Direct Current Electrical Properties of Plasma Treated Jute

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Abstract— **Plasma is an ionized gas and low temperature plasma (LTP) treatment is an environment friendly surface modification technique. Jute fibers, a cellulosic and environmentally friendly fibers are treated with low temperature Argon plasma for 5, 10, and 15 minutes exposure times and at various discharge power levels of 50, 75 and 100 W. The current density-voltage (J-V) characteristics of tablet formed jute fibres were studied at room temperature in the voltage range of 5-100 V. It was seen that the J-V plots follow a power law of the form J α Vn, where n is a power index. It was also observed that with the increase of exposure times and discharge powers, the current flow through the tablet decreases. Moreover, resistivity increases with the exposure time as well as discharge power.**

Index Terms— **Jute, Plasma, Exposure time, discharge power and Direct current**

I. INTRODUCTION

Conductivity is the most important parameter to understand electrical properties of any material. The electrical properties of polymers cover an extremely diverse range of molecular phenomena. Obviously insulating polymers have low level conduction can take variety of forms. Conduction may be by impurities that provide a small concentration of charge carriers in the form of electrons or ions (1-4). There are three types of the electrical conduction process from one electrode to another electrode due to the applied external electric field in the polymeric materials.

Schottky type conduction process: Basically Schottky type conduction process is electrode-limited and show highly dependence on the potential barrier at the metal-polymer interface. When the electric field is applied to the sandwich (metal-polymer-metal) form sample an electron may escape from the metal surface, polymer becomes polarized and exerts an attractive force on the electron.

Poole-Frenkel (PF) effect: In Poole-Frenkel effect emission of electrons occurs from trapping centres in polymeric materials by the joint effect of temperature and electric field. This process is the bulk analog of the Schottky effect at an interfacial barrier.

Space charge limited conduction process: Space charge is a concept in which excess electric charge is treated as being a continuum of charge distributed over a region of space rather than distinct point-like charges. Space charge usually only occurs in dielectric media because in a conductive medium the charge tends to be rapidly neutralized or screened.

In the past few years interest has increased in the use of Low Temperature Plasma (LTP) technique which is a promising approach for surface modifications of human made as well as natural fibres. Plasmas are ionized gases. An ionized gas consists mainly of positively charged molecules or atoms and negatively charged electrons. A gaseous complex that may be composed of electrons, ions of both polarity, gas atoms and molecules in the ground or any higher state of any form of excitation as well as of light quanta is referred to as plasma (5-6). The ionization degree can vary from 100 % (fully ionized gases) to very low values (partially ionized gases). The presence of a non-negligible number of charge carriers makes the plasma electrically conductive so that it responds strongly to electromagnetic fields. Plasma therefore has properties quite unlike those of solids, liquids or gases and is considered to be a distinct state of matter. As a type of environmentally friendly physical surface modification technology, LTP treatment is one of the methods used to modify surfaces in a dry process. Advantages of this technique, compared to a conventional wet process, are: (i) because of the very thin treatment layer, only the surface is modified without interfering the bulk properties and (ii) the process is simpler, fewer steps and less time are required, involving no chemicals.

Jute is a golden fibre as well as a major cash crop of Bangladesh. A great advantage of jute fibre is that, it is environment friendly natural fibre. At present jute is facing tough competition from the convenient and competitive synthetics counter parts in world market. The only way to save jute is through its uses in various diversified ways (7-9). Hence for better performability and to explore diverse use of jute study of DC electrical properties of jute fibre is very important.

II. MATERIALS AND METHODS

A. *Low Temperature Plasma Treatment*

Jute fibres (Corchorus Olitorius or Tossa jute) were collected from the local market in Bangladesh. The fibres were introduced into a bell jar type capacitively coupled glow discharge reactor as shown in figure 1.

