New Insights into Maxwell's Equations Based on New Experimental Discoveries

Xia Cao[1, 2*]

1 School of Chemistry and Biological Engineering, University of Science and Technology Beijing, Beijing, 100083, China

2 Beijing Institute of Nanoenergy and Nanosystems, Chinese Academy of Sciences, Beijing, 101400, China

*Corresponding Author: E-mail: caoxia@ustb.edu.cn

Abstract

No scientific theory is absolutely correct and unchangeable. Any scientific theory is the product of human's periodic cognition, which will continue to be improved with the development of new discoveries and scientific technology. It has been found that the electric field can be generated by the friction, and the changing electric field can be generated by constant friction. After the friction stops, the electric field called electrostatic field will exist for a period of time or even longer. Accordingly, a series of experiments were designed. The 1-watt bulb can be lighted by collecting the changing electric field energy when a polymethyl methacrylate (PMMA) board was rubbed with polytetrafluoroethylene (PTFE) film by hand. When a closed coil was placed in the generated changing electric field, an induced current and an induced electromotive force were generated in the coil, and the scissors in the coil can be magnetized. The 1-watt bulb can be lighted by the generated changing electric field, when one end of the plastic rod was rubbed by fur. Besides, the magnetic phenomenon was produced in the

closed coil connected to the plastic rod. In addition, we found that shaking the plastic rod with an electrostatic field generated by the friction can also generate a changing electric field, which not only wirelessly lighted the 28-watt fluorescent tube lamp, but also produced an induced current and an induced electromotive force in the closed coil nearby the lamp. Based on the above experiments, we have the following speculation. Just as the unified theory of electromagnetism, the changing electric field produces a magnetic field, and the varying magnetic field produces an electric field. In fact, the electric field is a magnetic field and the magnetic field is an electric field, so they can be regarded as energy fields in essence. The coil and conductor can be regarded as the energy collector that can collect energy from the energy field, as long as there is a relatively constantly changing energy field in the collector. The conduction current is transmitted in the collector, while part of the energy field that is not collected in free space, which corresponds to the displacement current in the fourth equation of Maxwell's equations. The essence of Maxwell's equations and related laws are two different phenomena resulting from energy field in the closed-loop self-circulating state or open-loop acyclic state. The first equation describes an open-loop static energy field, and the second equation describes a closed-loop static energy field. The third equation describes how the induced conduction current can be generated in the closed-loop energy field, and the fourth equation describes how the induced conduction current can be generated in the open-loop energy field. Based on the new experimental discoveries, this work interprets Faraday's law of electromagnetic induction, Maxwell's displacement current and Maxwell's equations from a new perspective, which is important to understand the nature of Maxwell's equations systematically.

Key words

Maxwell's equations; changing electric field; electromagnetic induction; displacement current; field current

1. Introduction

Maxwell's equations are the foundation of classical electromagnetism, which unified the known laws including the Gauss's law for electricity, Gauss's law for magnetism, Faraday's electromagnetic induction law and Ampere's law.[1] Gauss's law for electricity is the first equation (1) that dictates the relationship between the electric field and the distribution of charges in space. Electric field lines start from the positive charge and end at the negative charge or the infinity. [2, 3] Gauss's law for magnetism is the second equation (2) that dictates that magnetic field lines have no starting point and no ending point, which can form a closed loop.[4, 5] Faraday's law of electromagnetic induction is the third equation (3) that explains how a time-varying magnetic field induces an electric field. The rate of change of magnetic flux across the surface is equal to the circulation of the induced electric field. [6, 7] Ampere-Maxwell's law is the fourth equation (4) that describes the magnetic field can be generated by the conduction current or a time-varying electric field (Maxwell's displacement current). The rate of change of the electric flux across the surface and the current contained in the surface are equal to the circulation of the induced magnetic field.[8-11] Maxwell's equations show the propagation and interaction between electric field and magnetic field. Due to the limitations of science and technology in the 18th century, these theories have not been updated and verified more comprehensively. [12] Most of the studies about Maxwell's equations focus on the theoretical derivation, but little actual experimental verification has been realized.[13, 14]

$$\nabla \cdot \boldsymbol{D} = \rho_v \quad (1)$$

$$\nabla \cdot \boldsymbol{B} = 0 \quad (2)$$

$$\nabla \times \boldsymbol{E} = -\frac{\partial B}{\partial t} \quad (3)$$

$$\nabla \times \boldsymbol{H} = \frac{\partial D}{\partial t} + J \quad (4)$$

Where D is the displacement field, ρ_v is the free electric charge density, B is the magnetic field, E is the electric field, H is the magnetizing field, J is the free electric current density.

In 2016, Professor Xia Cao found that the LED lamp could be lighted up wirelessly by the constant friction of her clothes made of chemical fiber. Then she thought that the electric field can be generated by the friction, and the changing electric field can be generated by the constant friction. Thus, the displacement current was firstly discovered to be generated by the friction, and a new wireless power delivery mode by using the Maxwell's displacement current was designed, which quickly attracts attention to the experimental study of displacement current.[15] In subsequent studies, it has been further found that there will be energy field during any dynamic interactions of all things. It has been reported that electromagnetic fields can be generated when two objects touch each other (tap, rub, collide, etc.).[16] Three types of collision were investigated that mechanical energy can be converted into electromagnetic energy during any collision of two objects.[17] Moreover, high-frequency interaction between two objects under force can generate the oscillating electromagnetic waves.[18] More actual experimental verification and scientific discoveries can provide new explanations of classical theory, which helps us understand the world deeply.

As the research continues, the experimental phenomenon can be understood more thoroughly. We found that an electromagnetic field can be generated when an object was tapped or rubbed by the hand. A changing electric field can be generated when there was a constant tapping or rubbing, and there was an electrostatic field that can exist for a period of time when the tapping or rubbing stopped. When a closed coil was put into the changing electric field produced by the friction, an induced current (conduction current) can be generated. The produced current in the closed coil gradually became lower with the increasing distance of coil from the center of the force. But the closed coil can collect energy and generate the conduction current when it was placed in a large spheroid area around the center of interaction. The electromagnetic field generated by the continuous friction formed a spherical field, which radiates from the force point to all sides. When the polymethyl methacrylate (PMMA) board or the plastic rod were rubbed for a certain number of times, the scissors and iron wire inside the closed coil can be magnetized, which is similar to the magnetic effect caused by the current flow of wire. A 28-watt fluorescent tube lamp can be lighted wirelessly by the changing electric field, and there was the induced current generated in the coil simultaneously. When the rubbed and non-rubbed ends of a plastic rod were connected by a wire, both an electric current and a magnetic field were generated in the wire. Besides, the 1-watt bulb can be lighted when the plastic rod was constantly rubbed with fur.

