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Harvesting Atmospheric Ions Using Surface Electromagnetic Wave Technologies

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Abstract

For the first time, this paper discloses the use of flowing water for capturing atmospheric ions into a DC electricity. The proposed methodology can be employed to neutralize the positively charged pollutants in air, which are believed to be harmful to our health. Methodology: Atmospheric ions can be collected by a negatively charged antenna which comprises a dielectric layer sandwiched between a top aluminium layer and a bottom lead plate. The top aluminium layer is used to collect the ambient protons, whilst the bottom lead plate is negatively charged by a negative static electricity extracted from flowing water. The voltage has been measured between the top aluminium layer and the bottom lead plate with and without any sunlight. Results: Without any UV light or other electromagnetic disturbance, the generated voltage has rapidly increased from 200 mV to 480 mV within 5 seconds if the bottom lead plate is connected to the negative ion source. Without the negative ion source, however, the output voltage fell to around 10 mV and any significant voltage rise can be observed even in the presence of an UV light. Conclusions: Capturing atmospheric ions is technically feasible. Measured results suggest that, when used in conjunction with a negative ion source, the proposed device can harvest atmospheric ions without any UV light.

Keywords: cosmic rays, surface plasmon polarition, surface plasmonic resonance, Kelvin water dropper, Kelvin thunder

1. Introduction

Solar energy has been proposed as an alternative to fuel based energy sources which release tons of pollutants to our atmosphere on a daily basis. However, conventional solar cells are usually inactive before 6 am or after 6 pm. There have been many suggestions to overcome this issue. One suggestion is to use molten salts to store the sun's heat during the day so that power can be obtained by cooling during the evening time [1, 2]. French National Center for Scientific Research and the University of Tokyo has suggested mounting a solar panel in a high-flying balloon to tap solar energy above the clouds [2]. Unfortunately, neither of these solutions can be carried easily with household facilities.

What is little known is an energy source known as Cosmic rays. Cosmic rays which come from exploding stars from light years away can be harvested during the evening time. Cosmic rays are ionizing particles of cosmic origin traveling at near the speed of light [3-5]. The majority of cosmic particles are the nuclei of atoms, mostly protons. As these cosmic particles penetrate into the ionosphere, they induce nuclear-electromagnetic cascade ionizing air molecules all the way down to the surface of the Earth. The earth is an entity carrying negative charges, which repels the negative ions on the surface of earth. As a result of the earth's intrinsic negativity, air pollution and the cosmic ray induced ionization, the density of these positive ions in the lower atmosphere becomes 10-20% higher than the negative ions. The surface of the Earth, these positive ions mainly include positively charged dusts, bacteria, pollen, chemicals and fumes. The buildup of these excessive positive ions can be removed and turned into energy when they are attracted to an artificial source of negative charges. If these negative charges are freely abundant, then the amount of energy generated will be positively associated with the density of positive ions in the regions where atmospheric ions is to be harvested.

The most basic atmospheric ion collector was invented by Nikola Tesla in 1901 [6-7]. In his atmospheric ion collector, an antenna is used to collect cosmic particles or positive ions. The antenna comprises a sheet of optically smooth metal completely encapsulated in a dielectric. The antenna serves two purposes: 1) it collects the ultraviolet radiations in the form of surface electromagnetic waves; and 2) it attracts atmospheric ions. The captured radiations or a positive ion increases the voltage of the antenna with respect to the service earth connection. The condenser connected between the antenna and the earth has a high capacitance, thereby creating a high electrostatic suction to attract ions at high altitudes. When the voltage is high enough, it charges up a capacitor or a battery. Some researchers have replicated the Tesla's experiment with limited success [8-13]. However, this kind of atmospheric ion collectors do not work well when placed at low altitudes, where the density of the atmospheric ions is simply too low.

In the field of astrophysics, cosmic radiations are usually detected using a scintillator [14]. For example, an array of scintillator surface detectors samples the footprint of the cosmic-ray shower when it reaches the Earth's surface. A fluorescence telescope is used to measure the scintillation light generated as the shower passes through the atmosphere. While this technique is highly useful for the purposes of detection of cosmic rays, it may not be readily useful for neutralization of positively charged pollutants at low altitudes.

For the first time, this paper proposes a novel collector which uses flowing water as an energy source to capture positively atmospheric ions on the surface of the earth.