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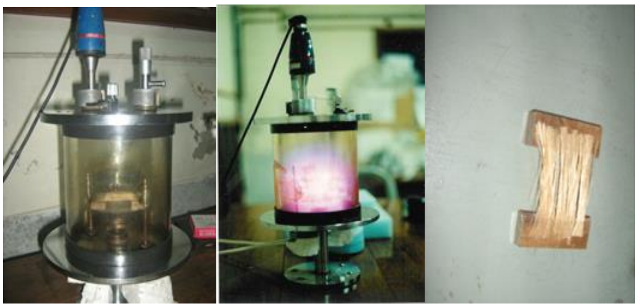

Fig. 1 Schematic diagram of jute fibre and position of it in the glow discharge reactor

To sustain a glow discharge i.e. for getting proper and uniform plasma, the conductive electrodes are separated 0.035 m apart from each other. In order to exposed all through uniform LTP treatment on the samples surface, the fibres (length of each fibre: 0.08 m) were inserted in between the two metallic electrodes by a carrier. After placing jute fibres between pair of electrodes, the glow discharge chamber was evacuated by a rotary pump at a pressure of 1.33 Pa. Ar was considered as plasma gas for treating the jute fibre. In all treatments, both process gases were introduced separately into the reaction chamber by a flowmeter at a flow rate of 0.2 L/min. which is maintained by a needle valve. The discharge powers were adjusted at 50, 75 and 100 W at a line frequency of 50 Hz with the duration of exposure times of LTP treatment of fibres were 5, 10, 15 and 20 min. Figure 2 shows a flow chart of a plasma treatment system which was used in this experiment.

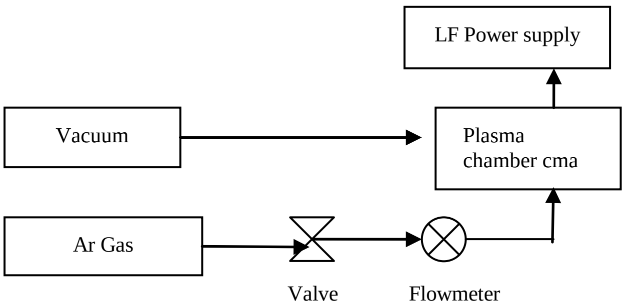

Fig. 2 Flow chart of the plasma treatment set-up

After plasma treatment has been finished, and the vacuum chamber was vented, jute samples were then removed and handled carefully in order to avoid possible surface contamination to the fibres. Later, the plasma treated fibres were immediately placed into a desiccator with the silica gel.

B. Sample Preparation

In preparing the samples, both raw and plasma treated jute fibres were cut into small pieces of sizes of about 1.0-2.0 mm. By mortar and pestle these small pieces of jute were ground, crushed and mixed in order to convert into powder form. Finally, the jute powders were seived by a very fine and thin net to make the powder finer. The powdered form jute of about 200 mg. was then put in a specially prepared high-pressure die. In order to make the tablets from jute powder, a high pressure (14000 psi) was applied by a hydraulic press (Model: X30659, 0-16000 psi, Mold Pressure, P.S.I: 1" and 5/4" Mold, Will Corporation, NY, USA). The diameter and the thickness of each equipped tablet was 13.5 and 1.5 mm respectively. In these way thirteen types tablets (one tablet was for raw jute and another twelve were for LTP treated jute) were prepared with treated jute samples of different discharge powers and exposure times. All the tablets were oven-dried at 100 °C for 20 minutes before characterization of the samples.

C. Ultraviolet visible spectroscopic analysis

The current density-voltage (J-V) characteristics of tablet formed jute fibres were studied at room temperature in the voltage range of 5-100 V. The current pass through the tablet was measured by a high impedance Keithley 614 electrometer (Keithley Instruments, Inc.,USA) and the DC voltage was applied by an Agilent 6545A stabilized DC power supply (Agilent Technologies Japan Ltd, Tokyo, Japan). The voltage was increased step by step. The samples were depolarized before each measurement run. The block diagram for DC measurements and DC measurement set up are shown in figure 3 and figure 4 respectively.