Based on these original experimental discoveries, the Maxwell's equations and related laws were reconsidered. Just as the magnetic field and electric field are two forms of energy fields, the changing electric field and the changing magnetic field can be collectively called the changing energy field. The part of energy field collected by the tangible wire can generate a conduction current, and a part of changing energy field that is not collected by the conductor corresponds to the displacement current in the fourth equation of Maxwell's equations. Therefore, we combined the theory and experiment to further reconsider the Faraday's law of electromagnetic induction, Maxwell's displacement current and Maxwell's equations based on new discoveries and new perspectives. If four Maxwell's equations describe everything about electromagnetism, the first equation describes the electricity, the second equation describes the magnetism, the third equation describes how the magnetism generates the electricity, and the fourth equation describes how the electricity generates the magnetism. Accordingly, the first equation can be interpreted to describe an open-loop energy field, the second equation can be interpreted to describe the closed-loop energy field, the third equation can be interpreted to describe how the closed-loop energy field generates the induced current, and the fourth equation can be interpreted to describe how the open-loop energy field generates the induced current. This work will have a profound impact on the practical applications of Maxwell's equations, electromagnetic theory and practical applications of new energy.

2. Results and discussions

It has been found that an electromagnetic field can be generated where there are interactions like the collision or friction. There is an energy field and an energy flow when we tap or rub one time. A changing energy field can be generated when there was a constant tapping or rubbing, and there was a constant electrostatic field that can remained for a period of time when the action was stopped. The energy field is not closed-loop, so it only exhibits the properties of electric field like the electrostatic attraction. A constantly changing electric field can be generated when there is constant tapping or friction. If we put a closed coil in the changing electric field, will an induced current (conduction current) be generated in the coil like Faraday's law of electromagnetic induction? As shown in Figure 1a, the closed copper coil was put on the polymethyl methacrylate (PMMA) board, and the PMMA board was constantly rubbed by hand to generate the changing electric field. Figure 1b and Figure 1c shows the current and voltage produced in the closed copper coil can reach 80 uA and 1200 V, respectively. It can be found that the generated changing electric field can be collected by the tangible closed coil. Like the electromagnetic induction (a changing magnetic field can be collected through the coil by cutting the magnetic field lines), the constantly changing electric field can be collected by a closed coil to generate an induced current (conduction current). In the fourth equation (4) of Maxwell's equations, a changing electric field can produce the Maxwell's displacement current, which is a form of field current. So like the changing magnetic field, can the changing electric field generate the displacement current and conduction current at the same time?

As shown in Figure 1d, a lamp board with 1350 LEDs and a closed coil were placed on the PMMA board at the same time, and the PMMA board was rubbed by the hand to generate a changing electric field. The lamp board can be lighted wirelessly and there was conduction current in the closed coil. (Video S1) Importantly, Figure 1e shows that the current produced in the coil still reached 80 uA. There were both conduction current and displacement current when the PMMA board was rubbed by hand. The closed coil can collect the energy generated by the changing electric field passing through it, while the energy of the changing electric field at other positions is not collected. Therefore, there is also a part of the energy in space that is not collected by the tangible coil, which is the displacement current in the Maxwell's equations. It can be seen that the field current (displacement current) can be generated by a changing electric field. So the lamp board can be lighted wirelessly, and a part of the field current can be collected by the closed coil to form conduction current. In essence, the conduction current is generated by a changing energy field, which is collected by a closed coil or wire to flow in the conductor. Besides, the distributions of the electric field generated by collision or friction were studied. As shown in Figure 1f, two coils were respectively placed on two side of the PMMA board to collect the generated electric field, when the PMMA board was rubbed by hand from the right side. Points 1, 2, 3 and 4 are the same distance of 28 cm from the point 0. As shown in Figure 1g, the current produced in the coil ① remained basically unchanged after the coil ② was placed on the right side. The current produced in the coil ② was lower than the coil ① because the energy collection of coil ② was affected by the hand on the right side. As shown in Figure 1h, the induced currents in the coil were nearly equal, when the closed copper coil was respectively placed with equal distance from the center of the force (Points 1, 2, 3 and 4). Therefore, the generated electric field is similar to a spherical power supply that the induced currents generated in closed coils tend to be equal on the equipotential surface. As shown in Figure 1i, the induced current gradually decreased as the distance between the coil and the PMMA board increased from 10 cm to 50 cm until it became undetectable by using our method.

