The electrostatic force that acts on the charged asymmetric conductor in a high electric field.

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Abstract

It is well known that the electrostatic force F that acts on a point charge Q in a electric field E can be estimated with the following equation.

$$F = Q*E \qquad (1)$$

Also, it is well known that the absolute value of this forces in a normal electric field and a reverse electric field are the same each other. On the contrary, it was found by this simulation that the absolute value of the electrostatic forces that acts on a charged asymmetric conductor in a normal electric field and a reverse electric field are different each other.

And, a simple experiment was performed for confirming this new phenomenon that was predicted with this simulation. The experimental apparatus consists of two electrodes and a box type conductor that was made from a thin copper sheet. This box conductor was negatively charged and was floated by an insulating raw silk thread between the electrodes. When a normal electric field was established between the electrodes, the box was shifted to their closed side with a large distance, and when a reverse electric field was established the box was shifted to their open side with a little distance.

Then, the electrostatic force that acted on this box was estimated from this shifted distance and the gravitational force that acted on this box. This measured electrostatic force agreed with the simulated electrostatic force. As a result, the existence of this new phenomenon was confirmed.

A new type electrostatic generator will be realized with this new phenomenon in the near future, and it is expected that the environmental problem and the energy crisis will be solved with this new type electrostatic generator.

Keywords: Electrostatic force, charged asymmetric conductor, normal electric field and reverse electric field.

I . SIMULATION METHOD AND RESULTS.

In the experiment mentioned later, a box conductor and two square electrodes were used. And, an axis symmetric finite difference method [1][2][3] was used to simulate the electrostatic force. However, this method cannot be used to simulate a square shape, so the box conductor was replaced with a cup conductor and the square electrodes were replaced with circular electrodes. And, the bottom area of the cup was set to become the same as the bottom area of the box.

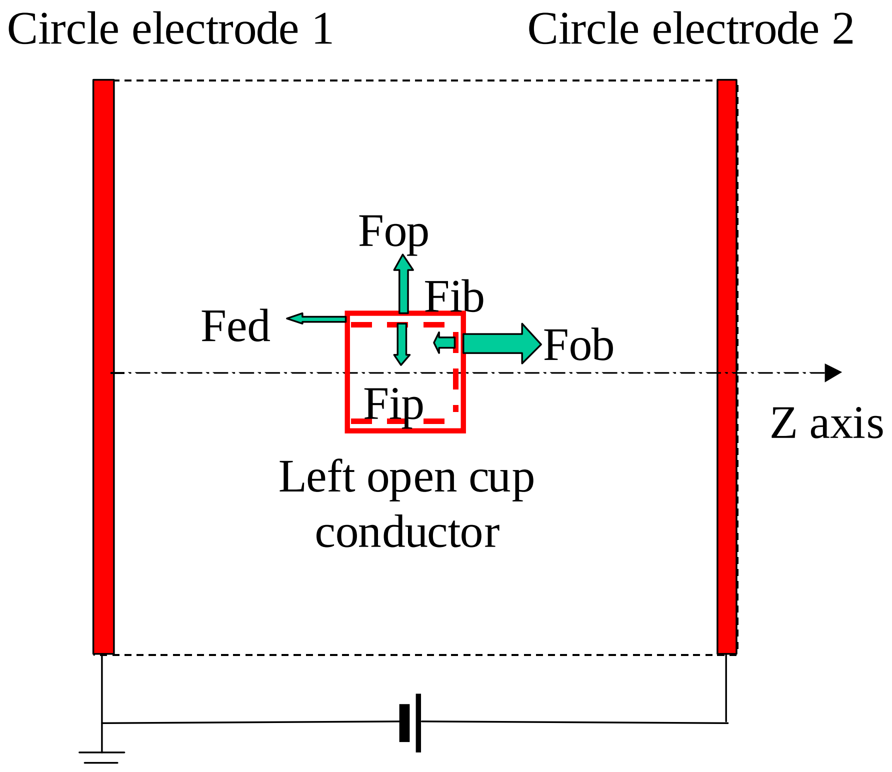

Fig.1. Schematic layout for simulating the electrostatic force acting on a charged cup conductor in a normal electric field.

Figure 1 shows a schematic layout for the simulation. The circular electrodes and the cup conductor were lined up on the Z axis. The radii of the electrodes and the cup were 56.4mm and 5.6mm, respectively. The distance between the electrodes was 96.0mm, and the width and thickness of the cup were 10.0mm and 0.1mm, respectively. Positive high voltages (10-30kV) were applied to left or right electrode to generate a normal or reverse electric field between it and the other grounded electrode. The charged cup conductor was electrically floated. Fed, Fop, Fip, Fib and Fob stand for electrostatic forces that act on edge area, outer peripheral area, inner peripheral area, inner bottom area and outer bottom area of the cup, respectively.

