Simulation of Charging Process in Forming Electret for Sensor Material

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● 요 약 ●

In order to estimate spatial charging process in the corona charging which has been used to make polymer electret, the electrical properties of polypropylene film were obtained from Thermally Stimulated Current(TSC) measurements after corona charging between knife electrode and cylinder electrode with the voltages of -5, -6, -7 and -8[㎸], respectively. And then the electrostatic contour and the electric field vector were also simulated by using Finite Element Method(FEM). The edge effect around edge of knife electrode affected the electrostatic contour on surface of specimen and the electric field concentration inside specimen. The uneven charging state in the electret due to the mistake on design could be calculated and so the optimal design of corona charging device which is appropriate to various materials is come to be practicable.

Keyword: Thermally Stimulated Current, Charging Process, Finite Element Method

Ⅰ. INTRODUCTION

Electret is formed by various electret methods in order to use polymer film as a sensor material, and corona electret method which electrify charge to spacemen with corona charging device is shorter in time and is simpler in the face of various equipments or charging process than other electret methods. However, the electrical properties of electret are not fixed because of the dielectric breakdown phenomena due to concentrating electric field or the aspect of corona occurrence. Owing to these reasons, as corona charging device is used for forming electret[1], the technologies which are able to analyze charging process in detail are needed.

In order to optimize the shaping corona charging device, the electrical properties are obtained from Thermally Stimulated Current measurements[2] and then the spatial charging process in forming electret is simulated by using Finite Element Method[3]~[6] which has been used in various engineering fields such as mechanical engineering. Also the distribution of electric potential which is appeared at specimen is analyzed according to an applied voltages and the spatial processing path is estimated in this study.

Ⅱ. EXPERIMENTAL

The whole experimental procedure is shown in Fig. 1.

1. Corona Charging

The corona charging device applies high voltages to specimen and forms electret. It is shown in Fig. 2.

2. TSC Measurements

After the corona electrets were formed by appling high voltages, -5~-8[㎸], to polypropylene film, TSC spectra were measured at the temperature range of -150~200[℃] with a step of 5[℃/min]. The schematic TSC experimental device to be used for TSC values is given in Fig. 3.

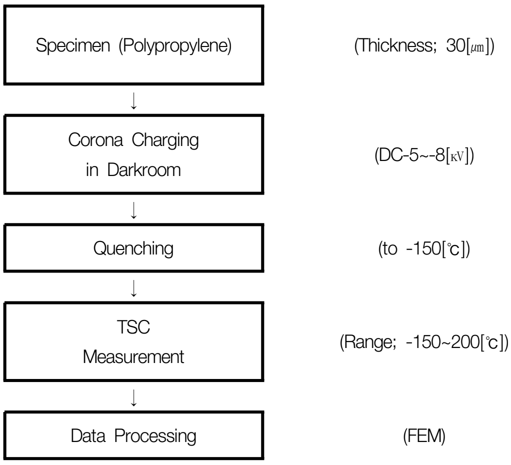

Fig. 1. Experimental Procedure

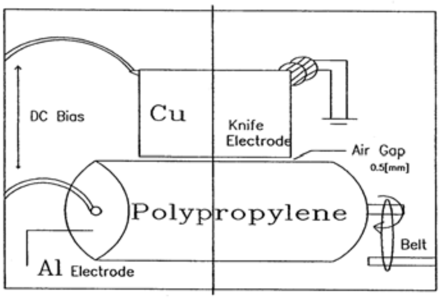

Fig. 2. Corona Charging Device

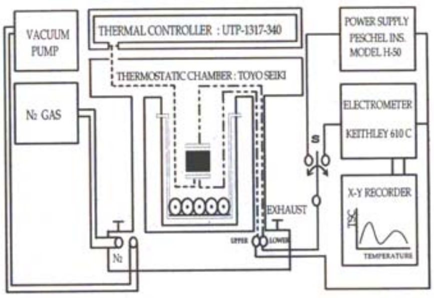

Fig. 3. Schematic of the TSC Experimental Device

III. SIMULATION

1. Element Division

A simple three nodes triangular elements were used in this study. Considering that analyzed domain is symmetrical at perpendicular face, the half face of total region is only regarded as analyzing subject. And with considering the memory and the converging time of computer system, the number of element is added or subtracted.

