Recent Developments in Applied Electrostatics

Proceedings of the Fifth International Conference on Applied Electrostatics

November 2~5, 2004, Shanghai, China

Edited by

Sun Keping and Yu Gefei

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PREFACE

This proceedings contains papers presented at the 5th International Conference on Applied Electrostatics held in Shanghai, China on November 2~5,2004. The ICAES 2004 Conference is of wide interest, as is shown by the contributions received from 11 countries and districts throughout the world. About 90 researchers attend the conference and more than 100 papers were submitted for presentation in the proceedings.

The paper sessions covered following topics:

- fundamentals and physics
- applications (precipitation, pollution control, spray, separation, material, Ozone, etc.)
- hazards and problems
- biology technology
- electrets
- measuring technology
- electromagnetic compatibility and others

These papers demonstrated recent research level and developing trends of the entire electrostatic field.

The objective of the Conference is to provide an opportunity for researchers from all over the world to discuss various topics of electrostatic field at many levels, obtain more information, absorb rich scientific nutrition and pick up the advantages from varied researchers. New friends can be met and both the friendship and the cooperation can be enhanced during the Conference.

The Conference is sponsored by the Commission on Electrostatics of Chinese Physical Society, Shanghai Physical Society and Shanghai Maritime University. We wish to thank all the authors for their cooperation and effort. We also thank Mr. Christopher Greenwell, Publishing Editor, Control, Electronic and Optical Engineering, Elsevier for his guide and assistance.

Prof. Sun Keping
Dr. Yu Gefei
November 1, 2004
Shanghai, China

The 5th International Conference on Applied Electrostatics

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Paper Presented at the 5th International Conference on Applied Electrostatics (ICAES'2004), Shanghai, 2-5 November 2004
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Charge behavior analysis in thin solid film by using simultaneous TSDC and LIPP measurements

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Thermal Stimulated Discharge Currents (TSDC) analysis is very effective technique to understand the charge stability and space charge behavior in a charged thin film but the real position of those charges cannot be identified. For that, a novel charge analyzing system has been developed. During TSDC measurements, a Laser-Induced-Pressure Pulse (LIPP) method is applied to observe the charge in-depth profile of the corona charged film ni that new system. That system and new results obtained by that system are explained.

INTRODUCTIONS

Recently various kinds of excellent dielectric materials have been developed which are very useful for us. However, such excellent dielectric materials are good insulators which may cause many unexpected electrostatic accidents (named as electrostatic discharge: ESD and electrostatic over stress: EOS); such as firing, explosion, device failure, computer misoperation etc. In order to prevent such trouble, the charge analysis of the stored charge on/in the dielectric material. For the charge stability analysis, relaxation process of the stored charge [1,2] in the dielectric material must be studied. Observation of the Thermally Stimulated Discharge Currents (TSDCs)[3] is one of analyzing methods of those relaxation processes. The authors also started to analyze the charge by the TSDC at first for the fly ash [4], for PTFE and High density Polyethylene (HDPE) films [5]. The TSDCs are very sensitive to the charge stability and it is easily to identify the different charge states. However, TSDCs cannot give us the information about the charge position in the film.

Many researchers developed various space charge analyzing method. Thermal Pulse method [6] and that modified Laser Intensity Modulation Method (LIMM) [7] are charge analysis by using thermal conduction and expansion effects of the film. Pressure pulse traveling in the film can cause compression of the film and the displacement current can be detected [8]. Sessler groupe developed a very sensitive and high special resolution method by using a picosecond laser [9]. Other German group also developed the space charge detecting method by using high speed piezoelectric device [10].The author also developed a similar laser induced pressure pulse method [11]. Takada et al also developed a new system by using a piezoelectric device[12].

However, the reproducibility of TSDCs and LIPP methods is not so good and they must be observed at the same time for the same sample. For that purpose, we developed a novel device that can observe LIPP signal during TSDC analysis. That is, LIPP observation need only ten seconds or so and can be done during TSDC analysis. Therefore at some temperature during TSDC analysis, a weak DC current measurement is stopped about ten seconds and connected to LIPP measurement.