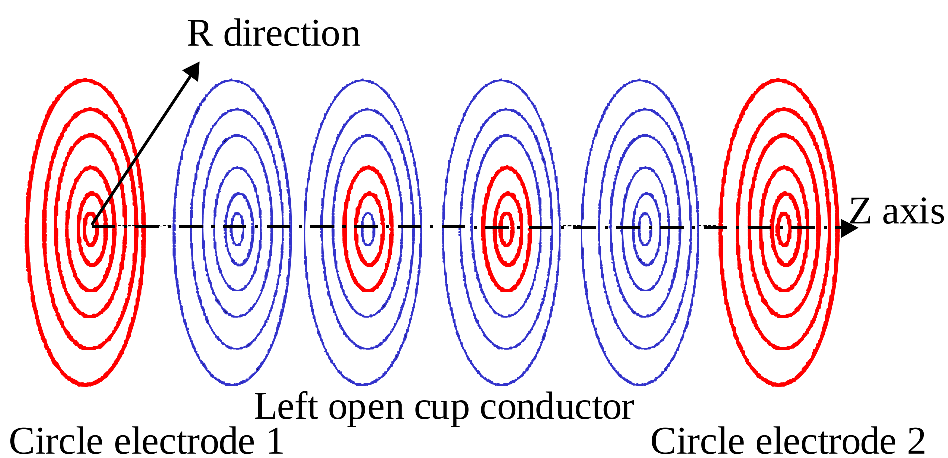

Fig.2. Schematic layout of the cells for the axis symmetric finite difference simulation.

Simulation target space between the two circle electrodes was divided into small cells as schematically shown in Fig.2. The space was divided into 25 in the R direction and 45 on the Z axis in the simulation, although in Fig.2 it is only divided into six in the R direction and five on the Z axis for clarity. The shape of the 45 cells on the Z axis is columnar and the shape of the other 1080 cells is cylindrical. The radii of all the columns are 1.4mm, the thickness of the cylinders and the width of all columns and cylinders vary from 0.1mm to 5.8mm as shown in Fig.3.

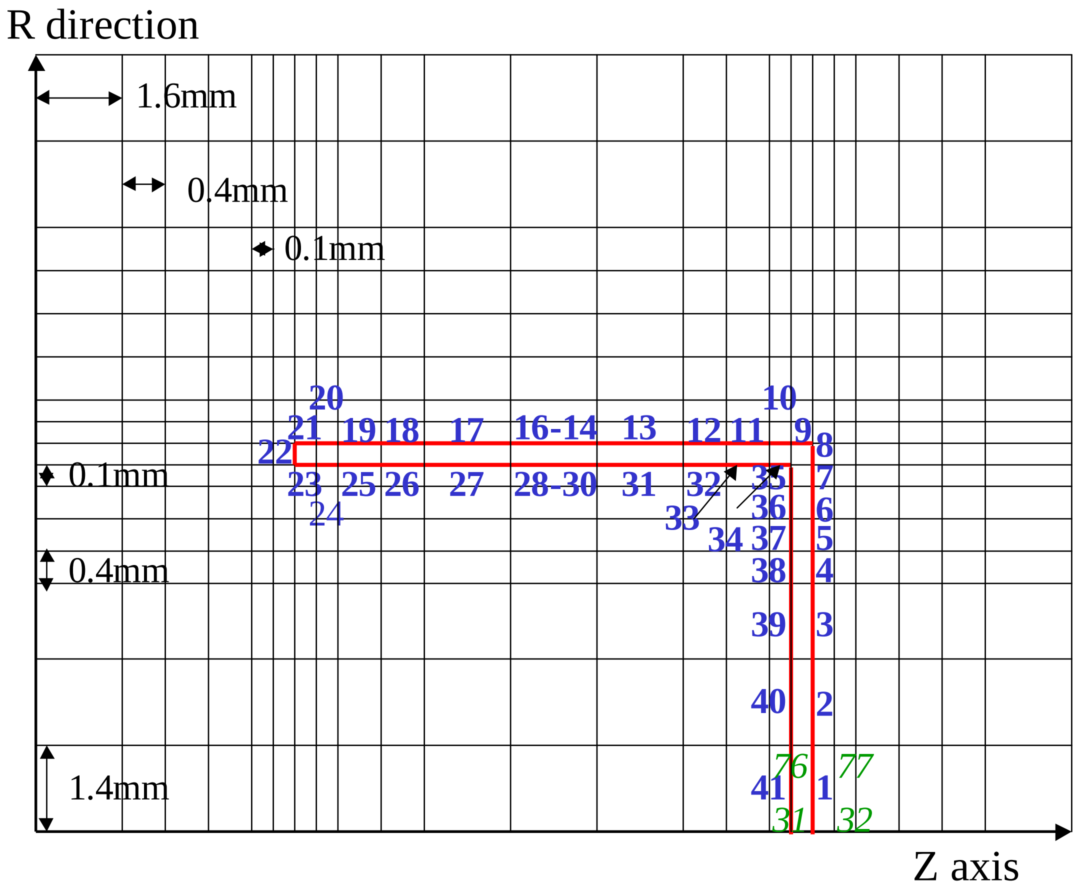

Fig.3. Cell layout around the cup conductor for the axis symmetric finite difference simulation.

Figure 3 shows some cells that were placed around the cup conductor. The surface of the cup was divided into 41 surface areas that are shown with boldface numbers. Each cell point numbers are shown with italic numbers. They are displayed as a dot in Fig.3, but they are actually a circle line of the cylinder cell edge as shown in Fig.2.