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2. Proposed antenna for collecting positively charged air ions

To harvest atmospheric ions, it is important to understand which frequency bands are available for direct energy harvesting. These frequency bands will determine what metal is to be used for the antenna (i.e. the part for capturing cosmic radiations). Fig. 1 shows a spectrum of radiations from outer-space. It can be seen from Fig. 1 that ultraviolet radiations are the only frequency band at which ionizing energy can be conveniently captured at the ground level [15]. These ultraviolet radiations are mainly of solar origin. A small amount of atmospheric ions come from these ultraviolet radiations.

The oxygen and ozone molecules in the atmosphere absorb most of the cosmic radiations from outer-space, including the x-rays and gamma-rays from the galaxy. There is no direct access to the primary cosmic particles on the surface of the Earth. However, it is incorrect to assume that atmospheric ions cannot be harvested on the surface of the Earth. The nuclei, the x-rays and the gamma-rays from the galaxy constantly induce cosmic cascades in the ionosphere, releasing a large amount of energetic ions that are far more penetrating.

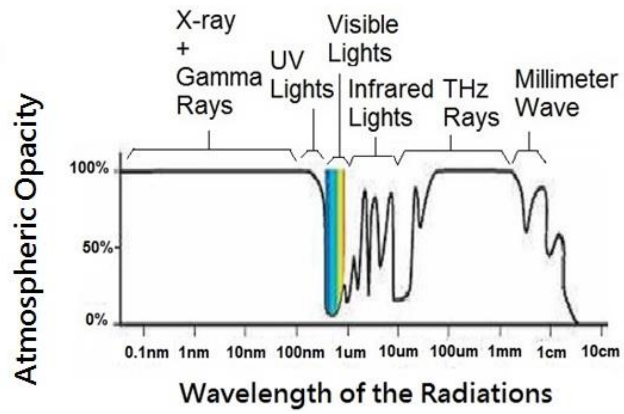

Fig. 1 Available spectrum for energy harvesting [15]

To maximize the energy which can be harvested, therefore, the antenna should be designed in such a way that it can capture not only ultraviolet radiations from the sun, but also the free ions that are moving randomly in the atmosphere. These two requirements can be easily fulfilled by following the following design strategies:

(1) The incoming UV light must be captured in the form of surface electromagnetic waves, which is concentrated on the surface. Either aluminum or silver should be used as the metal for capturing ultraviolet lights because these two metals naturally have a surface plasmonic resonance frequency right at the ultraviolet band; and

(2) On the other hand, the metal for the antenna, which can be aluminum or silver, should be biased to certain voltage so that it naturally attracts the nearby atmospheric protons. This can be done by connecting the metal indirectly to a source of negative charges.

(3) The induced current must be directed from the positive end, which is the antenna in this case, towards the negative end, which is the source of negative charges. This can be done with a high reverse breakdown voltage.

(4) The surface area of the antenna should be as large as possible in ways to maximize the chance of ionization.

(5) All the metal used in the collector should not be exposed and should be dielectrically coated in a way to minimize the charge leakage.

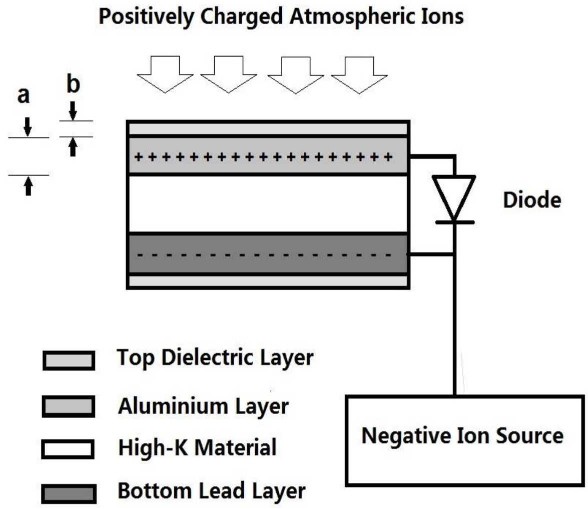

Fig. 2 Antenna for capturing atmospheric positive ions and cosmic particles

When the bottom lead plate is negatively charged by a negative ion source, the top aluminum layer will be electrostatically induced to a positive potential. If the top aluminum layer is fully covered by the dielectric coating, then the surface of the top dielectric coating will become negative. The atmospheric positive ions will be attracted to the surface of the top dielectric coating and the top aluminum layer will be further charged positively by electrostatic induction. When the potential difference between the top aluminum layer and the bottom lead plate exceeds the threshold voltage of the diode, a current will form.

