Atmospheric Humidity Energy Harvester.docx

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ABSTRACT:

Omega Energy has developed a solid-state energy harvester. It converts water vapor and oxygen into power through a series of reactions on transition metal suboxide intermediates in the presence of oxygen and water vapor from the environment. The anode is made from a transition metal suboxide and the cathode from a different transition metal suboxide. The separator is any polymer layer that will transport ion. It will produce energy as long as oxygen and water vapor are present in its environment and passing through the cell.

Field of Invention:

Energy Harvesters are devices that do not store energy, but rather gather it from the environment [1]. Examples include solar power, thermal energy, wind energy, salinity gradients, kinetic energy, and RF capturing devices like the crystal radio among others. These devices store energy rather than harvest it.

This invention uses various suboxides of transition metals that allow non-integer valence states in the mass of their crystal structures. Charge is transferred on the surface of the various suboxides from water vapor adsorption and subsequent dissociation driven by the suboxides. Oxygen from the environment enter the vacancies and assist in the vacancy balance within the crystal. Power is continuous as long as these two reagent components are present and humid air passes through the cell.

1 https://en.wikipedia.org/wiki/Energy_harvesting

General Theory of Operation:

We use several transition metal suboxides that have an average valence less than the integer value for that element's oxide: Thus, the name "suboxide". This valence value is the average over the crystal mass. A suboxide crystal contains less oxygens (called vacancies) in the bulk of the crystal structure than in a common oxide, thus resulting in an average metallic valence that is not an integer. This oxygen imbalance combined with the surface metal hydroxide gives each compound an electronegativity that differs for each compound resulting in a different "Point of Zero Charge" (zpc), which expresses itself as different pH values for adsorbed water on the surface of the powdered suboxides. The active cathode material is less electronegative than the anode material, and thus is "electropositive" relative to the anode. The charge is separated using any material that will transfer protons (H^+). We have used Nafion successfully, but now use hydrated, unplasticized cellophane, which will transport any water-soluble ion. In our case, only protons are transferred. The anode and cathode both also contain carbon to reduce the internal impedance of the system. Both the anode and cathode reactions are well characterized and are reactions of cascading vacancies and electrons within the crystal structures.

Cathode Mechanism:
Oxygen and water vapor enters the cathode. The oxygen reacts with a proton from the anode catalyzed by the tungsten suboxide, consuming two electrons and liberating a water molecule.

$$\tfrac{1}{2}O_2 + 2H^+ + 2e^- \xleftarrow{WOx} H_2O$$

This catalysis is due to cascading vacancies within the tungsten suboxide crystal structure.

The cobalt suboxide also catalyzes another electron consuming reaction where a proton and electron combine to make hydrogen gas. This catalysis is also a vacancy cascading reaction series.

$$2H^+ + 2e^- \xrightarrow{CoOx} H_2$$

It is also thought that a combined catalytic reaction with both the cobalt and tungsten suboxides react with adsorbed water to form hydrogen gas and consume electrons.

The water molecules, both adsorbed and created, migrate to the anode by diffusion.

Anode Mechanism:
A tungsten suboxide catalyzes the dissociation of a water molecule into a singlet oxygen, two protons and two electrons, which return to the cathode via an external circuit. This is the reverse reaction seen in the cathode.

$$H_2O \xleftrightarrow{WOx} \tfrac{1}{2}O_2 + 2H^+ + 2e^-$$

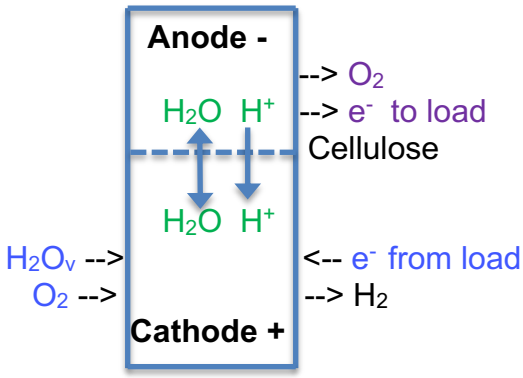
The titanium suboxide also splits water into an oxygen singlet, two protons and two elections by

$$H_2O \xrightarrow{TiOx} \tfrac{1}{2}O_2 + 2H^+ + 2e^-$$ giving a combined equation of:

$$H_2O \xrightarrow{TiOx\ \&\ WOx} \tfrac{1}{2}O_2 + 2H^+ + 2e^-$$

Both the titanium and tungsten reactions are a result of complex cascading vacancies within the crystal structure.