EXPERIMENTAL

TSDC and LIPP Observation

A newly developed TSDC and LIPP measuring cell is shown in Figs.1 and 2. Laser beam can enter the container from left side through a small window. The sample holder contains a charged sample film on

the detecting electrode (metal disk) on right side and that electrode is connected to the BNC connector with a straight wire. On that electrode, the charged surface of the sample film is pressed with a contacting grease. A back side of the film is metalized by sputtering of aluminum before corona-charging and connected with another ground electrode plate (aluminum). All materials are wounded by the electrical heater and heated with a computer control. From that BNC connector, TSDC signal is transferred to picoammeter (pA) and amplified signal is digitalized and stored in a personal computer as TSDC signals. At some temperatures, Signal cable is switched to another low noise amplifier. The LIPP signal is amplified and digitalized by the high speed digital oscilloscope connected with a personal computer.

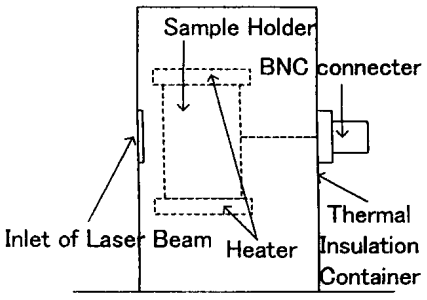

Fig.1 Simultaneous TSDC and LIPP for TSDC and OSC is for LIPP)

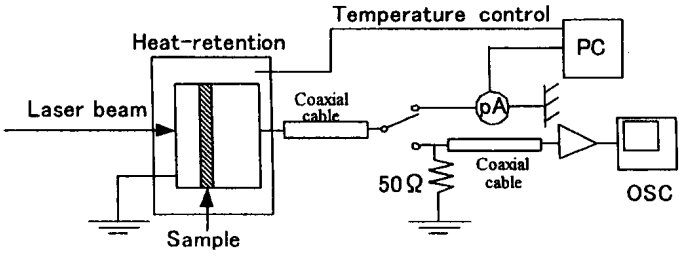

Fig.2 TSDC and LIPP measurement switching circuits. LIPP measurement and TSDC measurement (pA is measuring sample container)

Reproducibility of LIPP

To improve the data reliability, reproducibility of LIPP measurement was examined as shown in Fig.3 where the first shot means a laser ablation for the first time. 100th shot means laser irradiation is repeated 100 times on the target surface and 100th means the data is obtained by the last laser irradiation. From Fig.3, about 20 % signal decrease from the 1st to 100th data can be recognized. That degradation must be due to the increase of the surface roughness of laser irradiation target which coated with black special paint for better laser absorption. The impedance matching grease is not used because of heating. All peak values as shown X in Fig.3 are also shown in Fig.4 where the peak value gradually changes from -0.7 to 0.5 V during 100 laser irradiations. In Fig.4, 5 data are far from others indicating that the 5 % data are far from the real charge profile. In other word, if the data is far from the estimated value, LIPP measurement must be repeated.

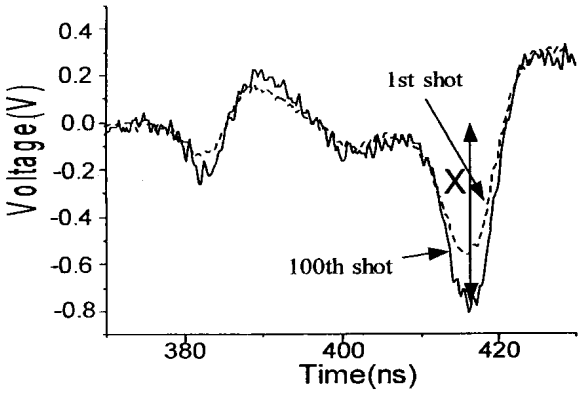

Fig. 3 LIPP signal change between the 1st laser shot and 100th laser shot.