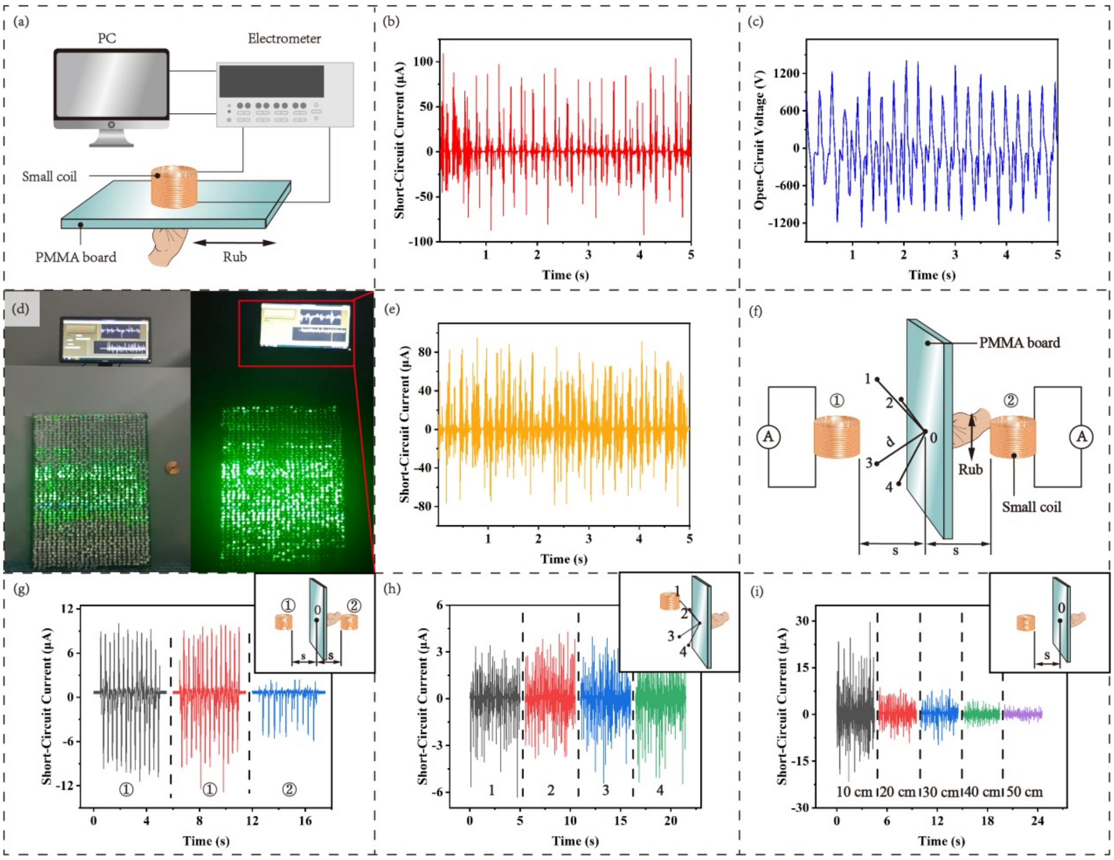

Figure 1. (a) Schematic diagram of collecting the electric field generated by rubbing. (b) The short-circuit current of coil and (c) open-circuit voltage when the PMMA board

was rubbed by hand. (d) The lighted lamp board with 1350 LEDs when the short-circuit current (e) produced in the nearby coil was measured by rubbing. (f) Schematic diagram of measuring the electric field generated by rubbing the PMMA board. (g) The influence of the coil ② on the current produced in the coil ①. (h) The short-circuit current produced in the coil at the position of the same distance from the central point. (i) The short-circuit current produced in the coil at different distances from the PMMA board.

When the speed of rubbing or tapping becomes faster, the induced current becomes higher and more energy can be collected by the coil in unit time. As shown in Figure 2a, the induced current in the closed copper coil increased as the speed of rubbing the PMMA board by hand (The setup in Figure 1a). Just like the law of electromagnetic induction, the magnetic induced current increases if the speed of rotating or moving is increased, when the magnetic field and the number of turns of the coil is fixed. Similarly, the iron wire in the coil can be magnetized when a current is passed through the coil. The scissors were put in the coil to test if the scissors can be magnetized, when the PMMA board was rubbed in the same direction by hand to generate induced direct current. As shown in Figure 2b, the scissors was taken out to approach the iron powder and the iron wire respectively, after a thousand times of rubbing on the PMMA board. Figure 2c and Figure 2d show that the scissors can attract the iron powder and even the iron wire, which shows that the scissors had been magnetized by the conduction current generated in the coil. In order to prove that the wire was attracted by the scissors due to the magnetic attraction, not the electrostatic attraction, the magnetized scissors were used to touch the compass. Electrostatic attraction can only produce the attraction, while the magnetic attraction can also produce repulsion. Figure 2e shows that the compass can be driven to rotate under the action of repulsion and attraction of the magnetized scissors. The electrostatic action can only attract the compass, but the action of magnetic field can produce the repulsive force. It proves that the scissors placed in the coil was magnetized by the current in the coil, which was produced by collecting the changing electric field generated by constant friction.

In order to investigate the field current (displacement current) generated by friction, various collectors were designed to collect more changing field current in the friction. As shown in Figure 2f, the friction block made of fluorinated ethylene propylene (FEP) film was used to rub the PMMA board to generate the field current, which can be collected by a specific circuit with conductive tape grid. As shown in Figure 2g and Figure 2h, the current and voltage can be 220 uA and 4500 V respectively, when the frequency of rubbing is 6-7 Hz. As shown in Figure 2i-k, the field current generated by continuously rubbing the PMMA board (20 cm*30 cm*3 mm) with the friction block can be collected by the collector and processed by the circuit, which can light a 1-watt bulb and charge a mobile phone. (Video S2 and Video S3) Besides, this is only a part of field current collected by the special circuit. It's hard to estimate how much energy can be generated by the friction, just like we could not imagine that 1-watt bulb can be lighted by the friction before. There may be a lot of potential field current generated by friction, which hasn't been collected at the moment.

According to the Faraday's law of electromagnetic induction, the changing magnetic field generates an electric field. One way is to fix the magnet and move the closed coil to cut the magnetic field lines, and the other way is to fix the closed coil and move the magnet. Two approaches are essentially the same as the above experiments, because there are changing energy fields generated by the external force. However, the source of the energy field is different. In the above two experiments, the energy field were generated under the action of external force, and the changing electric field was also produced under the external force. As for the electric field generated by electromagnetic induction, the source of energy field is closed-loop and self-circulating in the magnet. The changing electric field can be generated by the relative motion of the closed coil and magnet under the action of external force. Therefore, it seems that the essence of induced current is generated by the changing energy field.