Pictorial Presentation:
In the block-diagram below, I show that which comes into the cell, out of the cell and through the cell using colored ink to show that which is entering, leaving or transferred within the cell.



Entering the cell: The cathode inhales water vapor (H_2O_v) and the cathode also inhaling oxygen (O_2). The cathode accepts electrons (e^-) from the load.

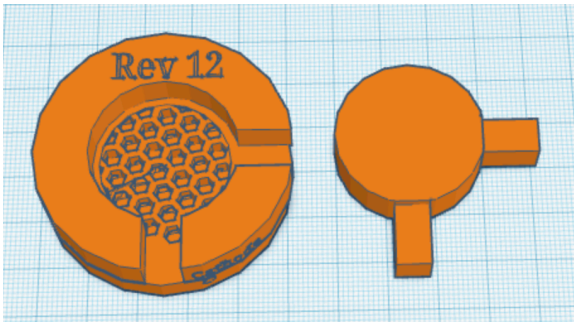
Internal transfers are the protons (H^+) produced in the reactions and liquid water (H_2O) on the surface of the powdered reagents through the separator and into the anode. The driving force is both from Knudsen diffusion and the concentration gradient.

Leaving the cell: Oxygen (O_2) from the anode and hydrogen (H_2) from the cathode are exhaled in gaseous form. Electrons (e^-) leave the anode to do work in the load.

Electrode and Cell Making:

The project started with pellets made in a piston-cylinder type compression apparatus. It has evolved into making electrodes using a rolled process making thin sheet anodes and cathodes all bound with unsintered PTFE powder. The powders for the electrode (anode or cathode) are blended in a high sheer blender at 20,000 rpm. Then acetylene black carbon is added and gently mixed in. This mix is then applied to a rolling press as a thin, uniform sheet of powder. The mill is under 650 pounds compression force. The result is an electrode sheet that is about 0.9 mm thick and very uniform. From this, disks are punched out and placed within a polypropylene grommet which is compressed to 2000 pounds to produce the final electrode. Between the anode and cathode is a disk of hydrated cellophane (or Nafion). This assembly is then placed inside the cell body to complete the finished cell with air entering the cathode half and exciting at the anode.

The Cell Body: The cell is printed using PETG (Polyethylene) to be sure it is moisture stable. The CAD drawing shows the air being distributed to the entire surface of the cathode. The inlet is to the left, so not visible in this view. A cathode current collector made of a fine stainless-steel screen is laid on the bottom and is shaped rather like a lollypop with the contact strip extending downward in this view. Then, a sheet of porous carbon paper is laid over that to protect the electrode from damage of the woven character of the screen. The cathode, separator and anode are then laid over the carbon in that order. Next is another "lollypop" shaped current collector made of thin brass that has been heavily gold plated.



Performance:

Our cell is still in the development stage. The exchange potential (OCV) will run about 0.4 volts. The maximum power density ranges from just below 20 to over 30 uW/cm^2. On a dead-short discharge, the cell will start at about 25 uAmps and drop to between 2 and 5 uAmps after years of discharge. Two of our cells have been discharging for nearly 2 years and produced over 37 ASec… and still going. They are now running between 1 and 5 uAmps. Our cells have a surface area of 3.9 cm^2.

Figure 1 shows the polarization curve expressed as a voltammogram after 24 hours of humidification.

Figure 2 shows the power curve, which is the first derivative of the polarization curve, being the product of the two axes versus potential after 24 hours of humidification. The maximum power point (MPP) is usually reached at about 60% of the exchange potential.