The potential of all 1196 cell points were calculated by solving multiple simultaneous equations from some points whose potential was already known. Then, the electric field strength, En, of the 41 surface areas of the cup was calculated using the potentials of the four corners points of the cell. For instance, the electric field strength E1 of surface area1 was calculated from the potential of four points V31, V76, V32 and V77, and the width of cells h, using the following formula (2):

$$E1=\frac{(V31+V76)/2-(V32+V77)/2}{h} \qquad (2)$$

The surface charge density of each area δ_n was calculated from the field strength E_n of the area and the vacuum permittivity ε_0, using the following formula (3):

$$\delta_n=\varepsilon_0 E_n, \qquad (3)$$

The charge on each area q_n was calculated from the surface charge density δ_n and area of the area S_n, using the following formula (4):

$$q_n=\delta_n S_n, \qquad (4)$$

The electrostatic force F_n acting on each area was calculated using the following formula, (5):

$$F_n=\frac{q_n E_n}{2}=\frac{\varepsilon_0 S_n E_n{}^2}{2} \qquad (5)$$

Then, five electrostatic forces that act on the five surfaces of the cup shown in Fig.1 were calculated using the following formulas, (6), (7), (8), (9), (10)

$$Fed=F_{20} \qquad (6)$$

$$Fop= F_{21}+ F_{22}+ ------ +F_{32}+ F_{33} \qquad (7)$$

. $$Fip= F_8+ F_9+ ------ + F_{19}+ F_{19} \qquad (8)$$

$$Fib= F_1+ F_2+ ------ +F_6+ F_7 \qquad (9)$$

$$Fob= F_{34}+ F_{35}+ ------ + F_{40}+ F_{41} \qquad (10)$$

And, the electrostatic force Ft that acts on the charged cup conductor was totally calculated using the following formula, (11)

$$Ft=Fed+Fib+Fob \qquad (11)$$

Fop and Fip that act on the outer and inner peripheral surface of the cup conductor were not included in formula (10) because they cancel each other at an interval of 180 degrees and ultimately become zero.

In this simulation steps, at first, the cup conductor was charged to –1.026 [nC], then the left electrode was grounded and the right electrode was applied at high voltage (from +10kV to +30kV). This condition formed a normal electric field for the negative charges between the electrodes, then the electrostatic force that acts on the negative charge of the cup conductor in a normal electric field was simulated.

At second, the cup conductor was charged to –2.052 [nC], and at third, the cup conductor was charged to –3.078 [nC] and the electrostatic forces that act on the charge were simulated respectively.

Finally, the left electrode was applied at high voltage and the right electrode was grounded. This condition formed a reverse electric field for the negative charge, then, the electrostatic force in a reverse field was simulated as above.

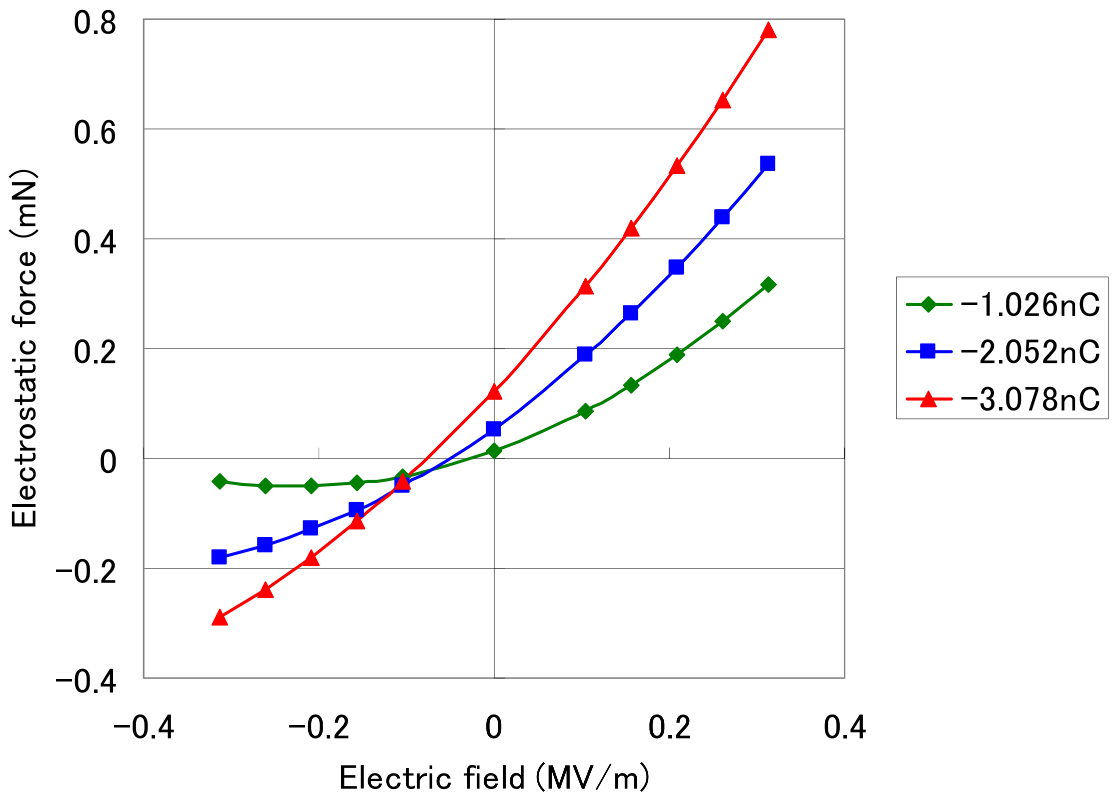

Fig.4. Simulation results of the electrostatic force acting on the negatively charged cup conductor in the normal (positive) electric field and reverse (negative) electric field.