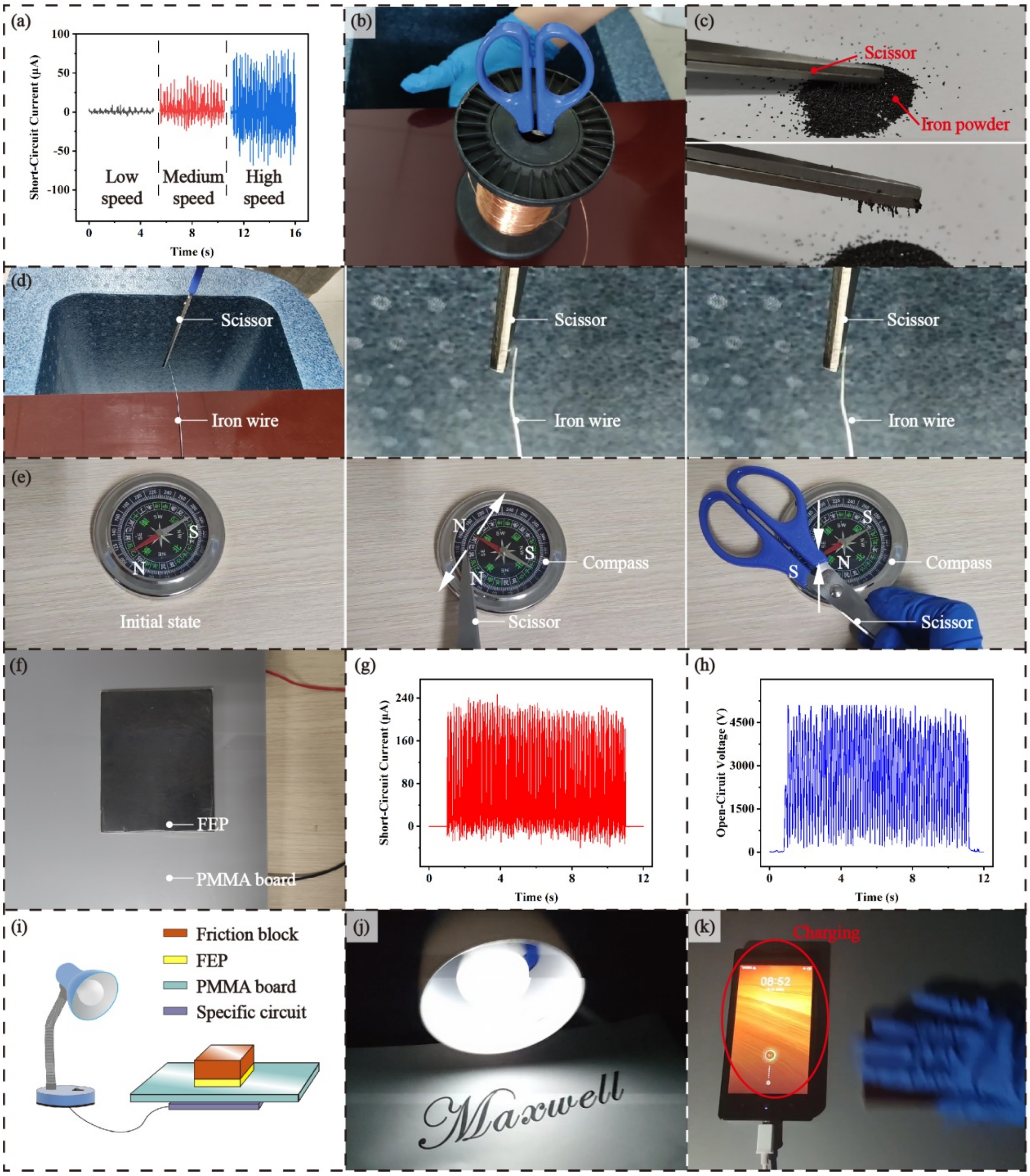

Figure 2 (a) The induced current of coil when the PMMA board was rubbed by hand with different speeds. (b) Photo of the experiment setup for the scissors magnetized by the generated energy field. (c, d) The iron powder and iron wire attracted by the magnetized scissors. (e) The compass under the action of repulsion and attraction of the magnetized scissors. (f) Photo of the experiment setup for collecting the energy field generated by rubbing the PMMA board with FEP friction block. (g) The short-circuit current and (h) open-circuit voltage of the specific circuit when the PMMA board was rubbed by the friction block. (i, j)1-watt bulb lighted up by the generated changing electric field. (k) A mobile phone charged by the generated changing electric field.

The above research shows that the electric field can be generated by friction, the changing electric field can be generated by constant friction, and the induced current (conduction current) and Maxwell's displacement current can be generated by the changing electric field. An electrostatic field can be generated after the friction, which will exist for a period of time after the friction is stopped. In following experiments, the changing electric field can be also generated by shaking an object with an electrostatic field. As shown in the Figure 3a, a plastic rod with an electrostatic field can be made by rubbing with fur, and it was waved near the coil to collect the changing electric field. As shown in the Figure 3b, there was an induced current generated in the closed coil, which can reach 0.5 uA. It shows that the changing electric field around the closed coil was generated by the constant movement of the plastic rod with the electrostatic field. Although the electrostatic field of plastic rod was continuously attenuated, this factor accounts for a small proportion. Different from the electromagnetic induction generated by the magnetic field, the magnet itself produces a stable closed-loop and self-circulating energy field. The induced current can be generated by the relative movement of the closed coil and the magnet. They are different, but they can be unified to be the induced current produced by the changing energy field. One is the electromagnetic induction generated by the relative movement of the closed coil and the magnet, while the other is the induced current generated by the relative movement of the closed coil and the plastic rod with an electrostatic field. Obviously, the energy collected by the coil is only part of the generated changing electric field, and the amount of energy collected by the collector is different under different conditions. As shown in Figure 3c, hundreds of LEDs can be lighted wirelessly when the plastic rod with an electrostatic field was shaken over the lamp board. (Video S4) The energy can be also collected by the conductors at the ends of LEDs although the LEDs were not connected to form a loop by wires. The field current generated by the changing energy field in the free space is corresponding to the classical Maxwell's displacement current. More importantly, the 28-watt fluorescent tube lamp can be also lighted up by the moving charged plastic rod in the Figure 3d. (Video S5)

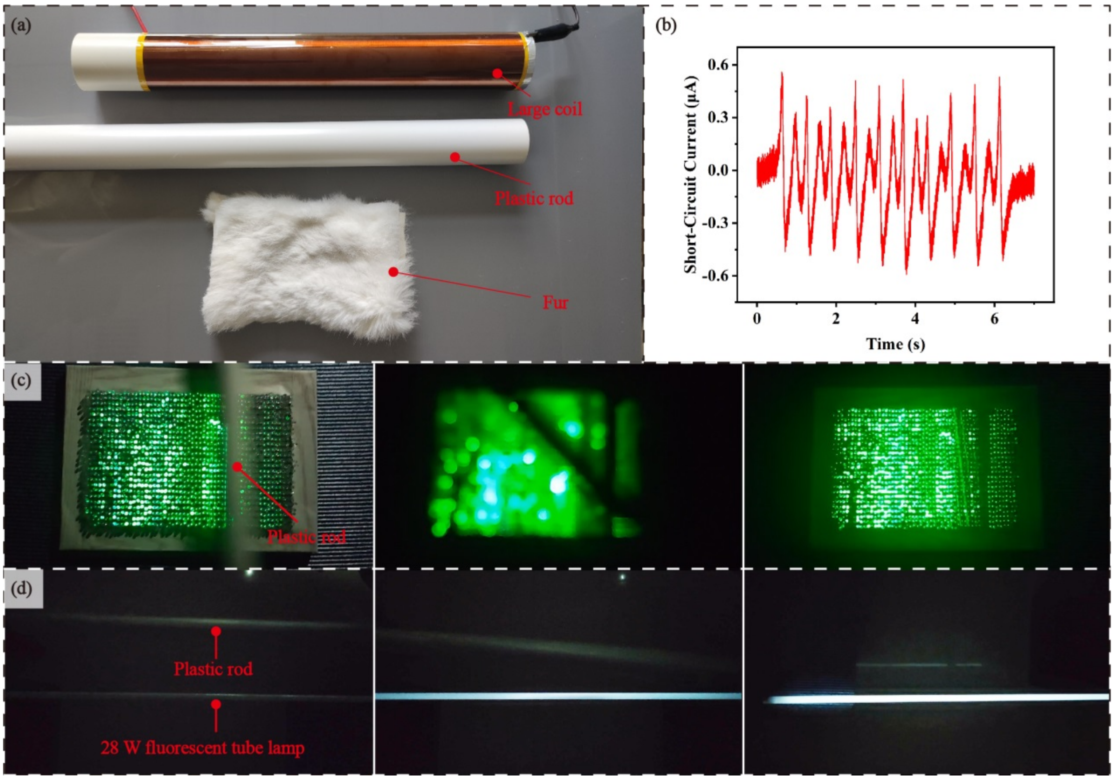

Figure 3 (a) Experiment setup of changing energy field generated by shaking a plastic rod charged by the fur. (b) The induced current in the coil when the charged plastic rod was waved. (c) The lamp board and (d) the 28-watt fluorescent tube lamp lighted by the waving charged plastic rod.

