An Innovation in Corona Charging of Electrets

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Abstract— **An innovation in corona charging of electrets of polymer films has been adopted in locally designed and fabricated corona charging set up by replacing the regular high voltage DC power supply with a light, portable handy 3V-6V DC to DC 400kV boost step-up power module high voltage generator. Polymer film electrets of polyethylene transparency film have been corona charged using this innovative setup. The measurements were done and the results have been analyzed in the light of cited literature to show the effectiveness and advantage of the innovation**.

Keywords— **charge injection, corona discharge, high voltage, ions, polymers, surface potential decay**

Fig.1 DC to DC High voltage module

.1. Introduction

Electrets have been prepared using different methods for different electret types. [1] Corona charging of electrets can be done by depositing charge on the surface of electret material for example polymer film. Corona discharge processes provide charges in the form of ions and electrons for deposition on the surface of the material. Corona discharge is the electrical discharges taking place at or near atmospheric pressure. The corona is usually generated by a strong electric field associated with small diameter wires, needles, or sharp edges blades on an electrode and emphasizes one of the two aspects of the discharge, the ions produced or energetic electrons producing the plasma.

In the needle plate electrode configuration, the positive corona discharge starts with burst pulse corona and proceed to the streamer corona, glow corona and spark discharge while for negative corona in the same geometry the initial form is Trichel pulse corona followed by pulseless corona and spark discharge as the applied voltage increases.[2]

Making procedures in a conventional discharge device consists of an intense electric field in a neighborhood of biased corona point, usually tungsten wire, and grounded plate electrode to produce an electret of polymer film sample placed on the plate electrode. The electret is formed due to deposition and or penetration of the charge carriers produced in ionization of air at atmospheric pressure.

We have for the first time innovated the traditional corona charging set up by using a low cost (less than the US $ 10) pulse width modulated DC- 3V-6V to DC 400 kV boost step-up power module high voltage generator (Kits Guru-KG493 supplied by Amazon.in, Figure 1) in place of traditional high voltage power supplies which are quite expensive and cumbersome to use. This module uses the principle of the Tesla coil and is made of high voltage pulse output current. The device is a small production with a high-pressure science inverter transformer/booster based on

technical review [3] and can be used as an ion generator high voltage source.

We have used our innovated easy handy portable set up to make corona charged electrets of commercially available transparencies films of polyethylene (PE) polymer. Our choice of material has been motivated to explore the possibility of using these electrets as a portable dosimeter being placed on various parts of the human body to monitor radiation exposure during radiotherapy treatment.

2. Experimental Setup

A. Charging Setup)

The corona discharge was generated using the locally designed and fabricated setup shown schematically in Figure 2 as the charging cycle. This setup uses a pulse width modulated DC 3- 6V to DC 400kV boost step-up transformer module (KG493) shown in Figure 1 as a high voltage source. This is powered by connecting the input terminals to a battery pack of 4x1.5 V= 6V DC 4 A Duracells. The pulsed high voltage output is connected respectively to charging corona electrodes Anode and Cathode. The anode is a thin naked tungsten wire electrode of 350 mm length and 0.17 mm diameter. It is passed through a 2 ml glass pipette for required safety in the use of high voltages. A circular brass disc of 50 mm diameter and thickness 04 mm forms the cathode which is earthed and

is connected to the cathode terminal of the output. Corona point electrode tungsten wire in the glass tube is held above the brass plate electrode by clamping it to stand with provision to change the height above the plate.