The diagram of analysis region and the diagram of essential element for analytical domain are shown in Fig. 4 and Fig. 5, respectively.

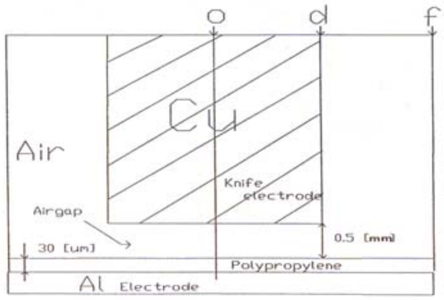

Fig. 4. Diagram of Analysis Region

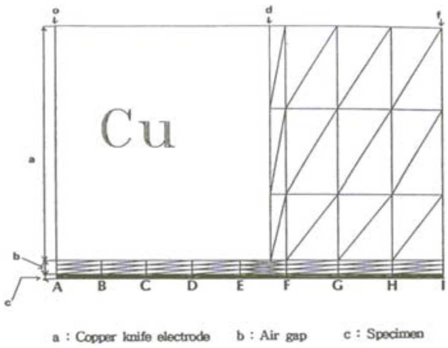

Fig. 5. Diagram of Essential Element for Analytical Domain

2. Ruling Equation of Conducting Mechanism

Generally, the conductive current which is flowed at polymer insulator is divided according to strength of electric field; Ohmic region, Fowler-Nordheim region, Schottky region and Poole-Frenkel region[7]~[9]. Because the corona charging method being used in this study applies concentrative electric field to the localized part of specimen, this method may be regarded as a case of Schottky region, and Schottky conduction mechanism in specimen can be given as follows;

$$\frac{\partial^2 \Phi}{\partial^2 x} + \frac{\partial^2 \Phi}{\partial^2 y} = -\frac{eN_d}{\epsilon_0 \epsilon_s}$$

where, e is an electric charge, Nd is a donor density, and εs is a specific relative dielectric constant. The εs of polypropylene is 2.23 in Schottky region.

Also, the equations on 2D-three nodes triangular elements are shown as follows;

$$\Phi_1 = \alpha_1 + \alpha_2 X_1 + \alpha_3 Y_1$$
$$\Phi_2 = \alpha_1 + \alpha_2 X_2 + \alpha_3 Y_2$$
$$\Phi_3 = \alpha_1 + \alpha_2 X_3 + \alpha_3 Y_3$$

Above equations can be expressed by

$$[\Phi] = \sum [N_e(X, Y)] [\Phi_e]$$

where, e is an element number and Ne(X, Y) is a shape function.

IV. RESULTS AND DISCUSSION

1. TSC Spectra according to Applied Voltages

The curves of Fig. 6 are TSC spectra that were observed from electrets which were formed by corona charging with the range of -5~-8[㎸]. From a series experiments, the three peaks of γ, δ and α were obtained at the temperature of -30[℃], 40[℃] and 100[℃], respectively. The γ peak which is appeared at -30[℃] was smaller than other peaks, and in case of the β peak, the amplitude size of -8[㎸] is larger than it of other voltages.

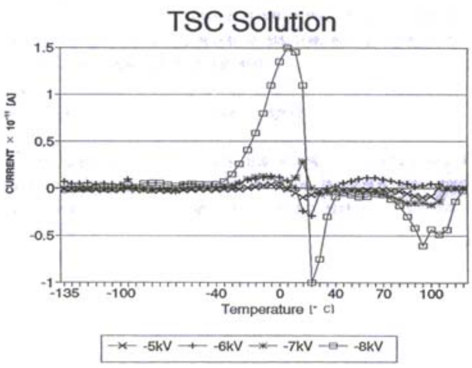

Fig. 6. TSC Spectra according to Applied Voltages

2. Potential Distribution and Electric Field Concentration

It is considered that the modulus of potential distribution shown in Fig. 7 is large between B point and C point of x-axis because electric field distribution shown in Fig. 7 is concentrated around B point and affects as a primary factor which rises a surface potential.

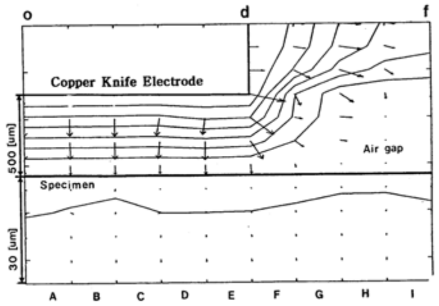

Fig. 7. Electrostatic Contour and Electric Field Distribution (→: Electric Field)

Fig. 8 is a figure which shows electrostatic contour and electric field distribution between knife electrode and surface of specimen, and Fig. 9 is a figure which shows electrostatic contour and electric field distribution inside specimen.