We further studied the characteristics of the changing electric field generated by the motion of an object with an electrostatic field. As shown in Figure 4a, a 28-watt fluorescent tube lamp and a large coil were placed at some distance on the same level, and a plastic rod with an electrostatic field produced by rubbing with a fur was constantly waved between them. As shown in Figure 4b and Figure 4c, a changing electric field in the space was generated by the motion of the plastic rod with the electrostatic field, which not only produced the conduction current of 0.6 uA in the coil, but also wirelessly lighted the 28-watt fluorescent tube lamp. (Video S6) Thus, when the plastic rod with the electrostatic field was waved in the air, there was a changing electric field. A part of the changing electric field collected by the coil generated the conduction current, and a part of changing electric field corresponding to part of the displacement current was collected by the 28-watt fluorescent tube lamp. Besides, the rest of changing electric field was not collected by the coil and fluorescent tube lamp and transmitted in the space, which is corresponding to the displacement current generated by the changing electric field.

To further investigate the nature of the changing electric field, we studied the energy fields generated by both the rubbed and non-rubbed ends of the plastic rod. As shown in Figure 4d, one end of the plastic rod was rubbed with fur, and then the rubbed end and the non-rubbed end of the plastic rod was waved over the coil. Figure 4e shows there was also induced current of 0.3 uA in the closed coil when the non-rubbed end of the plastic rod was waved next to the coil. Although the induced current was lower, it still shows there were differences in the strength of the energy field in different positions of the plastic rod. Next, two ends of the plastic rod (the rubbed end and the non-rubbed end) were connected with a wire to simulate a power supply, which generated a potential difference under the constant friction. As shown in Figure 4f, a short-circuit current of 75 uA was generated in the wire by continually rubbing one end of the plastic rod. Besides, we further investigated the magnetic effect of changing electric field through experiments. As shown in Figure 4g, the plastic rod was rubbed with fur and a rectifying bridge was used to rectify the conduction current generated in the wire, which was connected to the coil with an iron wire inside. As shown in Figure

Xia Cao E-mail: caoxia@ustb.edu.cn

4h, the iron wire was slightly magnetized after rubbing for several thousand times, because the current is low and intermittent. The iron powder can be attracted by the magnetized iron wire, which indicates that the magnetic effect of the induced current generated by friction is consistent with the magnetic effect of the conduction current in the traditional closed circuit.