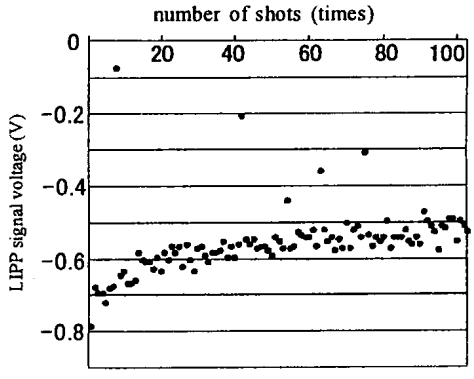

Fig. 4 LIPP signals for 100 laser shots.

Sample Preparation

For our experiment now, 50 and 100 μm PTFE Teflon sheet (Tomobo9001 supplied by Nichiasu) and a polyethylene terephthalate (PET) sheet are used as the sample. They are corona-charged where the grid voltage is -5 kV where the corona voltage at the needle electrodes is about -30 kV at room temperature or high temperature (50, 100 and 150 °C). In this paper, all data shown here are charged at 100 °C.

RESULTS AND DISCUSSIONS

100 μm PTFE Sheet Charged at 100 °C.

A typical example of TSDC spectra of 100 μm thick PTFE Teflon sheet corona-charged at 100 °C is shown in Fig.5. Two current peaks, b and g can be identified at about 250 °C and 110 °C. Since the charging temperature is 100 °C, there is no current peak below 100 °C. LIPP signal for that sample before TSDC measurement (see Fig.5) is shown in Fig. 6 which is quite different from the TSDC spectra of corona-charged at the room temperature [13] as shown in Fig.7. At 345ns(that time is from the laser beam

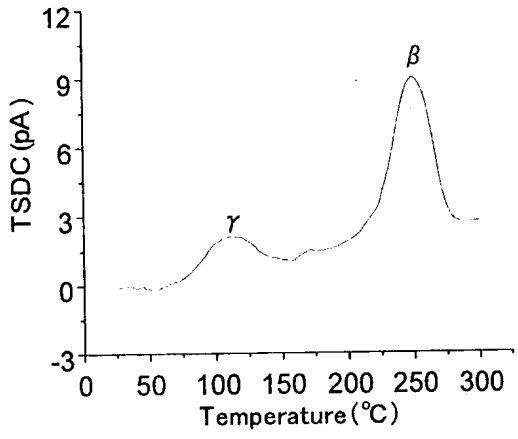

Fig. 5 TSDC spectra of corona-charged 100 μm thick PTFE thin film.

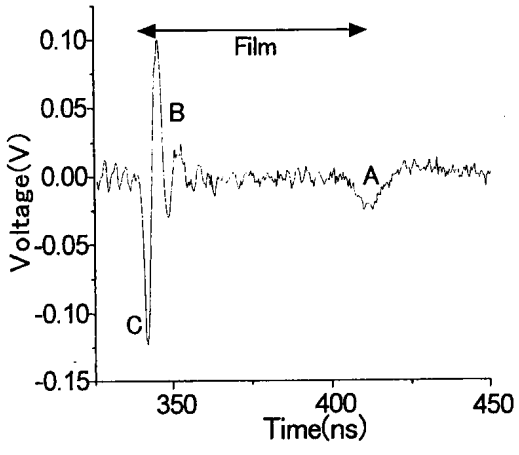

Fig.6 LIPP signal of 100 μm, thick PTFE film corona-charged at 100 °C (before TSDC).

irradiation and means the vertical position of the charge), a large negative charge (peak C) is observed which may be negative charge in the sputtered aluminum back electrode and next peak B shows positive charge maybe injected from the back electrode but that is not so sure. There are two other mechanisms can be estimated. One is that the negative charges near the interface move from the PTFE to the back metal electrode and positive charges remains near the interface. Another model is that the strong negative electric field caused by the corona-charging induced the moving of the negative charge from the corona-charged film (right side) to the left side and accumulate near the metal-PTFE boundary which is shown as peak C. That can well explained low negative charge peak A at the corona-charged surface. This model can well explain that a large surface charge peak (A) is observed in Fig.7 but becomes very small in Fig.8 because high temperature increases conductivity of PTFE. However, that explanation cannot explain why

