

# Property on levitation for EHD and Electrostatic Propulsion Device Using Multi-layered Electrode

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## Abstract

Electro hydro dynamic (EHD) and electrostatic propulsion devices has no moving parts and, in the air, operates on electrical energy. It is expected to develop electric propulsion systems without future moving parts of airplanes and helicopters propellers in the future.

In this time, we developed an EHD propulsion device with multiple layers of electrodes, and confirmed the effectiveness of the multiple layers. Usually, the metal weight increases and the input voltage threshold for levitation should increase as the number of layers increases. In the experiment, it was confirmed that the threshold voltage for levitation is kept constant even if the weight is increased by multilayering the electrodes. This means that the power efficiency of the device per unit weight is also improved at the same time. However, it was also found that this threshold increases if the size of the apparatus is increased.

## 1.Introduction

It is expected to develop electric propulsion systems without future moving parts of airplanes and helicopters propellers in the future. The advantage of this propulsion system is that 1) there are no moving parts, easy to maintain and 2) the propulsion efficiency may exceed the conventional engine.

There is a report that the principle of ion craft considered as a part of a series of thrust generation experiment by Brown effect using high voltage is propulsion by the imbalance of electrostatic force, attraction by space charge. We also think so from many experimental results other than that paper. It is considered that the propulsion principle is determined not by the ion wind but by the external electric field (applied voltage) and the amount of electric charge accumulated in the electrode. Much research has been done on the principle of lifters.

In order to realize drone, the levitation force needs to exceed the weight of the EHD device. Of course, the efficiency of thrust per unit weight (N/kg) and thrust per unit power consumption (N/W) are need to improve. Electrode multiplexing, utilization of polarization structures, and low voltage operation of ion sources, and generation of magnetic field by pulse operation are effective methods to improve them. However, even with these improvements, the levitation force cannot exceed the weight of the EHD device unless the above weight problem is solved.

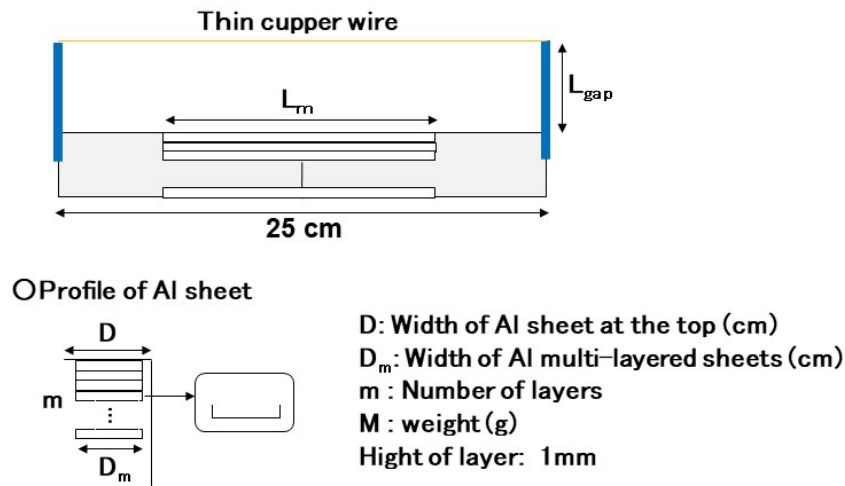
Multi-layering of wide plate-shaped electrodes is expected to improve the amount of accumulated

charge. In this study, we experimentally investigated whether the levitation force per unit power consumption can be improved by multilayering the electrodes and obtaining the threshold value of the input voltage for levitation.

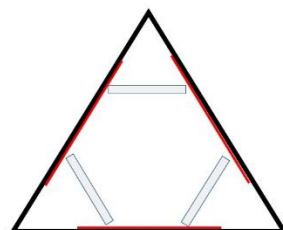
## 2. Experimental set up

The experimental setup for EHD propulsion is shown Fig.1. The single electrode(1 unit) is shown Fig.1(a). The used triangle EHD propulsion device is shown Fig.1(b). Triangle EHD device is shown in Fig.1(b). Three multi-layered electrodes are set at the tree red parts one by one. The devices are made of Aluminum foil. The length of the electrode was 25 cm.  $L_m$  is set to be 12.5cm. The maximum output voltage of the used DC rectified power supply in this experiment was 30 kV. A Cockcroft-Walton rectifier driving by single output wire of Tesla coil with CW mode operation was used to obtain DC high voltage output in this experiment. The output frequency of the TC was 1.9 MHz. We can rectify the output signal from TC by connecting only single wire. The  $L_{gap}$  was set to be 4.5 cm. The used ultra-thin wire (the thickness was  $50\mu\text{m}$ ) was connected to the + electrode, and the long plate electrode was connected to - electrode. The reason for using the ultra-thin wire is to enable low voltage operation. The EHD devices can operate up to be 30 kV. The input voltage is limited by the discharge between the wire and the body.