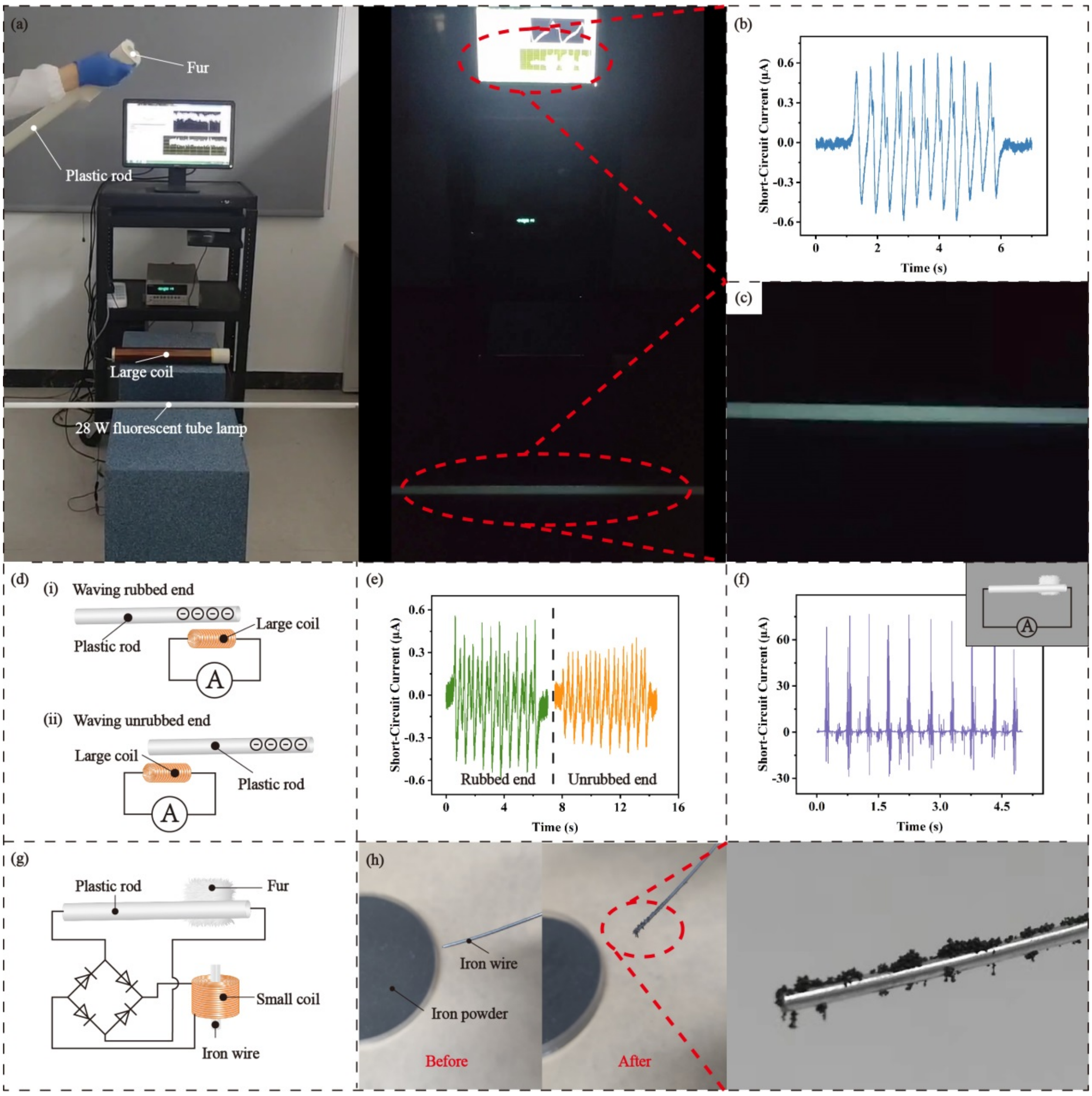

Figure 4 (a) The lighted 28-watt fluorescent tube lamp when the short-circuit current (b) produced in the nearby coil was measured by waving the plastic rod with an electrostatic field. (c) The lighted 28-watt fluorescent tube lamp. (d) Schematic diagram of comparison of energy field generated by shaking the rubbed or the non-rubbed end of the plastic rod. (e) The currents produced in the coil when the rubbed or the non-rubbed end of the plastic rod was waved next to the coil. (f) The short-circuit current of two ends of the plastic rod connected with a wire when one end was rubbed by fur. (g) Schematic diagram of iron wire was magnetized by the coil connected to the plastic rod and a rectifier bridge. (h) The iron powder attracted by the magnetized iron wire.

Now, the energy field can be discussed further. The last two equations of Maxwell's equations mainly unify the electric field and magnetic field. A changing magnetic field gives rise to an induced current, and a flowing electric current or displacement field can produce a magnetic field. However, it has always been difficult to clarify the relationship that the electricity is magnetism, and the magnetism is electricity. As shown in Figure 5a-(i-iii), an electric field will be generated, as long as the PMMA board is tapped or rubbed by the hand. The electric field is open-loop acyclic field and electric field lines start from the positive charges and end at the negative charges or the infinity. When the hand is removed from the board, the electric field gradually weakens over time. A constantly changing electric field can be generated when there is constant tapping or rubbing. The changing electric field can be collected by the coils. Figure 5a-(iv-vi) show an induced current can be produced in the coils when the board was tapped by hand continuously and vertically. Figure 5a-(vii-ix) show an induced current can be also produced in the coils when the board was rubbed by hand continuously and horizontally, which is consistent with the previous experimental results.

In fact, the magnetic field and the electric field can be collectively called the energy field. Besides, magnetic field lines and electric field lines are collectively called the energy field lines. The relationship between magnetic field and electric field was further investigated. As shown in Figure 5b, a magnet can spontaneously produce a circulating energy field. The energy field is closed-loop and self-circulating that the field's lines exit the magnet from its north pole (N pole) and enter its south pole (S pole). As shown in Figure 5c, the traditional electrostatic fields (positive electric field, negative electric field) are open-loop acyclic field, such as the electric field generated by the triboelectricity, and the electric field of disconnected flat electrode plates. For the individual charged body, it exhibits the properties of electric field. If the energy fields of different strengths are connected, energy will be in a state of flow and circulation and the whole system exhibits the properties of magnetic field. As shown in Figure 5d-(i-ii), one end of the plastic rod has more energy after it is rubbed by the fur, and the other end has less energy. There is an energy difference between the two ends. As shown in Figure 5d-(iii), the energy field becomes in a state of flow and circulation and there are a current in the wire and a magnetic field at the same time, when the rubbed and non-rubbed ends of the plastic rod are connected by a wire.

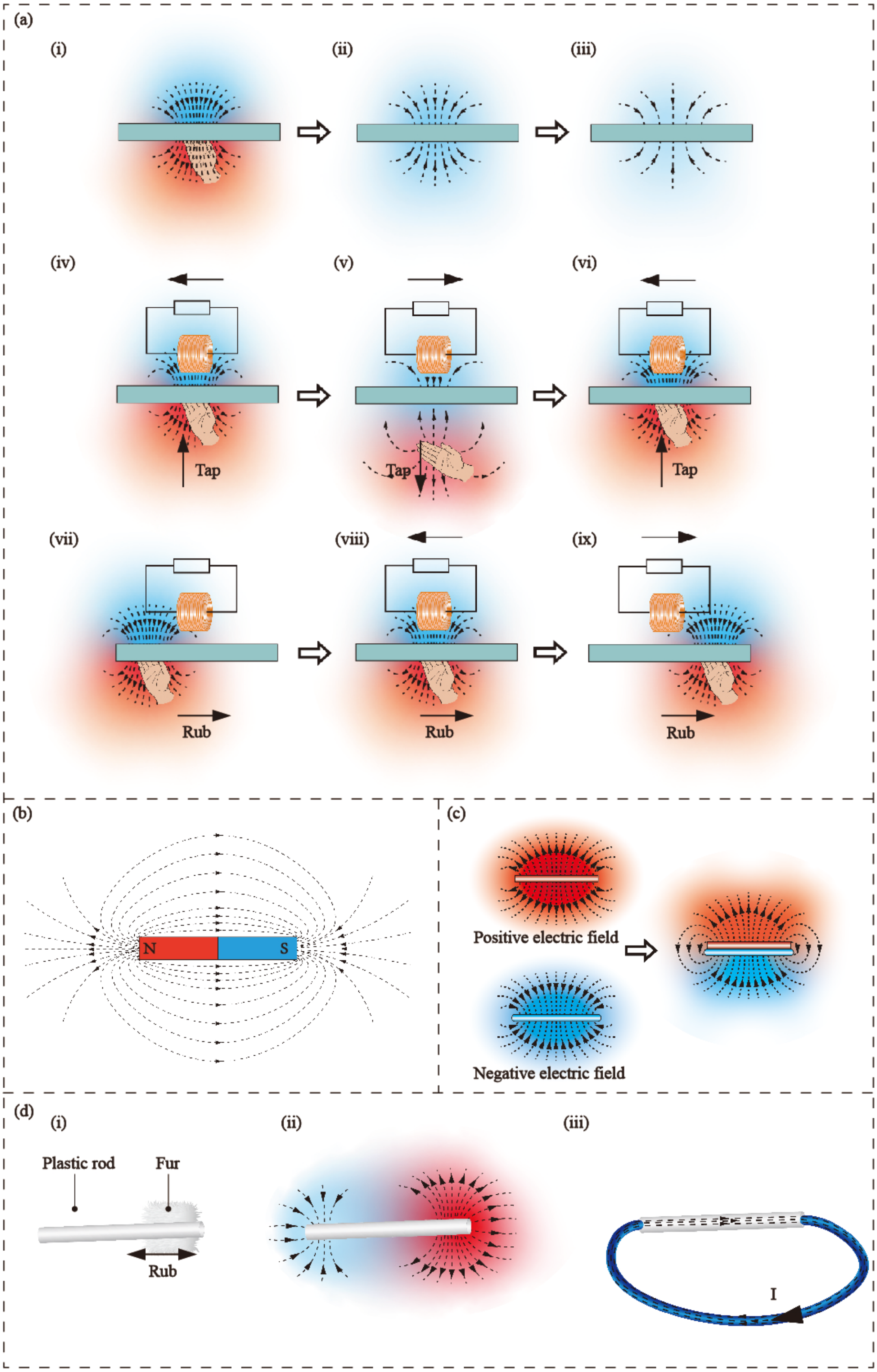

Figure 5 (a) The changing electric field generated by constant tapping or rubbing. (b)

The closed-loop and self-circulating field of a magnet. (c) The magnetic field produced by connecting the positive electric field and negative electric field. (d) The magnetic field produced by connecting the rubbed and non-rubbed end of the plastic rod by the wire.