In addition to the atmospheric positive ions, some other cosmic-ray induced particles or ultraviolet radiations from the sun also play a role in ionization. The fast-moving particles in these radiations will be slowed down significantly as they reach the top dielectric layer. The cosmic radiations are ionizing. When the atmospheric ions reach the aluminum layer, ionization is expected to occur. The energy that is created due to this ionization process is mainly electromagnetic in nature. This electromagnetic energy can either be trapped as a result of the intrinsic localized surface plasmon resonance in aluminum or be transmitted as a surface electromagnetic wave, also known as surface plasmon polariton. Surface electromagnetic wave differs from the conventional electromagnetic wave in that the former propagates along the interface between two different media whilst the latter propagates through the 3D dimensional space. Unlike the conventional electromagnetic wave, which is radiating in all directions, surface electromagnetic waves tend to be transmitted in a more concentrated manner.

The efficiency of this surface plasmon polaritan can be optimized by making sure the antenna reaches the surface plasmonic resonance. The surface plasmon resonance occurs when the leaky modes are minimum and the propagation modes are maximum, according to [16]. In the structure as shown in Fig. 2, a complete surface plasmon resonance condition will occur mainly at the interface between the top dielectric layer and the aluminum layer (also referred as MI structure) and, to some extent, in the high-k material between the aluminum layer and the bottom lead plate (also referred as MIM structure). During surface plasmon resonance, most of the energy will concentrate in the horizontal direction in the forms of propagation modes and there should be very little leakage in the form of radiations in the vertical direction.

2.1. Surface plasmon resonance for the MI structure

To attain surface plasmon resonance condition in the MI structure (that is, the interface between the top dielectric layer and the aluminum layer), the criterion shown in Eq. (1) and (2) must be met, according to [16]:

$$\varepsilon_a a_a + \varepsilon_b a_b = 0 \tag{1}$$

where ε_a and ε_b are respectively the dielectric constants of the dielectric coating and the aluminum layer. a_a and a_b are respectively the thicknesses of the dielectric coating and the aluminum layer. The dielectric constant of aluminum is obtained according to the Drude's model. At UV-C band frequencies, the dielectric constant of aluminum is about -12. Dielectric constant of the top dielectric layer is in the neighborhood of 3. The aluminum thickness b is about 100 microns. According to Eq. (1), since a layer of PMMA of 30 micron in thickness has been coated on the top of the aluminum layer.

The other condition required for surface plasmon resonance in the MI structure is [16]:

$$\frac{k_a}{\varepsilon_a} + \frac{k_b}{\varepsilon_b} = 0 \tag{2}$$

where k_a and k_b are propagation constants for top dielectric layer a and the aluminum layer b. They can be computed using the following mathematical relationships [16]:

$$k_a^2 = k_x^2 - \varepsilon_a k_0^2 \tag{3}$$

$$k_b^2 = k_x^2 - \varepsilon_b k_0^2 \tag{4}$$

k_o is the propagation constant of vacuum in the horizontal axis. k_x is the propagation constant in the direction of propagation.

2.2. Surface plasmon resonance for the MIM structure

To attain this resonance condition in the MIM structure (that is, the high-k dielectric between the aluminum layer and the bottom lead plate), the following criterion shown in Eq. (5) and (6) must be met. The first condition is [16]:

$$\varepsilon_b a_b + \varepsilon_c a_c + \varepsilon_d a_d = 0 \tag{5}$$

where ε_b , ε_c and ε_d are respectively the dielectric constants of the aluminum layer, the high-k material and the bottom lead plate. In addition, a_b, a_c and a_d are respectively the thicknesses of the aluminum layer, the high-k material and the bottom lead plate. Dielectric constant of the high-k material is in the neighborhood of 10. The thickness of the bottom lead plate d is about 300 microns. According to Eq. (5), the thickness of the high-k material should be 72 microns.

The other condition required for surface plasmon resonance in the MIM structure is [16]:

$$\frac{k_b}{\varepsilon_b} + \frac{k_c}{\varepsilon_c} + \frac{k_d}{\varepsilon_d} = 0 \tag{6}$$

where k_b, k_c and k_d are respectively propagation constants for the aluminum layer, the high-k material and the bottom lead plate.