The threshold of the input voltage for revitating the EHD device was decided to judge if the device start to keep floating in the air.

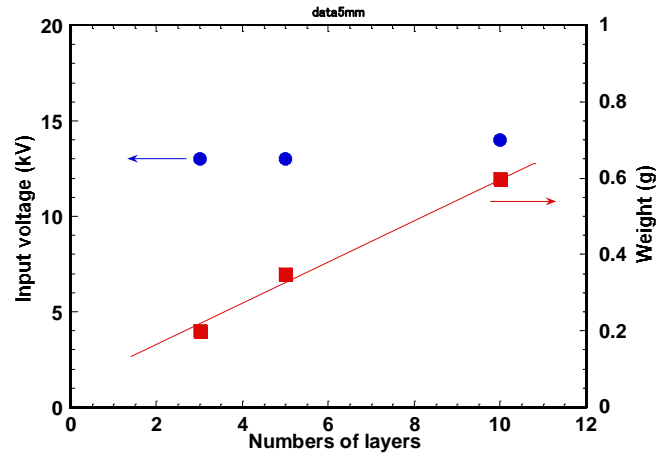


(a)

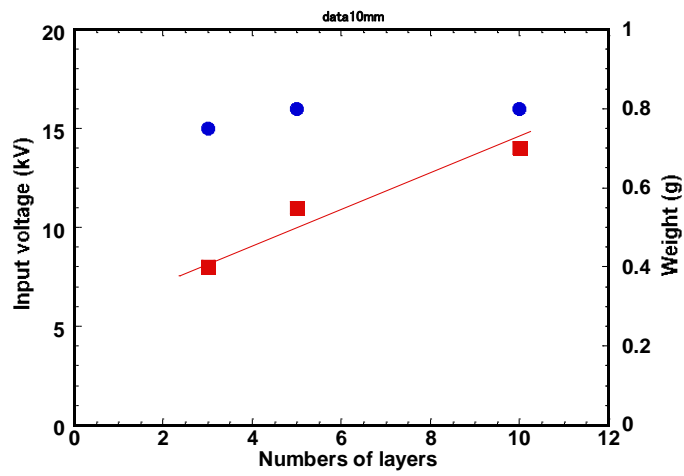


(b)

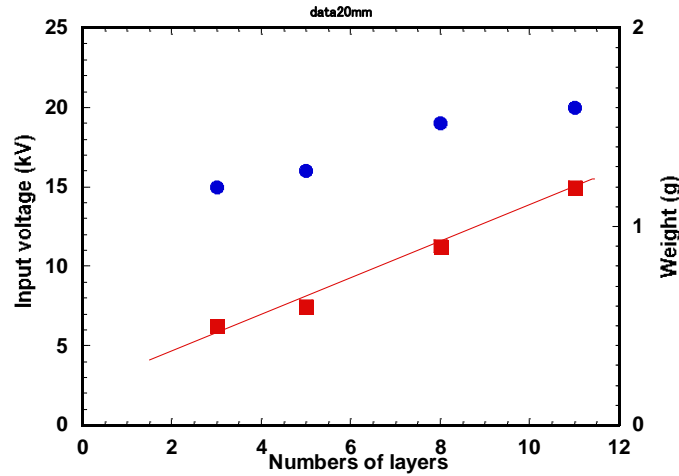
Fig.1. Experimental setup for levitation of EHD device. (a) Single plate electrode (1 unit), (b) triangle EHD device.



(a)



(b)



(c)

Fig.2. Threshold of input voltage for levitation. (a)  $D=0.5\text{cm}$ , (b)  $D=1.0\text{cm}$ , (c)  $D=2.0\text{cm}$ .