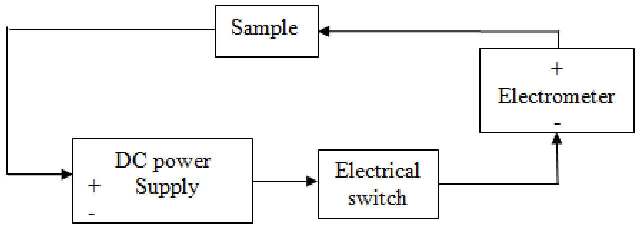

Fig. 3 A schematic block diagram for room temperature DC measurements

Fig. 4 Arrangement for DC measurement

D. Calculation of different DC electrical parameters

(i) DC resistance: DC resistance (R) was calculated using the relation

$$R = \frac{V}{I} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

where, V is the DC voltage (in V) and I (in A) is the current.

(ii) DC resistivity: DC resistivity (ρ) was calculated using the relation

$$R = \rho \frac{l}{A} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

where, R is the DC resistance (in Ω), ρ is the DC resistivity (in Ω-m), l (in m) is the thickness of the jute tablet and A (in m^2) is the cross-sectional area of the tablet, here,

$$A = \pi r^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where, r is the radius (in m) of the circular type jute tablet From equation (4.1) and (4.2) resistivity, ρ can be calculated as

$$\rho = \frac{V}{I} \times \frac{A}{l} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

III. RESULTS

Current density-voltage (J-V) graphs of tablet formed raw jute and LTP treated jute with Ar plasma at various discharge powers (50, 75 and 100 W) and exposure times (5, 10, 15 and 20 min.) are presented in figure 5.

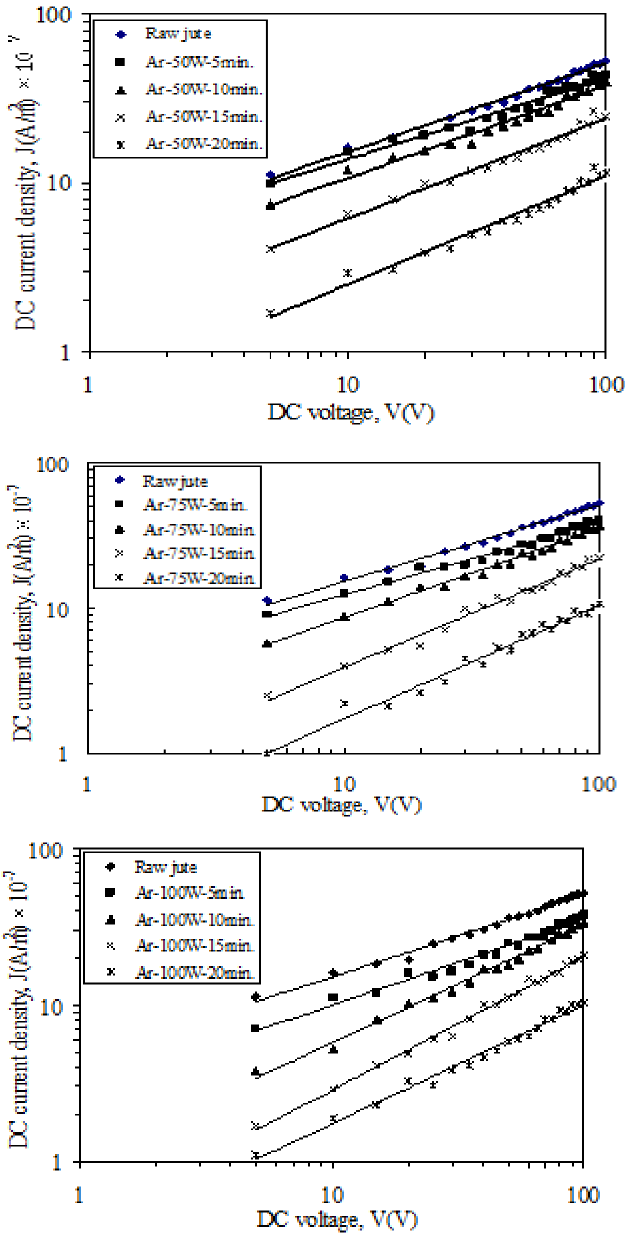

Fig. 5 J–V plots for raw jute and LTP treated jute for Ar plasma at various discharge powers and exposure times.