As a safety measure, the setup is provided with a switching circuit consisting of a momentary push to on switch to check the spark and a latching switch for continuous switching during charging duration. We have also made the provision
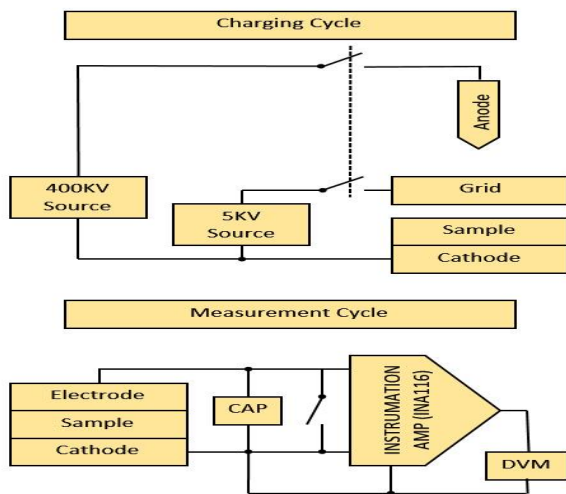
Fig. 2 Schematic diagram of Charging and Measuring setup

of a grid circuit using a similar high voltage module of lesser specifications and tested it for the possible use of a grid between point and plane electrode. However, for the present investigations of corona charging, we have used a dual-type electrode or a diode configuration. In this setup, the corona discharge current can be measured using an appropriate ammeter in series with the anode circuit.

B Measuring Setup

The measuring setup is a FET I/P High Impedance Preamplifier designed and fabricated locally using an ultra-low input current (3fA), unit gain (G=1), and an instrumentation amplifier (INA116 from TI/BB). The circuit is biased with DC batteries of 9V. The schematic diagram of the measuring setup is shown as a measuring cycle in Figure 2. The standard capacitor of 1 µF used in the setup is equipped with a push to on switch across it to reset before every measurement. The surface charge on the surface of the sample electret is measured as surface potential in volts by transferring the charge to the standard capacitor of 1 µF and measuring the potential developed in volts. The surface potential can be converted to charge in Coulomb according to relation Q=CV. The probe used in charge transfer is a solid brass disc of 28 mm diameter with a knob.

3. Experimental Procedure

We have used the following parameters and procedures for our experimental studies.

- DC high voltage was kept constant keeping input voltage fixed at 6 V using 4 cells of 1.5 V.

- Corona point electrode was kept positive and the plate electrode was earthed throughout our measurements.

- The polymer sample surface in contact with the plate electrode was not metal coated.

- The sample surface facing the point electrode has been termed as Top surface and the surface in contact with the plate electrode is termed as Bottom surface.

- The surface potential measurements have been done on both the surfaces of corona charged electrets.

- Top surface measurement has been done immediately after the expiry of the charging time while the bottom surface measurement could be done after 5 seconds of the top surface measurement due to manually reversing the surface using plastic forceps.

- The top surface has been marked to distinguish with the bottom surface.

- The measured values have been manually recorded.

- Circular disc samples of diameter 30 mm have been cut out of polymer polyethylene (PE) transparencies sheets of 50µm thickness.

- Four series of 4 electrets each have been made by keeping the point to plate electrode distance fixed at 5mm, 10mm, 15mm, and 20mm varying the charging time as 5s, 10s, 15s, and 20s(seconds) for each series at a fixed distance.

- The surface potential measured immediately after charging on the Top and The Bottom surfaces are recorded as initial surface potential.

- The surface potential decay(SPD) is recorded by measuring the surface potential on both the surfaces respectively after the 30s, 60s, 90s, 120s, 150s, 180s, and 210s(seconds) of the initial measurement.

- The results of experimental studies have been analyzed in light of the possible available literature on the subject to understand the effectiveness of the innovation in corona charging of polymer electrets in the air under ambient conditions.

4. Results and Discussions

We have prepared four series of polyethylene (PE) polymer electrets using our experimental setup for corona charging by keeping point to plate electrode distance fixed at 5mm, 10mm, 15mm, and 20mm respectively for each series. We have varied corona charging time as 5 seconds (s), 10s, 15s, and 20s for four electrets in each series. We have made measurements on each electret for surface potential decay after every 30s up to 210s.

Experimental results obtained have been analyzed in terms of various parameters to understand the consistency of used innovation in corona charging of electrets and their properties.