Figure 4 shows the simulated electrostatic force in the normal (positive) electric field and the reverse (negative) electric field as a function of the field intensity between the electrodes. It is apparent from Fig.4 that when electric field strength is equal in the normal electric field and the reverse electric field, the electrostatic force that acts on the charged cup conductor in the normal field is larger than the electrostatic force in the reverse field. And, it is apparent too that when the electric field becomes strong, the electrostatic force becomes bigger generally. However, as for the case that quantity of the charge is a few (-1.026[nC]) and the reverse electric field is strong (-0.3[MV/m]), the electrostatic force becomes adversely small. This result can be explained with the overlooked electrostatic force acting on a non-charged asymmetric conductor. [4].

II. EXPERIMENT METHOD AND RESULTS

Figure 5 shows the schematic layout of the experimental instrument that was used for measuring the shifted distance of the box conductor. As mentioned above, the simulation method can't use a box conductor. Therefore a cup conductor was used in the simulation. However, making a cup shape by hand is very difficult, so, a box conductor was used in the experiment.

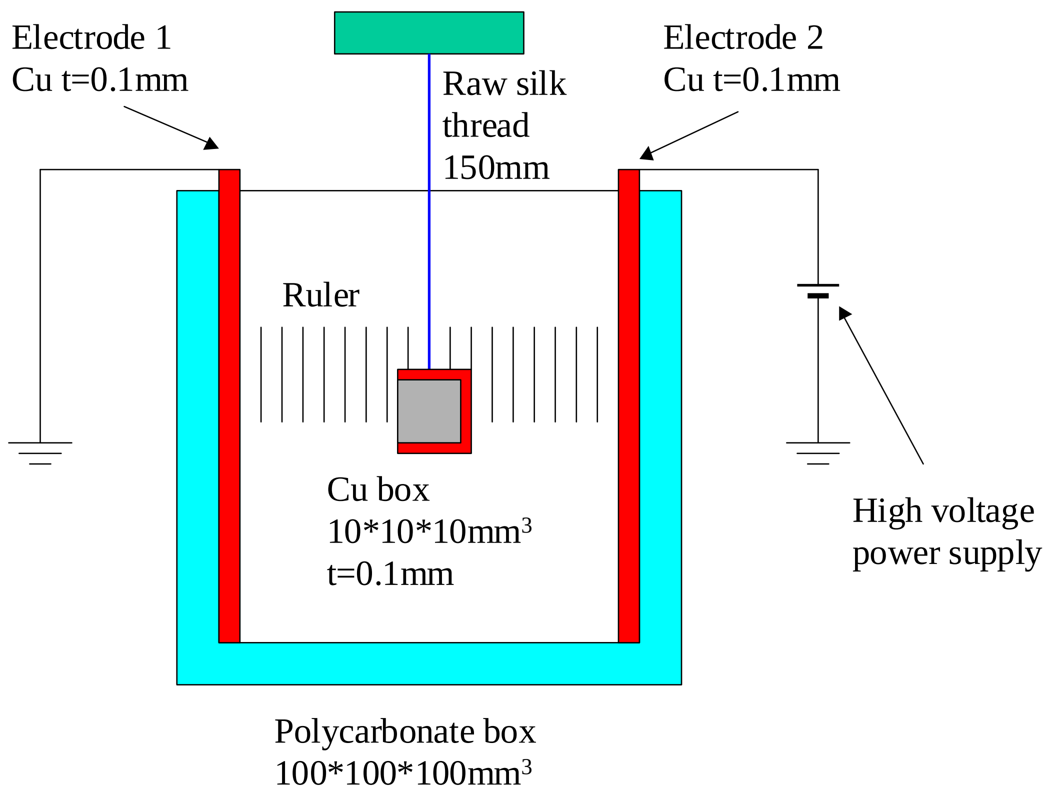

Fig.5. Schematic layout of the experiment instrument used to measure shifted distance of the negatively charged left open box conductor in a normal electric field.

Initially, a large transparent polycarbonate box was prepared. This box protects the small box conductor from wind that was produced by the air conditioner. The thin copper plate 100mm*100mm with a thickness of 0.1mm was attached to the left and right wall of the large box as a left and right electrode. The right electrode was connected to a positive high voltage power supply and the left electrode was grounded. This condition formed a normal electric field for negative charge. A small left open box conductor that was made from a thin copper plate with a thickness of 0.1mm was floated by an insulating raw silk thread with a length of 150mm at the center of both electrodes. The edges of the electrodes and the box were lightly rubbed by a fine sand-paper to prevent corona discharge. A ruler was attached on the back wall of the large box for measuring the position of the small box. A Matsusada Precision Model HAR-50PS was used as high voltage power supply.

The experiment was performed as the following procedure.

① The left and right electrodes were grounded and the box conductor was touched to the grounded electrode for discharging.

② The box conductor was centered between the electrodes and the position of this box was measured using the ruler after the vibration of the box stopped.

③ The right electrode was applied at V1 (+10kV) and the box conductor was touched to the grounded left electrode for induction charging and it was kept away from the electrode, then negative charge was kept in the box conductor.