3. Negative ion source

To counter balance the incoming positive charges accumulated on the top of the antenna, there must be a corresponding negative charge source. This negative charge source can be generated through frictions between two insulators. In this work, the two insulators are water and plastic. Fig. 3 illustrates the whole system for harvesting energy from cosmic radiations and atmospheric ions. The sub-system highlighted by the box on the left is the negative ion source capable of generating a negative voltage with respect to the ground out of flowing water. In the negative ion source as shown in Fig. 3, the ends of the plastic tube act as the water inlet and the water outlet. The water inlet and the water outlet are respectively fastened with metal ring A and metal ring B. These metal rings never touch water but, between the metal rings and the flowing water, the dielectric material must have a high dielectric constant. Between these two metal rings, pin A, pin B and the ground pin are nailed into the plastic tube, submerging into the water flowing through the plastic tube. Pin A is wired to metal ring B, whilst pin B is wired to metal ring A. The ground pin, GND, is wired to the metal faucet. The ground pin can also be shorted to pin A without negatively affecting the measured results. Since water is an insulator, running water through the plastic tube will generate static electricity in the inner surface of the plastic tube. Assume that the water running at the region close to metal ring A is positively charged. Metal ring A will be electrostatically induced to a negative potential, whilst pin A will carry a positive potential. Since pin A is wired to metal ring B, the water at the region close to metal ring B and pin B will be negatively charged. The wire connection between pin B and metal ring A forms a positive feedback which amplifies their negative potential. By the same token, the wire connection between pin A and metal ring B forms another positive feedback, amplifying their positive potential.

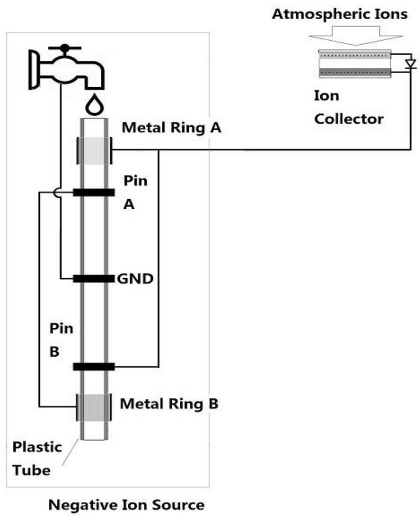

Fig. 3 Schematic view of the prototype modeling the whole atmospheric ions collecting system

As shown in Fig. 3, the ions in water tend to have a short-circuit effect on the pathway between Pin A and the ground and on the pathway between the ground and Pin B. To increase the negative charge for the antenna, it is important to decrease the mobility of ions in the region between Pin A and the ground or in the region between Pin B and the ground.

4. Measurements

The prototype as shown in Fig. 3 has been constructed and its performance has been measured with and without sunlight in the eleventh floor of a building based in Shenzhen. We have used a voltmeter (RIGOL DM3051) to measure the voltage across the diode as shown in Fig. 3 at different times of the day. During the measurement, all the sources of electromagnetic disturbance has been removed, or placed very far away from the proposed system, to rule out any possibility of any non-cosmic energy source.

The measurement setup is illustrated in Fig. 4. The same measurement was taken repeated every lunch break and evening throughout the last month of autumn. Our findings are summarized in the following table:

Table 1 Measured voltage across the diode when the water was running at 150 cm 3 per second

Situations	General Observations	Final Voltage	Starting voltage	Starting voltage between the top Al layer and the ground
With sunlight	Voltage rose steadily for 5 seconds	~680 mV	200 mV	350 mV
Without any sunlight	Voltage rose steadily for 5 seconds	~450 mV	200 mV	350mV

Fig. 4 Measurement Setup

The voltage between pin A and the ground pin of the proposed negative ion source was very stable and it tends to increases when the water flow rate increases. When water flow rate increases, the final voltage across the diode also increases with approximately a delay of 2 seconds. This is due to the fact that the atmospheric ions that can be harvested are positively associated with quantity of negative charges from the negative ion source.

When the bottom lead plate is disconnected from the negative ion source, however, the output voltage fell to around 10 mV and no significant voltage rise can be observed even in the presence of an UV light.

The voltage between the top aluminium layer and the ground connection has been successfully used to charge up a 470 uF capacitor.

The experimental setup was found to be highly sensitive to external electromagnetic disturbance. It was found that placing a lit compact fluorescent next to the proposed antenna can cause huge jump in the measured voltage.