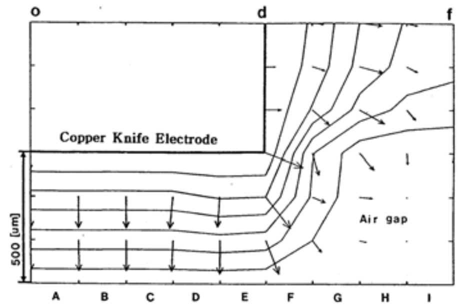

Fig. 8. Electrostatic Contour and Electric Field Distribution between Knife Electrode and Surface of Specimen (→: Electric Field)

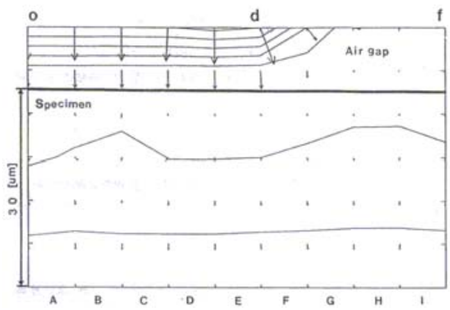

Fig. 9. Electrostatic Contour and Electric Field Distribution inside Specimen(→: Electric Field)

It is supposed that the electric field which is concentrated on the edge of electrode doesn't highly rise a surface potential and serves as a main factor which decreases potential because of dispersion of electric field vector in specimen as well as air gap.

Ⅴ. CONCLUSION

To settle the problem that the unbalanced distribution of electric field is caused by the edge of knife electrode for corona charge, and to solve the concentration of electric field, after the corona electrets were formed by appling high voltages, -5~-8[㎸], to polypropylene film with thickness of 30[㎛], TSC spectra were measured at the temperature range of -150~200[℃] and then the activation energy was obtained from these data.

Results of this study indicate that (1) the state of uneven potential and the phenomena of electric field concentration could be observed around edge of knife electrode because of edge effect; (2) parameters of FEM which can understand corona charging condition could be correctively served; (3) it is suggested that the strength of insulation outside the part, which could be used for sensor, is strengthened and the regulating design is needed at edge; and (4) it is considered that the 3D-simulator of loop calculation type would be needed for optimal design to compensate for the defect of corona charge device.

REFERENCES

[1] J. Van Turnhout, “Thermally Stimulated Discharge of Polymer Electrets”, Ph. D. Thesis, Elsevier Amsterdam, 1975

[2] J. G. Simmons and G. W. Taylor, “High-Field Isothermal Currents and Thermally Stimulated Currents in Insulators Having Discrete Trapping Levels”, Physical Review B, Vol. 5, No. 4, 1972

[3] G. Dhatt and G. Touzot, “The Finite Element Method Displayed”, pp. 129-162, 1982

[4] E. L. Washpress, “Two-Level Finite Element Grid Optimization by Direct Energy Search”, Appl., Math., Model 1, 1977

[5] M. R. Simpson, “An Integrated Design Environment for Semiconductor Device Simulation”, IEEE Trans. on Computer Aided Design, Vol. 10, No. 9, pp. 1163-1174, 1991

[6] H. Steinbibler and D. Haller, “Comparative Analysis of Methods for Computing 2-D and 3-D Electric Fields”, IEEE Trans. on Electrical Insulation, Vol. 26, No. 3, pp. 529-536, 1991

[7] R. H. Bube, G. A. Dussel, C. T. Ho and L. D. Miller, “Determination of Electron Trapping Parameter”, J. of Appl., Phy., Vol. 37, No. 1, pp. 21-31, 1966

[8] S. Maeta and K. Sakaguchi, “On the Determining Trap Depth from Thermally Stimulated Current”, J. of Appl., Phy., Vol. 19, No. 3, pp. 519-526, 1980

[9] T. Takuma, “Field Behavior at Triple Junction in Composite Dielectric Arrangements”, IEEE Trans. on Electrical Insulation, Vol. 26, No. 3, pp. 500-509, 1991