④ The right electrode was grounded again, and it was gradually applied to the target high voltage V2 (+10kV). As a result, the box conductor was shifted to right direction. This position of the box was measured using the ruler.

⑤ ①→④ procedure was repeated with varying the voltages of V1 (+20kV, +30kV) and V2 (+15kV, +20kV, +25kV, +30kV).

⑥ Finally, the left electrode was applied to positive high voltage and the right electrode was grounded, this condition formed a reverse electric field for negative charge, and the same experiment was performed again.

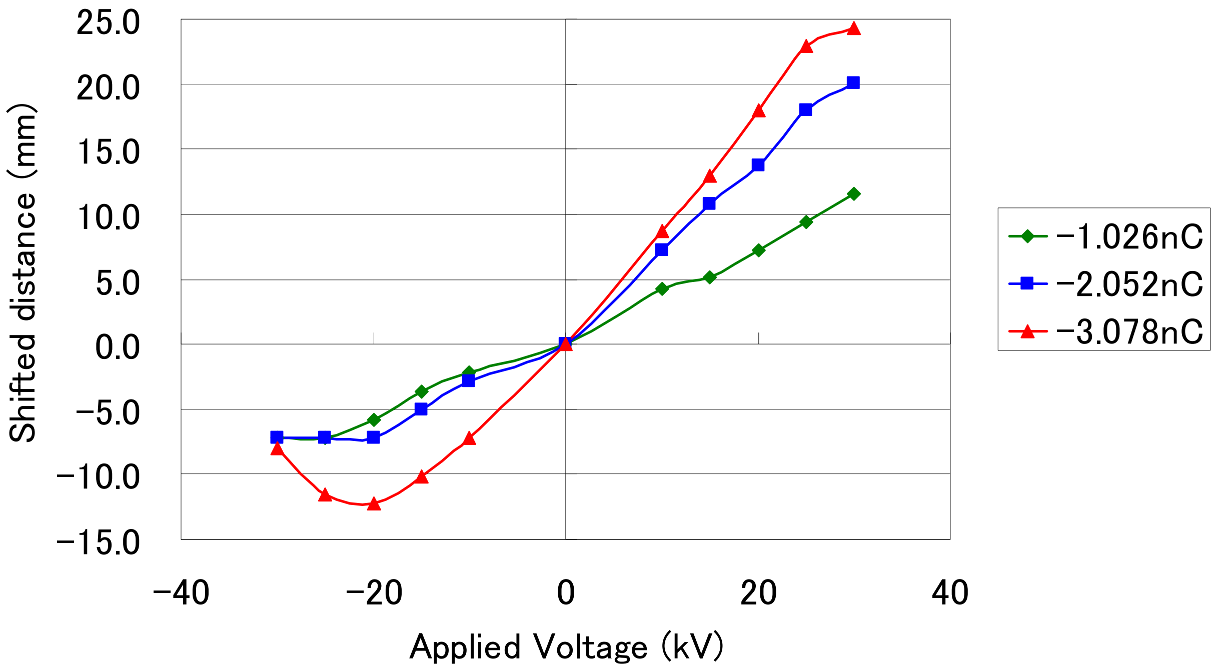

Fig.6. The measured shifted distance of the box conductor in the normal electric field and the reverse electric field as function of the applied high voltage.

Figure 6 shows the measured shifted distance of the box conductor as function of the applied high voltage. It is apparent from Fig.7 that the measured shifted distance of the box in a normal electric field is large, but it is small in a reverse electric field.

Ⅲ. COMPARING THE EXPERIMENTAL RESULTS WITH THE SIMULATION RESULTS.

The shifted distance D of the charged box conductor floated in a high electric field was measured as stated above.