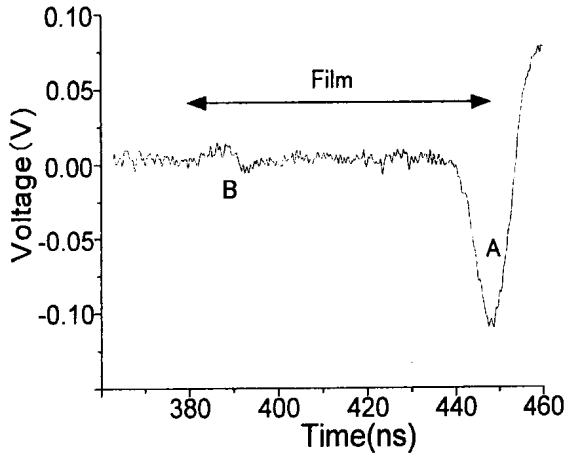

Fig.7 LIPP signal for 100 mm thick PTFE film charged at room temperature (before TSDC)[13]

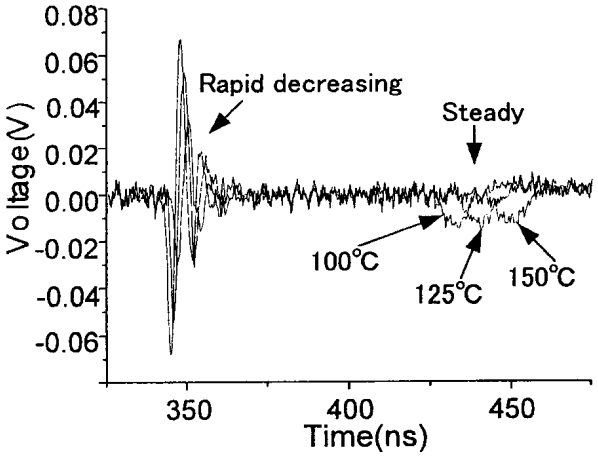

Fig.8 LIPP signals at 100, 125 and 150 °C during TSDC measurement. Sample is charged at 100 °C.

very sharp charge double layer as shown peaks B and C in Fig.6. More details will be discussed in near future. During TSDC measurement, LIPP measurements can be done at some temperature range which is shown in Fig. 8 and Fig. 9.

By increasing the TSDC temperature, Peaks B and C are still very sharp but decrease with TSDC temperature. On the other hand, peak A is pretty stable and does not decrease at about 200 °C. Therefore those results suggested that γ peak in TSDC is strongly related with the charge peaks B and .C. TSDC current peak α should be related with charge peak A because both peaks are stable at 200 °C and other apparent charge signal is not yet found. Off course, LIPP method is also not so highly sensitive for dipole

moment and there is a possibility that some new charges or dipoles are influenced TSDC α peak but not yet detected in LIPP method. That fact is an experimental result.

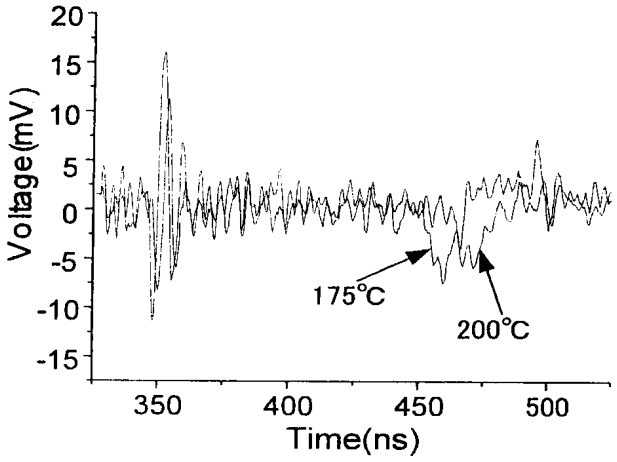

Fig. 9 LIPP signals at 175 and 200 °C of PTFE charged at 100 °C during TSDC measurement.