The surface potential developed on both the top and bottom surfaces of the sample has been measured and the results are shown in Figure 3. Figure 3(a) shows the surface potential decay measurement as a function of the charging time of 5s. 10s, 15s, and 20s for the four series. The top surface facing the point electrode of each electret shows positive potential while the bottom surface in contact with the plate electrode as also
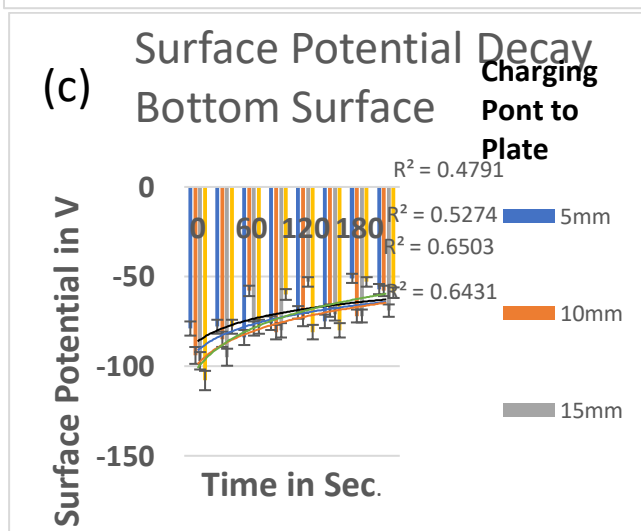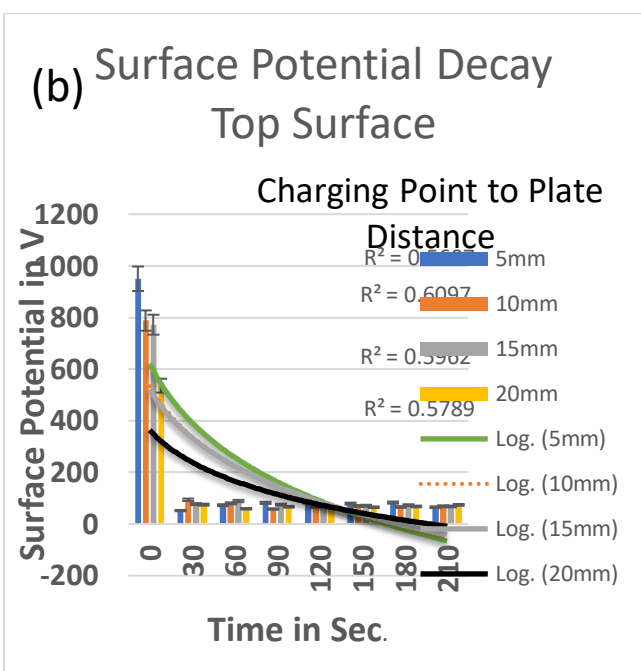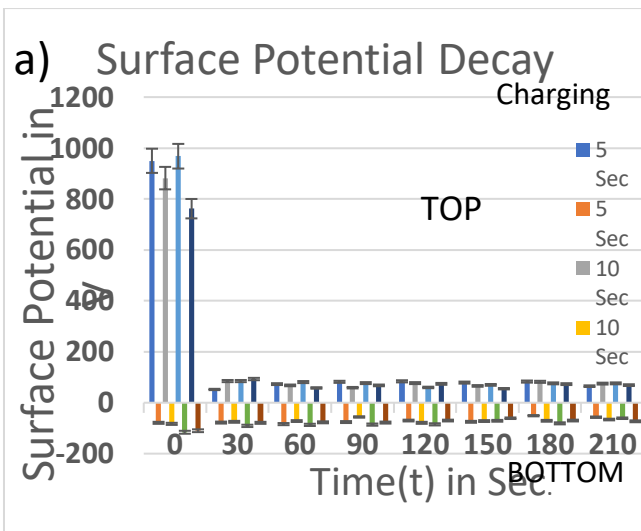
a) Surface Potential Decay