It is seen from the above figure that the J-V plots follow a power law of the form J α V^n, where n is a power index. It is also observed from the above figures that with the increase of exposure times and discharge powers, the current flow through the tablet decreases. The electrical resistivity versus discharge powers and the electrical resistivity versus exposure times of LTP treated jute by Ar plasma at various and are exposure times are presented in figures 6 and 7.

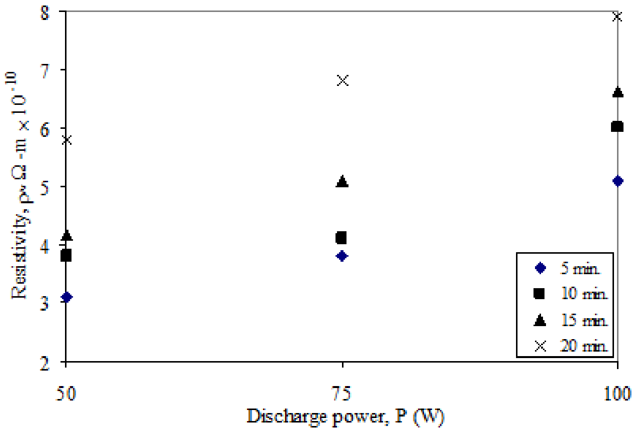

Fig. 6 Resistivity vs. discharge power for Ar plasma at various exposure times

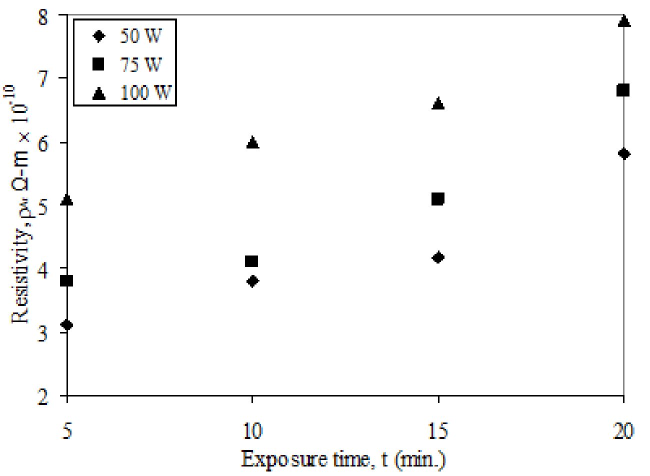

Fig. 7 Resistivity vs. exposure time for Ar plasma at various discharge powers

It is observed that resistivity increases with the exposure time as well as discharge power. This is in good agreement with the results found by the UV-Vis. analysis where the E_g increases due to the LTP treatment as discussed in the previous section.

IV. DISCUSSION

It is seen from the current density-voltage (J-V) graphs, which were obtained from DC electrical analyses that with the increase of exposure times and discharge powers, the current flow through the jute decreases and these graphs follow a power law. It is also seen from DC electrical analyses that the ρ increases with the increase of discharge power and treatment time. Chemically jute possesses high content of semicrystalline and amorphous materials, such as cellulose, hemicellulose and lignin. Moreover, due to the presence of the hydroxyl and carboxyl groups on the fibre surface and in the amorphous region, the jute fibres can absorb moisture from the atmosphere under standard conditions of temperature and pressure (10-11). Therefore, the jute are hygroscopic as well as hydrophilic in nature. When jute is exposed to LTP condition, energetic charged particles inside the plasma are able to interact chemically with the surface to be treated. Such interactions can also affect the material properties and the moisture content of the treated jute decreases due to the surface modification of the jute fibres. In the LTP process, the water (H_2O) dissociates into H and OH species by energetic gaseous ion bombardment. The temperature sensitive jute were dried more effectively in plasma without damaging its constituents and also improved the crystallinity of jute (12). Therefore, ρ increases with an increase of exposure times as well as discharge powers.

ACKNOWLEDGEMENT

We would like to express our heartfelt thanks to the authority of Bangladesh Atomic Energy Centre, Dhaka, Bangladesh and the Bangladesh University of Engineering and Technology (BUET), Dhaka, Bangladesh for the conduction of our experimental work.

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