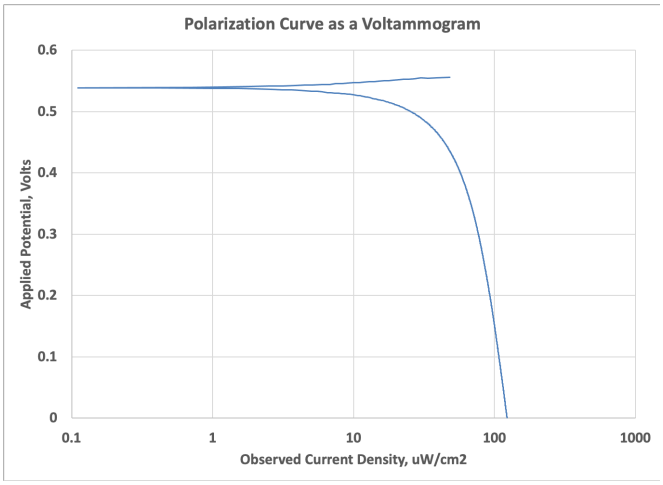


Figure 1

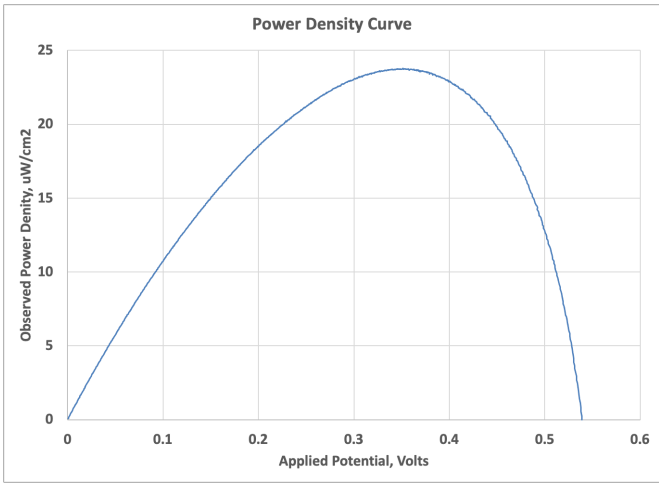


Figure 2

Figure 3 shows the impedance Bode plot after 24 hours of humidification. The Ohmic impedance for this control cell is roughly 15 Ohms or 270 Ohm-cm.

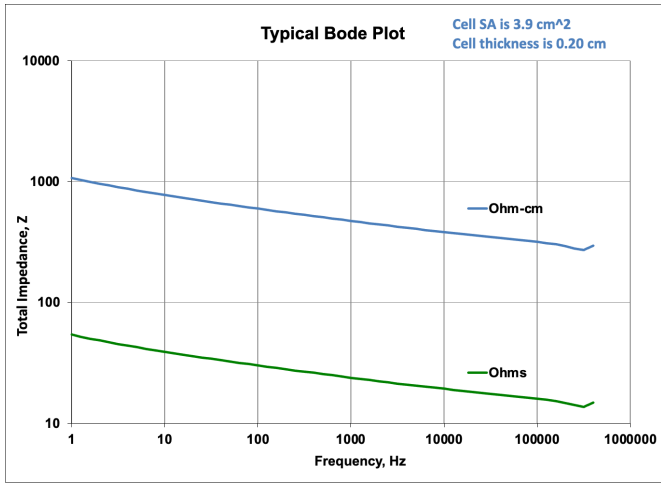


Figure 3

Summary:

- The Omega Energy Harvester is capable of continuously producing power from moving air and water vapor.
- It is relatively easy to manufacture and has a small physical footprint.
- The peak energy level is 20 to 30 uW/cm^2 at about 0.3 volts per cell.
- Could run a low power transmitter, receiver or other sensing devices.
- Series-parallel arrangements can deliver higher voltage and power.
- Three patents have been issued on the concept (one Horovitz patent prior to the formation of Omega Energy Systems, LLC).