50 μm PTFE Sheet Charged at 100 °C.

Similar experiments are done for 50 μm thick PTFE film. In this case, the electric field in the film must be double because the grid potential is the equal to -5kV which is the same for 100 μm PTFE film. The typical LIPP data before TSDC analysis is shown in Fig.10 and the TSDC data is shown in Fig. 11. LIPP signals at different temperatures during TSDC measurements are shown in Fig.12 where the sample back

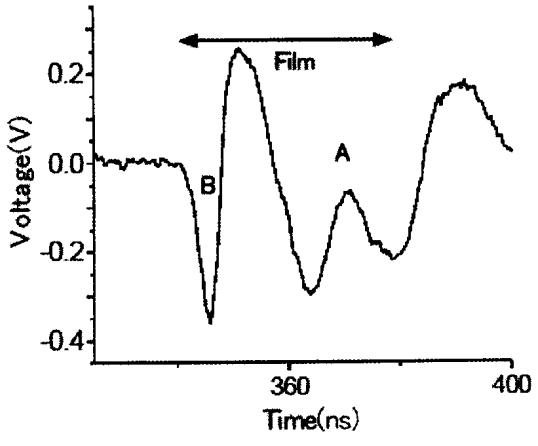

Fig. 10 LIPP signals of 50 μm thick PTFE corona charged at 100 °C. Before TSDC analysis.

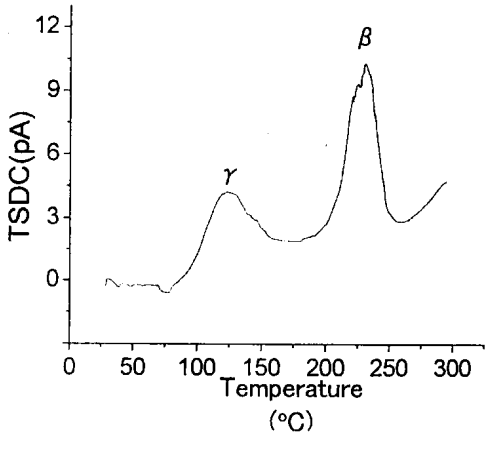

Fig. 11 TSDC of 50 mm thick PTFE film corona-charged at 100 °C.

electrode is at 305 ns and the corona-charged surface is at 400 ns, if the measuring temperature is 150 °C. When the measuring temperature increases, all peaks shift to larger time (right side) in all data which is due to the change of sound velocity, film expansion and elastic coefficient. From Figs. 11 and 12, γ peak at TSDC corresponds the back electrode interface charge which disappear at 200 °C for both in Figs. 11 and 12. β peak must .correspond surface charge (peak A). In other words, surface charge is trapped and stable if the sample is heated up to 100 °C. The double peaks A in Fig.10 are not sure but maybe surface special configuration effect and will be disappear by heating.

One LIPP example is measured for the 50 μm thick PTFE film corona-charged at 160 °C as shown in Fig.13. A large amount of negative charge and counter positive charge are invaded inside the PTFE film. The negative charge at the boundary is assumed to the induced charge in the back electrode by the positive charge at the bottom of the film. That results suggest that various charge can move inside PTFE if the PTFE temperature is more than 160 °C. Those phenomena are well-know as large peaks at about 100 °C by TSDC measurement, if the corona-charging temperature exceeds 180 °C.

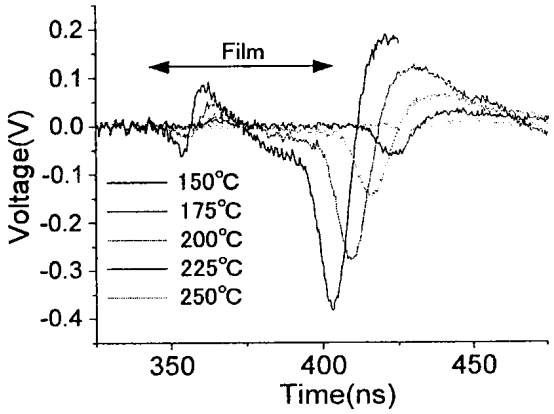

Fig. 12 LIPP sinals of 50 μm PTFE at 150, 175, 200, 225 and 250 °C corona-charged at 100 °C.

