor 1440RMP ; Vacuum When measured on Mc leod Guage 1 X 10^{-3} Ultimate m bar 5 X 10^{-2}Whit GB m bar; Oil Capacity 1.1Lts; Suction port 25KF



6.4. RGA

High precision Residual gas / mass analyzer-yes, Range:1 – 300 amu, Power requirement:+/- 24 VDC / 240 V AC, PC Compatible software for readout Filaments: Th-Ir,

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Filter type: Quadruple, Detector Type: Faraday Cup, Operating Pressure:5 X 10^{-4} mbar/ torr or better~10^{-4} torr,

Mass resolution: better than 0.5 amu

6.5. ION Gauge
Cold cathode ion gauge: Cold cathode sensor, Vacuum: 2 X10^{-2} Torr – 1 X 10^{-8} mbar or better 1000 – 5X10^{-9} : mbar, Control Unit with digital display Analog output: Linear, Accuracy (N2): +/- 30% , Repeatability: +/- 5 %, Interface: RS 232, Operating temperature: 0 – 40 °C, Input Power: 230V +/- 10 V AC, Or any standard low voltage power supply: 90 – 250 V AC

6.6. High Voltage DC Power Supply
Power O/P 2KV- 1Amp.±10% ,Protection with bleeder resistor ,Over Current trip Protection for O/P, Ripple factor :2-3 % ,0V start required aftere very shutdown/switch off ,Current & Voltage read out facility/P power: Floating, properly insulated with terminal block ,Appropriate rating plug point for I/P(~15A) ,Power indicator with Off/On switch on module

6.7. Mass flow controller:

Digital mass Flow Controller;Gas Type: WF6 & Hydrogen Digital Interface: RS 485 ,Seals: Kalrez , Flow rate: 0 – 10 sccm for WF6, Material of construction: SS, Pre Calibration Operation Software: Available, Power Supply with Display 230 +/- 10 V AC or +/- 15 VDC

6.8. Digital Pirani Gauge:

Measurement range 0.001 to 1000 mbar "0" adjustment on the signal conditioner PCB;1/8 DIN console; Brass body measuring cell with metal-sealed feed through; With universal power supply – input voltage from 90 ~ 264VAC, frequency 47 ~ 440Hz; Integrated set point adjustment and relay output; Dual Set Point Controller With 2 Relays

7. Conclusion

1. A system is designed fabricated and installed at Department of Physics, Shri Vaishnav Institute of Technology and Science, Indore for carrying out experiments for the Subsurface Modification, Surface Activation, Plasma Enhanced Chemical Vapour Deposition, Plasma Enhanced Physical Vapour Deposition, Thin Film coating, Nitriding, Nanoparticles composition, microelectronic fabrication, and textile Plasma treatment with slightly modification.

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2. The system is fully operational and preliminary DC Glow Discharge & RF plasmas with Argon, Hydrogen and Oxygen gas has been successfully obtained in the system. Characterisation of these plasmas is in progress

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