Threshold of input voltage for levitation of 1 unit is shown in Fig.2. It was found that the threshold is saturated and constant regardless of the magnitude of  $D$ . When the device mass increased but the value of  $D$  was small, the threshold was small and increased when  $D$  became large. Regarding saturation, it was found that the smaller the  $D$ , the faster the saturation with respect to the number of layers, and the larger the value of  $D$ , the less saturated the number of layers.

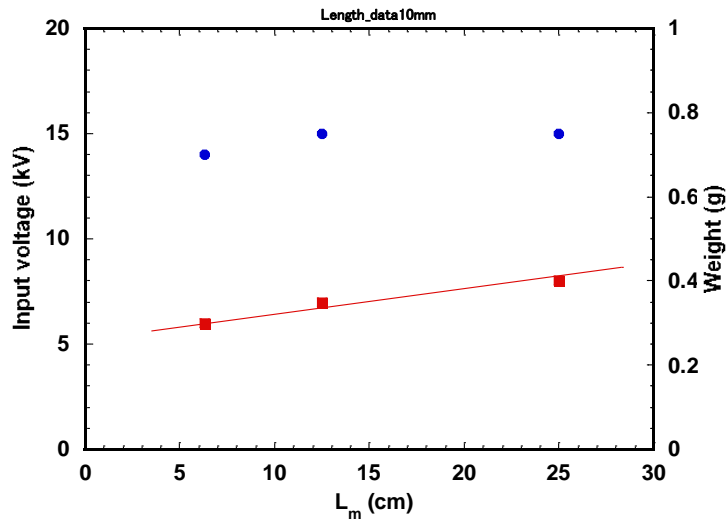


Fig. 3. Threshold of input voltage for levitation as a function of  $L_m$ .

Threshold of input voltage for levitation as a function of  $L_m$  is shown in Fig.3. When  $L_m$  is lengthened, it saturates and becomes constant as  $L_m$  becomes the same length as one electrode.

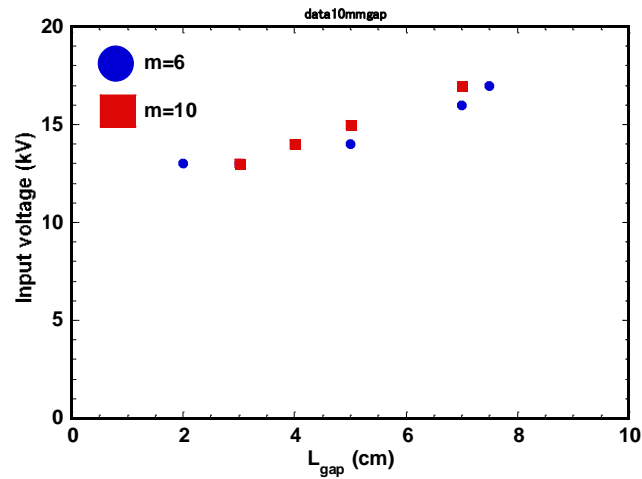


Fig.4. Threshold of input voltage for levitation as a function of  $L_{gap}$ .

Threshold of input voltage for levitation as a function of  $L_{gap}$  is shown in Fig. 4. When the gap was increased from 2 cm to 8 cm, the device lifted above its own weight. The threshold increased with increasing gap. With a gap of 8 cm, it went up to 22 kV. The threshold is slightly higher when the number of layers is 10.

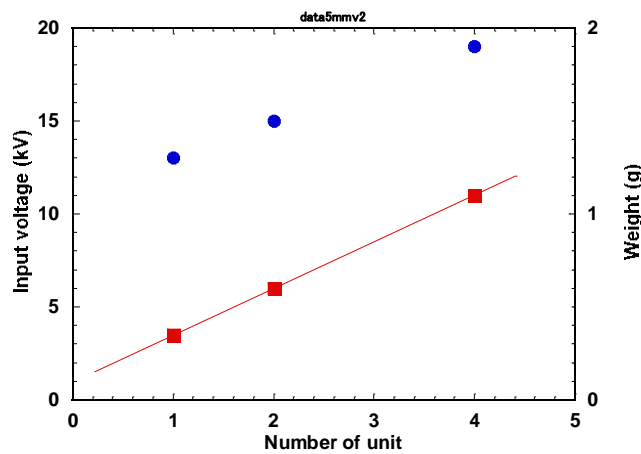


Fig.5. Threshold of input voltage for levitation of multi-layered electrode module.