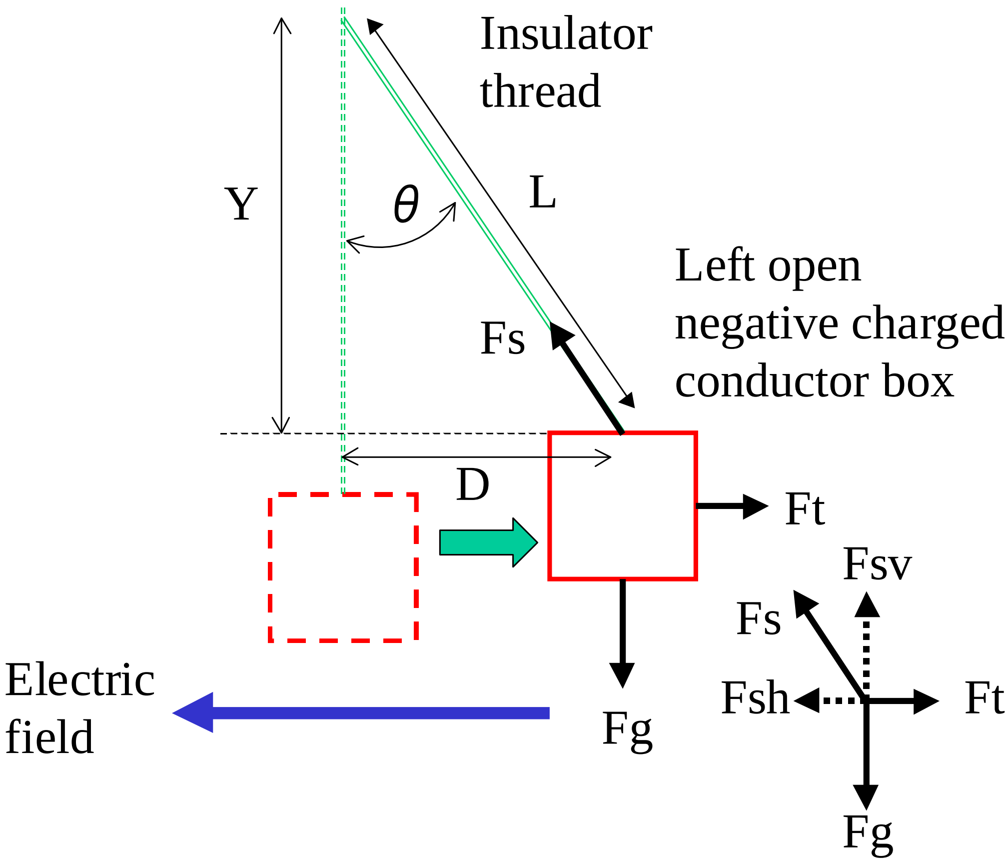

Fig.7. Schematic diagram of the electrostatic force, the gravity force and the tensile force that act on the charged box conductor in a high electric field.

This shifted distance D is related with length L and height Y of the thread as shown in Fig. 7. The ratio of length L:D:Y is the same as the ratio of the three force: the tension of the thread Fs: the electrostatic force Ft : the gravity force Fg. The horizontal component of the tension Fsh equal to the electrostatic force Ft, and, the vertical component of the tension Fsv equal to the gravity force Fg. Therefore, the electrostatic force Ft was calculated from the shifted distance D, the thread length L and the gravity force Fg, using the following formula (12):

$$Ft = Fg \times \tan\vartheta = Fg \times \frac{D}{Y} = Fg \times \frac{D}{\sqrt{L^2 - D^2}} \qquad (12)$$

where L=150mm, and Fg=4.39mN that was calculated from area of the box is 5cm^2, the thickness of the Cu plate is 0.1mm and the specific gravity of Cu is 8.96.

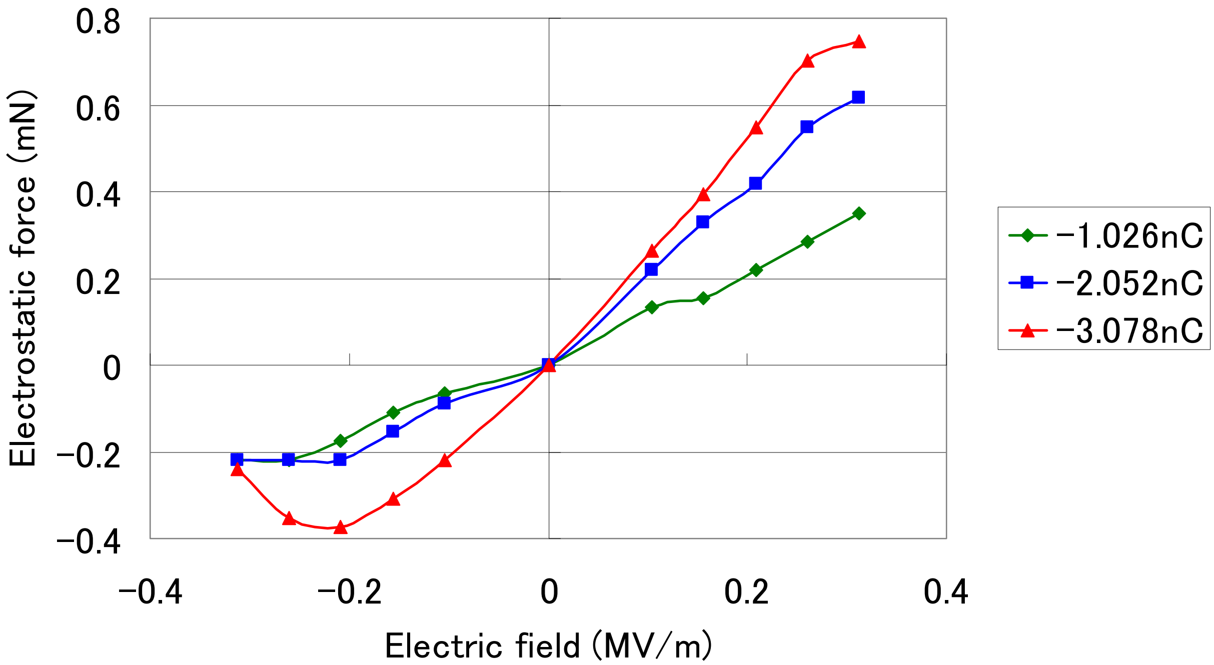

Fig.8. Experimentally measured electrostatic force acting on the charged box conductor as a function of electric field intensity.

The experimentally measured electrostatic force to act on the charged cup conductor in the high electric field is shown by figure 8. The total tendency of the experiment result is well similar with the result of the simulation (Fig.4).

It becomes complicated when the three simulation results and the three experiment results are shown on one graph simultaneously. So these results are shown separately in three figures according to a quantity of charge. When the charges are -1.026[nC], -2.052[nC] and -3.078[nC], the results are shown by figure 9, 10 and 11 respectively.