(b) Surface Potential Decay Top Surface

(c) Surface Potential Decay Bottom Surface

reported by Leandra P. Santos et al [4] and Chen's group [5,6,7]. Polymer surfaces under corona charging acquire high electrostatic potential due to the deposition of positive and negative ions moving through the atmosphere under the influence of the electric field.[8,9,10]. During corona charging, it is reported that polyethylene bottom surface negative charge is due to the injection of the electron from the cathode and holes from the anode according to Schottky Mechanism [7]. Contributions from the ions derived from a sample polymer as the charge carriers in contact and tribocharging have also been reported [11,12,13,14,15] Surface charging process may also take place within the space charge threshold established by Montanari et al [16,17].

In Figure 3(b) and 3(c), we found that the best-fit trendlines show the decreasing trend of the surface potential with decay time for different electrode distances. A strong dependence of the deposited charge on the surface potential decay evolution is indicated in a rapid decrease of charge on the sample surface To study this potential deposited effect on the sample surface we normalized the initial surface potential V_0 as shown in Figures 4(a) and 4(b) respectively for top and bottom surfaces. The nature of curves shows the existence of field-effect on the sample which may indicate that the phenomenon of electron trapping, electron acceleration depends on the field. An electron hopping from the level of the surface trap into the bulk is charge injection dependent on the field. This can further assist the
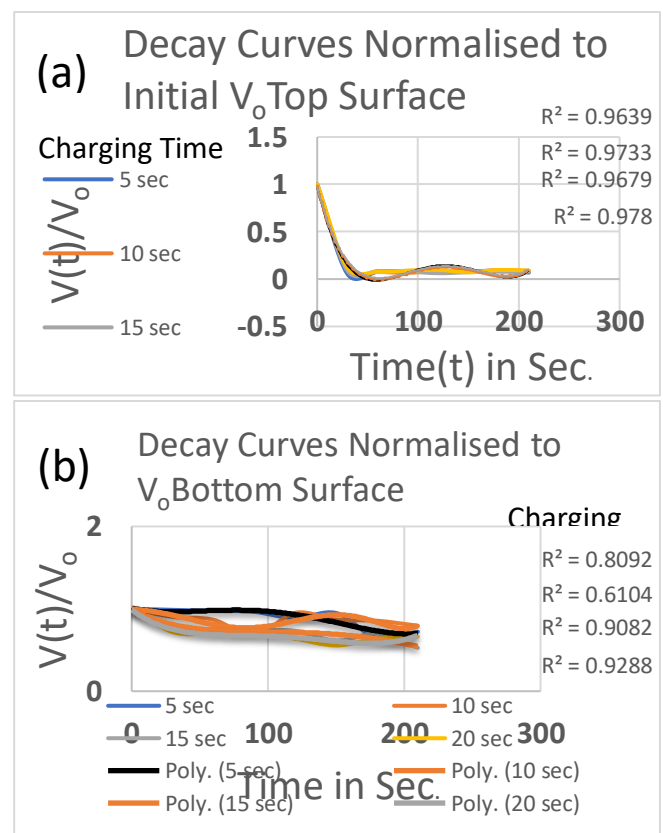