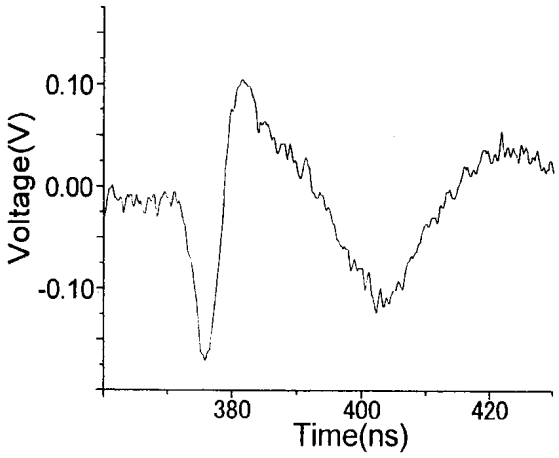

Fig.13 LIPP signal of 50 mm PTFE charged at 160 °C. Before TSDC measurement.

CONCLUSIONS

The simultaneous TSDC (thermally stimulated discharge current) and LIPP (laser-induced pressure pulse) measuring system is constructed for charge stability and charge position analysis. The position of charges which cause some TSDC peaks is identified and charge behavior in the PTFE film is visibly observed. Those results will explain various unknown electric current mechanisms near future by using that new device.

ACKNOWLEDGEMENT

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Induction Charging of Non-spherical Granular Materials: Size Analysis

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The charge and forces on a particle strongly depend on the particle size and shape. In research studying induction charging of granular materials, both the surface mean diameter (D_s) and the volume mean diameter (D_v) are needed to predict the theoretical induction charge and determine the average charge per particle based on measured values of average charge-to-mass ratios (Q/M). This paper describes a suitable way to measure the particle size of irregularly shaped induction charged particles that normally have a sampled mass of approximately 10 mg. The results of charge per particle were found to be in good agreement with the theoretical predictions.

INTRODUCTION

An accurate measurement of particle size and shape is vital for determining the average induction charge on each particle from the overall charge-to-mass ratio (Q/M) as measured in induction charging experiments. Although there are different techniques to measure particle size, each technique has its own limitations such as the required amount of the particle sample, the size range of the particles, the particle density, etc. There is no single sizing technique that is superior in all applications. [1] To achieve a reasonable result for the size of a group of particles, usually it is necessary to use several different methods to get meaningful measurements. Thus the relationship between the results from different methods needs to be considered. [2][3] Obviously particle shape takes a significant role in measuring particle size. [4][5] Quantitative analysis of the effect of shape on particle size has been less investigated. In this research efforts have been made to analyze particle size and shape and find a suitable way to measure the effective particle size in terms of surface mean diameter (D_s) and volume mean diameter (D_v) of the collected induction charged samples which normally had a sampling mass of approximately 10 mg.

PARTICLE SIZE AND SHAPE

Particle Size

Particles can have many shapes such as a sphere, ellipsoid, wedge, irregular, etc. For a spherical particle it is straightforward and unambiguous to use diameter to describe its size. It is also possible and useful to define the size of a non-spherical particle in terms of an equivalent diameter as defined in terms of either a circle or a sphere.

In practice different definitions of diameter are used for non-spherical particles depending upon the property for which the particle size is required. For example, the properties of a particle considered in the size definition include: surface area, volume, mass, sieve size, sedimentation rate, etc [1][4][5]. In the research reported here the surface diameter is used as the measure of particle size in induction charge analysis because the charge is dependent on the surface area of the particles. The volume diameter is used to calculate the mass of the particle to obtain the charge per particle from charge-to-mass measurements.

When a particle is observed under a microscope, a number of diameters may be defined to characterize the particle based on its 2-Dimension projection [4]. The diameter of a circle which has the same property as the projected outline of the particle may be used such as the projected area, perimeter, maximum diameter, minimum diameter, etc.