It is apparent from figure 9,10,11 that the experiment result agreed with the simulation result as a general tendency well. In particular, in the normal electric field, the simulation result agrees with the experiment result very well. However, in the reverse electric field, the experiment result does not always agree in the simulation result. In particular, on figure 9 and figure 11, an experiment result does not agree with a simulation result.

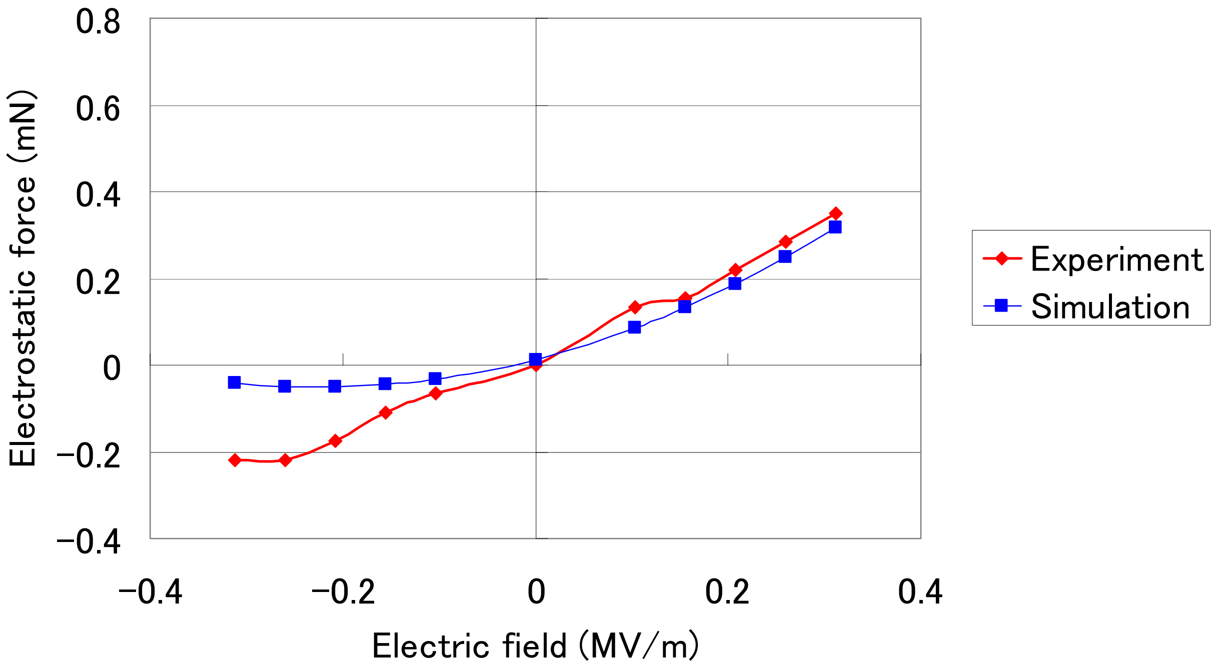

Fig.9. Experimentally measured and simulated electrostatic force acting on the charged asymmetric conductor as a function of electric field intensity. The charge quantity is –1.026 [nC].

In figure 9, in a reverse electric field, an experiment result is larger than a simulation result. The simulation and the experiment include this possible cause. If a smaller mesh was used in the simulation, the electric field becomes strong, and the electrostatic force becomes larger. In an experiment, the box conductor was made with handmade method. Therefore the accuracy to size was not good. It is expected that the electrostatic force becomes smaller if the complete box conductor was used.