The relationship between the electricity and the magnetism was further investigated by exploring the magnetic effect of electric current. As shown in Figure 6a-(i), the ends of two wires show the open-loop acyclic field, when the positive pole and negative pole of a battery are respectively connected by two wires. As shown in Figure 6a-(ii-iii), the electric current and magnetic field will be generated as long as the other ends of two wires are connected, and the compass is affected by the magnetic effect of electric current. The whole system exhibits the properties of magnetic field, which is a very mature experimental phenomenon. The dry battery and compass were used for the comparative experiment. Figure 6b-(i-ii) shows there was a clockwise rotation in the compass, when the switch was turned on and an electric current was produced in the wire. Figure 6b-(iii-iv) shows there was a counterclockwise rotation in the compass, when the direction of electric current was reversed. However, the system exhibits the properties of electrostatic field when two wires are disconnected. Because the current produced in the wire as the collector was relatively small, two large pieces of copper foil as collectors were attached to the inside of the plastic rod to collect the changing energy field. As shown in Figure 6c, a 1-watt bulb can be lighted after the energy field generated by rubbing the plastic rod with fur was collected and processed

Xia Cao E-mail: caoxia@ustb.edu.cn

by the circuit. Figure 6d shows that a conduction current of 85 uA can be generated by continually rubbing the plastic rod. Although the current is not enough to generate the magnetic field to deflect the compass, it can also account for the presence of a magnetic field around the wire. The magnetic effect can be produced by connecting the two ends of the power supply with wires, because the energy difference between two ends of the plastic rod like a pulse power supply was generated by constant friction.

Based on the above experimental findings and discussions, it can be believed that the last two items of Maxwell's equation (4) are essentially the same. The electric current can be produced by a changing electric field. The energy can be collected as long as the field changes relatively, whether it is a traditional magnetic field or an energy field generated by an external force. The part of the energy collected by the wire is called as the conduction energy (electrical energy, effective energy, conduction current). The changing energy field leaking outside is called as the displacement current (unutilized energy field). Compared with the traditional definition, both the conduction current and displacement current are generated by a changing energy field. Magnetic field and electric field are collectively called as energy fields, which are different forms of energy field in different states. Therefore, conduction current and displacement current are essentially the same, which are produced by the changing energy fields. When a wire or a closed coil is placed in a changing energy field, the conduction current is generated in the wire or coil so that the energy can be collected.

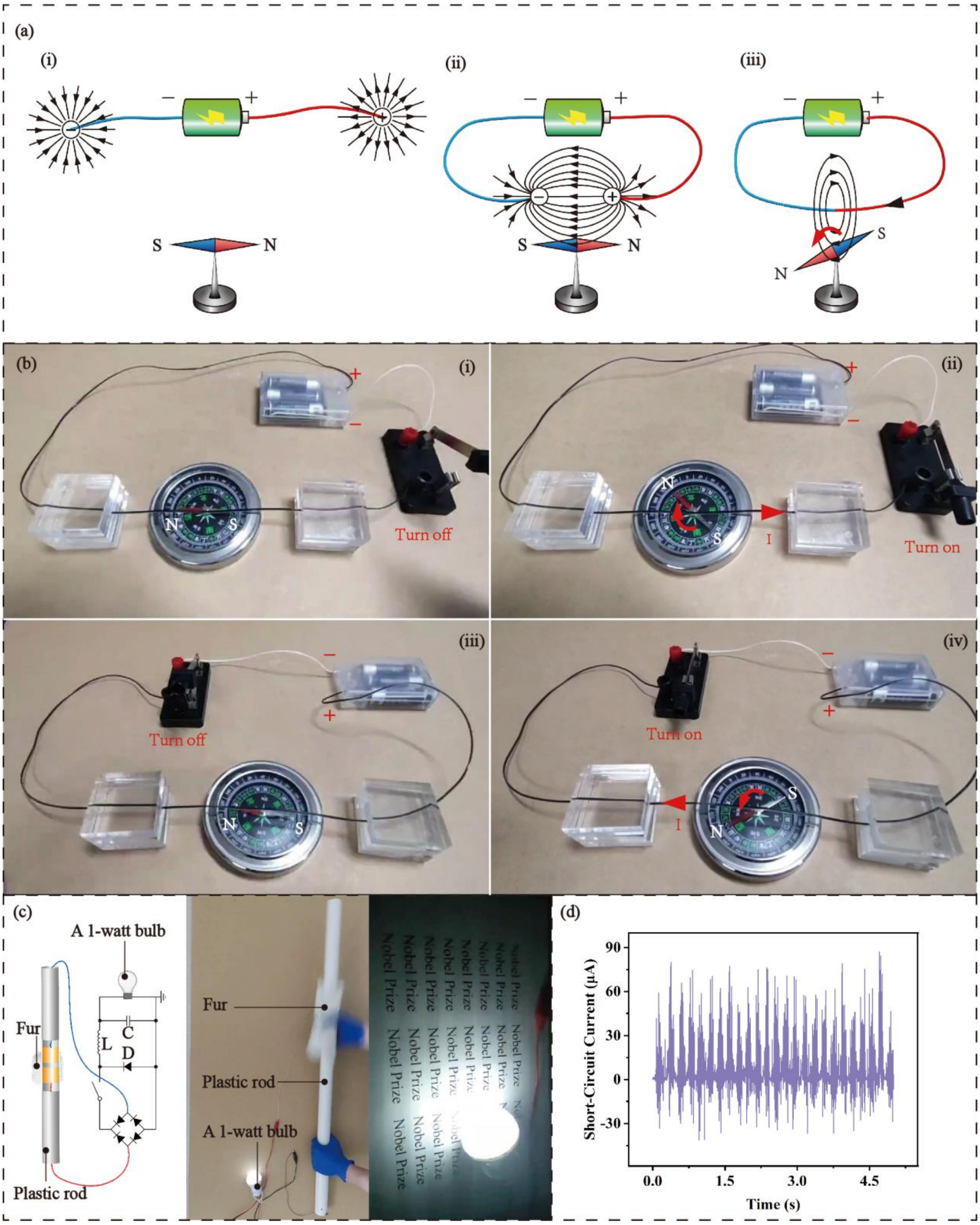

Figure 6 (a, b) The compass affected by the magnetic field produced by connecting the positive pole and negative pole of a battery. (c) A 1-watt bulb lighted with the collector and circuit by collecting the energy field generated by rubbing the plastic rod with fur. (d) The conduction current in the wire generated by continually rubbing the plastic rod.