Threshold of input voltage for levitation of multi-layered electrode module is shown in Fig.5. When one module was combined to increase the length in the horizontal direction, the threshold simply increased linearly rather than decreased.

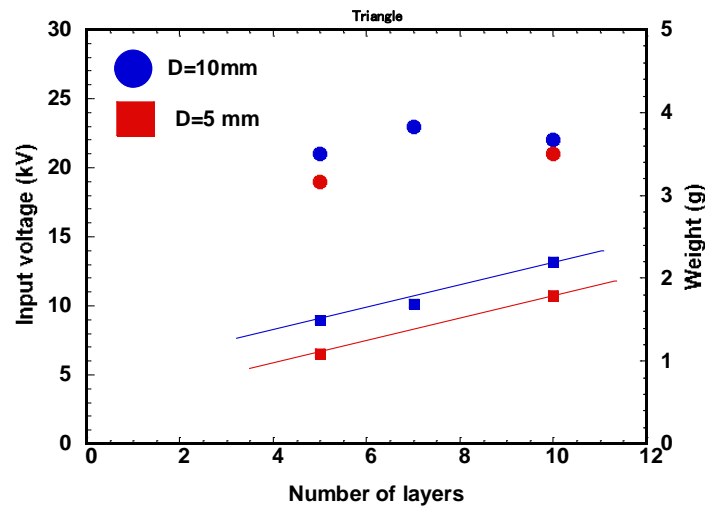


Fig.6. Threshold of input voltage for levitation of triangle EHD devices.

Threshold of input voltage for levitation of triangle EHD devices is shown in Figure 6. how did you measure The triangle was levitated, and the voltage was lowered to confirm the input voltage that prevented the levitation? When the number of layers was increased, the threshold was saturated when the number of layers was 7 or more. This trend was the same as for the one-electrode unit. The threshold was slightly higher when D was larger.

## Discussion

In this time, we have developed an EHD propulsion device with electrodes arranged in layers, and confirmed the effectiveness of the multilayer structure. The threshold voltage for levitation was kept constant even if the weight was increased by adding more layers. This means that the more layers there are, the higher the levitation force and the more efficient the levitation force per unit weight. Usually, the weight of the metal increases, which should increase the threshold, but this means that the levitation force increases proportionally to the number of layers. This means that metal having a large air volume can be levitated if a high voltage is applied to the metal in a structure containing cavities rather than in a bulk state. Giving a structure to a metal to include cavities is equivalent to lowering its density. The summary of the multi-layering performed this time is as follows. The difference in the electrode width and length, that is, the difference in the aspect ratio changed the threshold characteristics. This can be interpreted to be caused by whether the leakage of the electric flux density generated from the charge in the lateral direction is large or small. It is thought that when the width of the wide upper part of the negative electrode is narrow and the number of layers is large, electric flux leakage is small and the electric field is strengthened in the layer direction. Computer simulations of charge and electric field are necessary in the future. 1) The smaller the cross-sectional area of the structural material, the higher the thrust density. It is thought that the charge density is high. 2) The longer the electrode plate length,

the higher the threshold. 3) It has the function of lowering the thrust density due to the proximity of the unit units of the layered structure. 4) As the number of layers increases, the threshold becomes higher and saturates at a certain number. A large number of layers improves the levitation force. Although there is no experimental result of multi-layer, it may be possible to have several hundred layers instead of 10 layers.

A large amount of charge is required to increase the levitation force in order to increase the size of the device. It is necessary to: 1) Enlarging the cross section of the microstructure electrode, 2) lengthening the electrode, and 3) increasing the number of layers to 10 or more. However, increasing the size causes an increase in the threshold value, but the threshold value should be lowered as much as possible in the design. This time, we adopted a structure that divides the layer structure for the configuration of the triangular EHD device, which combines three units. This is for stably floating the device. It has been confirmed by experiments that the stability is lowered when the multi-layered electrodes are combined and arranged in a circle.

## **Conclusion**

As a result of studying the effectiveness of multi-layering for EHD propulsion devices using layered electrodes, we could confirm it. It was shown that the threshold voltage of levitation is kept constant even with multiple layers. As the number of layers increased, the levitation force increased and the levitation force per unit weight, that is, the power efficiency was improved. However, it became clear that this threshold value increases when the size of the apparatus is increased.

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