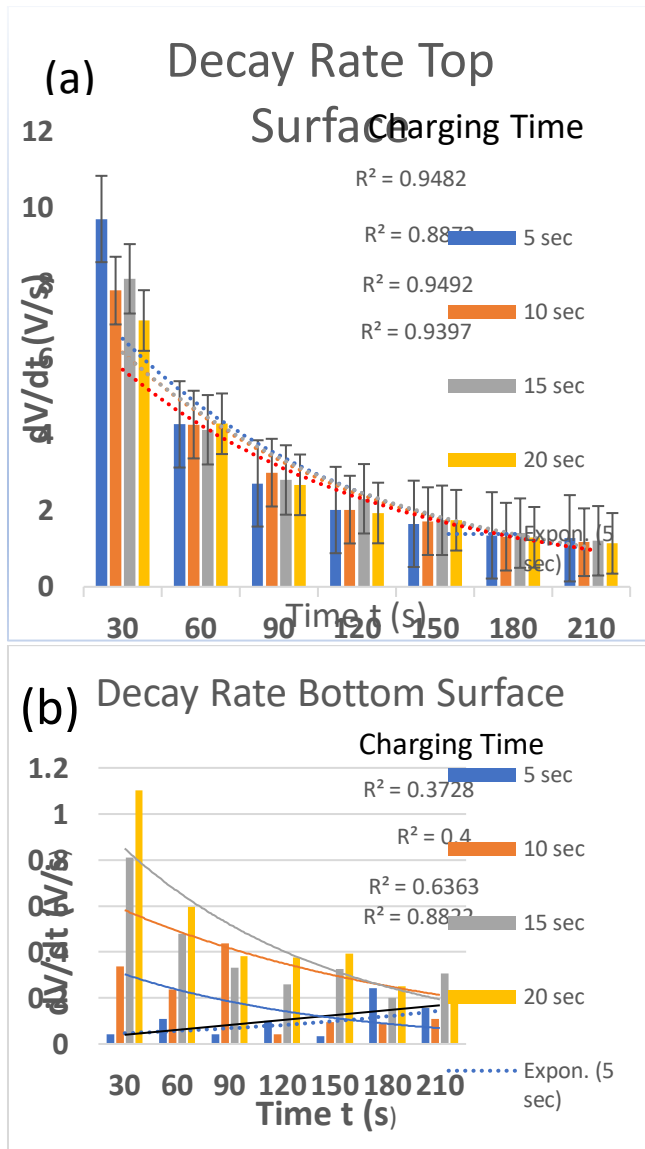(a) Decay Curves Normalised to Initial V_0 Top Surface

(b) Decay Curves Normalised to V_0 Bottom Surface

Fig. 3 Surface potential decay as a function of charging time for top and bottom surfaces (a), as a function of electrode distance top surface (b surface and bottom (c).

Fig. 4 Decay curves normalized to V_0 top surface (a) and bottom surface (b)

Fig. 5. Decay Rate top surface (a) and bottom surface (b)

Fig. 6 Log – Log Plot of Decay Rate.

electron to hop and then accelerate into the sample moving under their electric field towards the grounded plate electrode.[18] In our case point to plate configuration with the pointed tip of the tungsten wire may produce a high electric field and may inject a charge into the dielectric possibly also into the deep traps.[19,20,21,22].