Based on the above experimental results, Maxwell's equations can be reconsidered. The first equation (1) shows the Gauss's law for electricity, which actually indicates the properties of electric field exhibited by an open-loop acyclic field, such as the electrostatic attraction. The second equation (2) is the Gauss's law for magnetism that confirms that the magnetic field of magnet is a closed-loop self-circulating field, which is a relatively stable closed-loop self-circulating field from the N pole to the S pole. The third equation (3) is the Faraday's law of electromagnetic induction. The magnet is surrounded by a relatively stable closed-loop self-circulating field, so conduction current can be generated by the changing magnetic field due to the relative motion of a closed coil and a magnet. Because the field generated by the magnet is a relatively stable closed-loop field, the coil must be closed so that it can move relatively to the magnetic field to produce the changing magnetic field in the coil. However, the essence is that the induced conduction current is produced by the changing energy field. As for the fourth equation (4), the changing electric field produces Maxwell's displacement current and conduction current. In essence, the changing energy field generates an electric field. In the experiments, the part of the changing electric field collected by the wire (coil) becomes the induced conduction current, while the other part that has not been collected is the field current (Maxwell's displacement current). Therefore, the equation (3) and equation (4) can be unified that the changing energy field produces the field current, which is collected by the coil to form the conduction current. Four Maxwell's equations are essentially the same that are all about the content of the energy field. The equation (1) and equation (4) represent the properties of an open-loop acyclic energy field, such as the electrostatic attraction, and conduction current can be produced by the changing open-loop acyclic energy field. The equation (2) and equation (3) indicate that the closed-loop self-circulating energy field shows the properties of magnetic field, and the changing closed-loop self-circulating energy field can produce conduction current. On the whole, the energy field is magnetic when it is in the closed-loop self-circulating state, and the energy field is electric when it is in the open-loop acyclic state. No matter whether the energy field is closed-loop or open-loop, the energy field can be collected by the coil to generate an induced conduction current as long as the energy field changes. Besides, the part of energy field that is not collected in the space corresponds to the displacement current (field current). In general, Maxwell's equations describe the properties of energy field.

3. Conclusions

In summary, an electric field can be generated by friction, the changing electric field can be generated by constant friction, and there will be the electrostatic field when the friction stops. The changing electric field can be generated by tapping or rubbing a PMMA board or rubbing a plastic rod, and an induced current can be produced in the closed coil placed in the changing electric field. More importantly, the changing electric field can not only produce an induced current in the closed coil, but also wirelessly light the 28-watt fluorescent tube lamp and the LED lamp board. It has been proved that both the field current (displacement current) and conduction current exist, and the field current can be collected to be conduction current by a coil or wire to flow in a conductor.

Therefore, it can be found that the third equation and fourth equation of Maxwell's equations are essentially the same. Both are generated by the changing energy field, and they are essentially the displacement current generated by the changing electric field. The part of energy field collected by wire is the conduction current, while the other part is the displacement current (in the traditional formula) that is not collected. Electric field and magnetic field are two different properties exhibited by the energy field. The essence of Maxwell's equations and related laws are two different phenomena resulting from energy field in the closed-loop self-circulating state or open-loop acyclic state. The first equation describes an open-loop static energy field, and the second equation describes a closed-loop static energy field. The third equation describes how the induced conduction current can be generated in the closed-loop energy field, and the fourth equation describes how the induced conduction current can be generated in open-loop energy field. Based on the new experimental discoveries and through the combination of experiments and theory, this work will have a disruptive impact on the development of Maxwell's equations, electromagnetic theory and new energy.

4. Experimental methods

The collection of the electric energy generated by rubbing

The small coil (0.15 mm) was placed on the PMMA board or at a specific position relative to the PMMA board. The current and voltage generated in the coil were measured when the PMMA board was rubbed by hand.

The scissors magnetized by the energy field generated by rubbing

The medium coil (0.25 mm) was placed on the PMMA board, and a non-magnetic scissors was put into the inner cylinder of the coil. The PMMA board was rubbed continuously by hand wearing nitrile gloves. After the scissors was magnetized, it was used to attract the iron powder and the partially dangling iron wire. Then two poles of the magnetized scissors were respectively taken to approach the compass and observe the rotation of the compass.

The collection of the energy field by the specific circuit

A specific circuit with conductive tape grid was placed on the bottom of a PMMA board (20 cm*30 cm*3 mm). Each piece of conductive tape grid was connected to a diode one by one, and the diodes were connected in series. A friction block made of fluorinated ethylene propylene (FEP) was used to rub the surface of the PMMA board, and the specific circuit was used to collect the generated energy field. Besides, two large pieces of copper foil as collectors were attached to the inside of the plastic rod to collect the changing energy field. A fur was used to continually rubbing the plastic rod.

The changing energy field generated by shaking a charged rod

One end of the plastic rod was rubbed with the fur, and the rubbed or non-rubbed end of the plastic rod was respectively waved on the large coil (0.3 mm) in the direction perpendicular to the axis of the coil. A plastic rod charged by rubbing was waved to light a fluorescent tube lamp or a lamp board (1350 LEDs in series). A rubber rod was rubbed with the fur, and a glass rod was rubbed with the silk. And the charged rods were waved over the lamp board to light the LEDs.

The iron wire magnetized by the energy field generated by rubbing

The two ends of a large coil were connected by wire to the rubbed and non-rubbed ends of the plastic rod respectively. The iron wire was placed in the coil, and the fur was used to rub the plastic rod continuously. After a period of time, the iron wire was taken out to attract the iron powder.

Electrical measurement

The current was measured by an electrometer (Keithley 6514) with computer measurement software written in LabVIEW. The voltage was measured by a digital oscilloscope (Agilent DSO1012A).

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