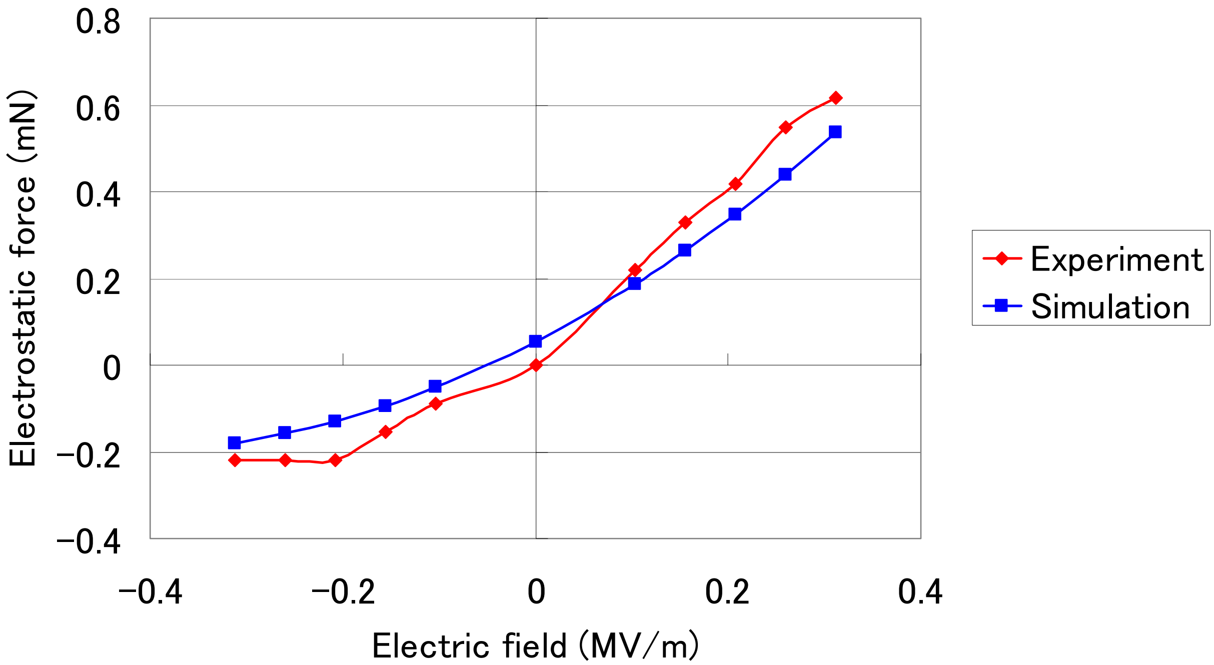

Fig.10. Experimentally measured and simulated electrostatic force acting on the charged asymmetric conductor as a function of electric field intensity. The charge quantity is –2.052 [nC].

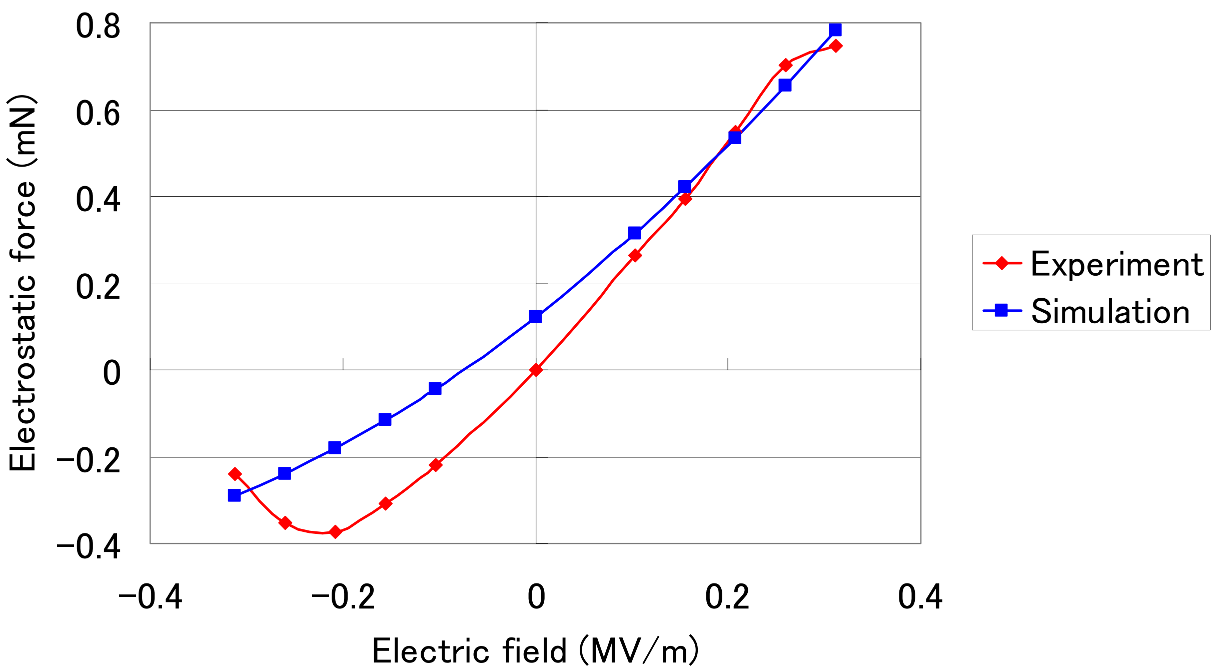

Fig.11. Experimentally measured and simulated electrostatic force acting on the charged asymmetric conductor as a function of electric field intensity. The charge quantity is –3.078 [nC].

If the reverse electric field becomes strong in figure 11, the simulation result becomes large, but the experiment result becomes adversely small from the middle.

I can explain this result by corona discharge generated with the edge. The negative charge that box conductor has is neutralized by the positive ion that occurred by corona discharge, then, the electrostatic force became small in proportion to lost negative charge.

As mentioned above, the experiment result is different from the simulation result a little. But, anyway electrostatic force in the normal electric field is (two or more times) bigger than the electrostatic force in the reverse electric field. As a result, the new phenomenon that the electrostatic force to act on the charged asymmetric conductor in the normal electric field and the reverse electric field is different is confirmed experimentally here.

Ⅳ. CONCLUSION

Because the experiment results agreed with the simulation results almost, I can judge that there is really the next phenomenon. That is the absolute value of the electrostatic forces that acts on a charged asymmetric conductor in a normal electric field and a reverse electric field are different each other.

A new type electrostatic generator will be realized with this new phenomenon in the near future, and it is expected that the environmental problem and the energy crisis will be solved with this new type electrostatic generator.

I reported in this paper only the simulation results and the experiment results, and have not done explanation of the theory of this new phenomenon. So, on the next time, I will present an explanation of the theory of this new phenomenon.

Complete consensus of the experiment result and the simulation result will be achieved with the complete box conductor and a three dimensions simulation method with fine mesh.

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