Decay rate calculations from Figure 3(b) and 3(c) have been represented in Figure 5(a) and 5(b) respectively for top and bottom surfaces. The best fit trend is found to be exponentially showing a high initial growth rate followed by a slower value. The strong decrease initially suggests the deposition of injected charges under the field effect created by their charge. This leads to a crossover phenomenon since the injected charge is dependent on the quantity of the deposited charge. Local field dependence of the injected charges leads them to the sample bottom surface. Molinie [23,24,25.] has shown in his work that the material polarization mechanism gives an absorption current
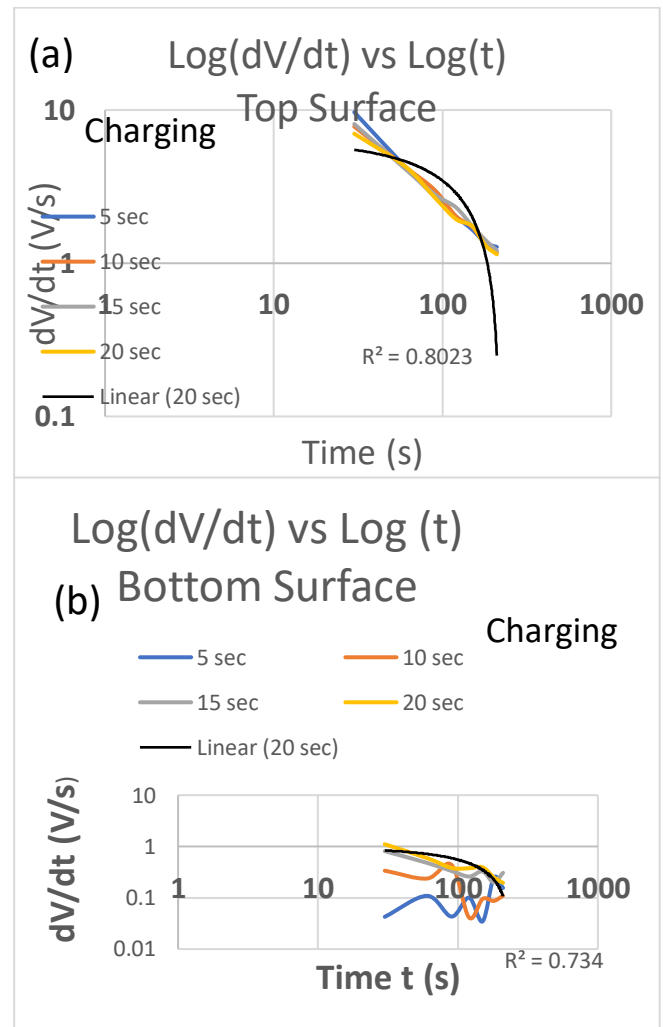
according to Curie-von Schweidl law which can be linked to surface potential decay rate dV/dt. Therefore, the decay rate dV/dt can be conveniently used to understand the conduction intervening nature at charge deposition.

We have displayed the data of Figures 5(a) and 5(b) on the Log-Log plot showing the variation of Log(dV/dt) with Log(t) in Figures 6(a) and 6(b). We note that the linear best fit on the curves is a curve having two straight-line slopes indicating two regimes of surface potential decay separated by a transit time to be determined by the intersection point of the two slopes[26,27]. Finally, we could measure the retained charge on the corona charged electret surfaces after a lapse of 136 days as due to COVID- 19, lockdown and other restrictions in India we could not monitor the retained charge on daily weekly or monthly basis. Never the less the Figure 7, showing the results of measurement, reveal the successful formation of electrets of polymer films using our innovative setup for corona charging of electrets.
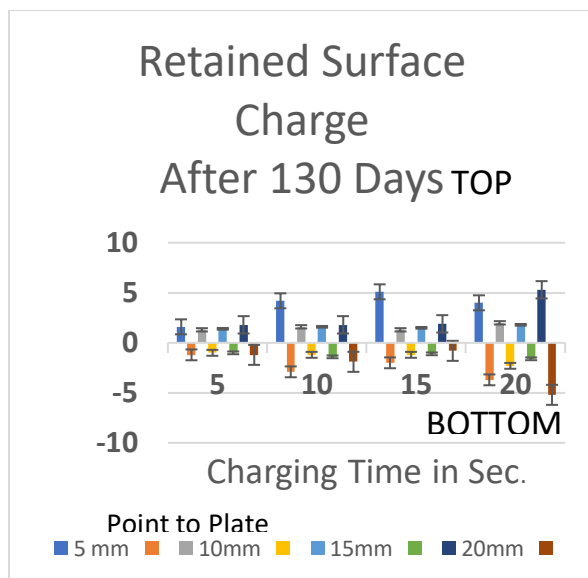
Fig. 7 Retained Surface charge on both the electret surfaces after 136 days.

Conclusions

We have successfully demonstrated the use of our handy innovation of using DC 3V – 6V to DC 400kV booster step-up power module high voltage generator in corona charging of polymer film electrets. Our results of measurements on the electret have been successfully analyzed and discussed in the light of the work cited in the literature showing the effectiveness and advantage of our innovation. We plan to optimize the setup and the method according to the need of the applications.

Acknowledgments

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