5. Discussions

In this work, the process of ion harvesting, which is mainly driven by flowing water, does not necessitate consumption of fuels to operate. This water can flow from natural sources, including waterfalls, springs, heavy rainfall, tidal waves or rivers. Flowing water carries ions which can be further polarized in the proposed negative ion source. The ions from the proposed negative ion source contribute to a potential difference which can be further increased by connecting the proposed negative ion source in series. The end result is that the output voltage will increases, depending on how many of these proposed negative ion source are connected in series.

Table 1 shows that the output voltages measured with and without sunlight are clearly very different. Sunlight, background radiations or other forms of electromagnetic disturbance can lead to increased voltage across the diode, suggesting that there are indeed background radiations or atmospheric ions being captured. The quantity of the negative charges from the negative ion source determines how much and how fast the energy from atmospheric ions can be captured into a DC electricity. Unlike a conventional solar panel, this energy can be continuously harnessed throughout the day.

In general, the purer the water is, the more negative charges can be generated from the negative ion source. Impure water contains ions which neutralize the generated electrostatic charges. However, our latest experimental results suggest that sea water yields a much higher voltage.

Increasing the ionization rate is the key to improve the efficiency of an atmospheric ion collector. The expression for rate of ionization at different altitudes, q(h) or different phases of solar cycle can be summarized by the following equation [17-21]:

$$q(h)=\frac{\sum i\int_{Ei}^{\infty}\int_{A=0}^{2\pi}\int_{\theta=0}^{\frac{\pi}{2}+\Delta\theta} D_{(i)}(E)\left(\frac{dE}{dh}\right)_{(i)}\sin(\theta)\,d\theta\,dA\,dE}{Q} \tag{7}$$

where (dE/dh) are ionization losses [23-24] of particles of type i, A is the azimuth angle and θ is the angle towards the vertical. dh takes into account that at a given height h that the particles can penetrate from the space angle (0, hmax=90+dθ), which is greater than the upper hemisphere angle (0, 90) for flat model. $D_{i(}(E)$ is the cosmic ray differential spectrum that can be used to calculate cosmic rays during different phases of solar cycle [16-18].

Ionization in the atmosphere takes place as a result of cosmic radiations or ultraviolet radiations. Mounting the atmospheric ion collector at high altitudes in theory can lead to higher ionization rates. Mounting a device at high altitudes is not always practically realistic. However, there are alternatives.

At ground levels, air pollution is major source of positive ions that can be easily captured using the proposed device. Other ionization sources include the ultraviolet radiations from sporadic solar energetic particles, cosmic rays and the ions due to the natural radioactivity of the soil which is blamed for the unwanted radon gas.

Ultraviolet radiations tend to be intensive in ozone depleted regions, where the air is usually saturated with positively charged air pollutants. During the process of electricity generation using the proposed technology, the negative charges from the proposed atmospheric ion collector will neutralize the positively charged pollutants in air to some extent. Whether the energy comes from UV light, cosmic radiations or from positively charged pollutants, the total of the energy that can be captured depends very much on the sun and the detectable solar activity. Hence, it also depends on the diurnal (time of day) effect and a seasonal effect. Levels of ionization tend to be low during the winter time because the Sun is farther away. The activity of the Sun is also associated with the sunspot cycle. There will be more solar radiations when the sun is active.

Positive ions are known to be detrimental to our health. The atmospheric positive ions are electrostatically attracted to the body, which naturally carries negative charges, and cause oxidative damages. There have been published reports on the link between lack of negative ions in the body and ailments, including headaches, and/or fatigue [23-24]. In 2013, the International Agency for Research on Cancer (IARC) even classified these particulates as a carcinogen [23]. In its evaluation, the IARC showed an increasing risk of lung cancer with increasing levels of exposure to outdoor air pollution and particulate matter. The process of energy harvesting, which is mainly driven by gravity, involves neutralization of atmospheric positive ions. Harvesting atmospheric ions in areas plagued by air pollution is one of the few solutions to nullify the harmful effects of the excessive accumulation of positively charged pollutants in the atmosphere.

6. Conclusions

In this paper, we have proposed the use of flowing water for capturing atmospheric ions into a DC voltage. Measurement has been performed with and without any sunlight. Measured results suggest that atmospheric ions can be harvested to an observable extent by the proposed atmospheric ion collectors with or without a sunlight. The harvested energy is positively associated with the purity of water and the quantity of the negative charges from the negative ion source.

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