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A Novel DVR-ESS-Embedded Wind-Energy Conversion System

M.Jeesriya[1], T.Rajkumar[2]

Department of Electrical and Electronics Engineering, The Kavery Engineering College, Mecheri, Salem, India[1]

Assistant Professor, Department of Electrical and Electronics Engineering, The Kavery Engineering College, Mecheri, Salem, India[2]

ABSTRACT: Conversion cells for harvesting solar energy and mechanical energy are usually separate and independent entities that are designed and built following different physical principles developing a technology that harvests multiple-type energies in forms such as sunlight and mechanical around the clock is desperately desired for simultaneously harvesting solar and mechanical energies. Using aligned ZnO nanowire arrays grown on surfaces of a flat substrate, a dye-sensitized solar cell is integrated with a piezoelectric nanogenerator.the former harvests solar energy irradiating on the top, and the latter harvests ultrasonic wave energy from the surrounding.The two energy harvesting approaches can work simultaneously or individually, and they can be integrated in parallel and serial for raising the output current and voltage, respectively, as a well as power. It is found that the voltage output from the solar cell can be used to raise the output voltage of the nanogenerator. We are providing an effective approach for effectively storing and utilizing the power generated by the nanogenerator. Our study demonstrates a new approach for concurrently harvesting multiple types of energies using an integrated hybrid cell so that the energy resources can be effectively and complementary utilized whenever and wherever one or all of them is available.

I. INTRODUCTION

Our living environment has an abundance of energies .Rationally designed materials and technologies have been developed for converting solar and mechanical energies into electricity. Photovoltaic relies on approaches such as inorganic pn junction, organic thin films and organic-inorganic heterojunctions. Mechanical energy generators have been designed on the basis of principles of electromagnetic induction and piezoelectric effect. These existing approaches are developed as independent technologies and entities that are designed on the basis of drastically different physical principles and diverse engineering approaches to uniquely harvest a particularly type of energy.

A Solar cell works only under sufficient light illumination; a mechanical energy generator is applicable if there is significant mechanical movement/vibration .we report a hybrid cell that is designed for simultaneously harvesting solar and mechanical energies using nanotechnology.Our approaches relies an aligned ZnO nanowire arrays grown on surfaces of a flat substrate, a dye sensitized solar cell is built on its top surface to convert solar energy.

And a piezoelectric nanogenerator is built on its bottom surface for harvesting ultrasonic wave energy from the surrounding.the two energy harvesting approaches can work simultaneously or individually, and they can be integrated in parallel and serial for rising for developing integrated technologies for effectively scavenging available energies in our environment around the clock.

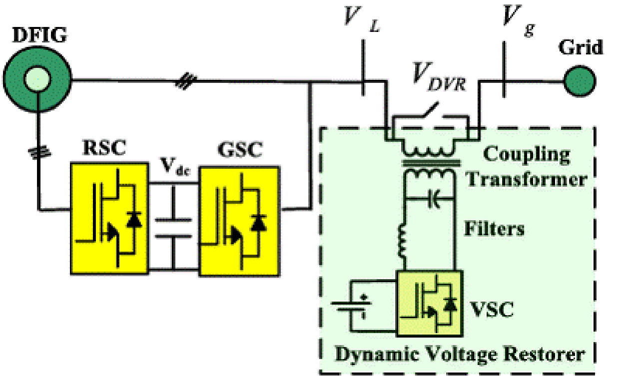

Figure 1: **PROPOSED BLOCK DIAGRAM**

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ZnO NANOWIRES:

A number of methods have been employed to achieve nanostructured arrays, including chemical and physical vapour deposition, hydrothermal process,

Metal organic, Vapor-phase epitaxial growth, template growth method and electrochemical deposition technique.The ZnO nanowires were grown in a furnace by chemical vapour deposition with gold as catalyst.The image revealed that the ZnO wires are vertically alinged ,the length of nanowire is around 1-2mm and the diameter is in the range of 70-100nm,the synthesis and characterization of three –dimensional heergeneous graphene nanostructures comprising continuous large-area graphene layers and ZnO nanostructures,fabricated via chemical vapour deposition.A new method of epitaxial ZnO column deposition that exhibits uniformity and reproducibility over a large surface area were demonstrated.this method employs a aqueous solution containing NaOH and coated with sputtered ZnO and does not require the use of complexing agents and can produce micrometer-thick films in less than 1h.

The resulting quasi-epitaxial films of highly ordered columns have the reproducibility and uniformity over large areasto be employed in the development of solar cells and other devices.Because chemical and physical vapour deposition need to workin vacuum and/or at high emperature,these techniques require sophisticated and expensive equipments.The electrochemical deposition technique is becoming an important means for the fabrication of ZnO nanowires due to the low cost,mild condition, accurate process control and widely used in industry.

II. EXPERIMENTAL DESIGN

The hybrid cell (HC) integrates a dye-sensitized solar cell (DSSC) 6.11 and a piezoelectric nanogenerator (NG) 12-14 built by sharing electrodes and using ZnO nanowires arrays (NWs) as a common material for both units. The integration between the DSSC and NG can be either in series or in parallel by introducing different fabrication procedures. Serially integrated SC-NG hybrid cell (s-HC) is designed by integrating the anode of DSSC and the cathode of NG onto one single silicon substrate. The structure of an s-HC is schematically shown in figure 1a. In general, the DSSC was fabricated using vertically aligned ZnONWs, which were grown on an ITO-coated glass substrate through a hydrothermal method. The counter electrode of the DSSC was the back side of a Pt- coated silicon substrate.

On the front side of the silicon substrate, a zigzagged surface was created by spin coating polystyrene (PS) on aligned ZnONWs. Capillary force agglomerated the vertical NWs into bundles, and the gaps were filled with PS, forming a smooth bumpy surface, on which a continuous Pt coating resulted in the formation of a “zigzag” electrode as required for the NG. Atomic force microscopy (AFM) imaging revealed that the space between teeth was ~2-3 μm in width and ~1-3 μm in depth. This dimension is ideal for inducing mechanical deflection of NWs during NG operation. ZnONWs used for the NG were grown on a GaN surface using the vapor deposition process with uniform polarity. The DSSC and NG are integrated in serial through a continuously coated Pt film around the silicon substrate at the middle. An equivalent circuit of the s-HC composed of serially integrated SC and NG is shown at the right hand side of figure 1a.

A cross- sectional image of the entire s-HC is shown in the inst SEM image between Figure 1b and 1c. It is made of three substrates: from top to bottom are ITO, silicon, and GaN. The DSSC structure between ITO and silicon substrates and Nstructures between silicon and GaN substrates are presented in figure 1b and c, respectively. In the SC unit, ZnONWs were coated with dye molecules and separated from the counter electrode by a ~10 μm gap that was filled with electrolyte. In the NG unit, ZnONWs were approached and contacted by the top zigzag electrode, which periodically bent/deflected the NWs once excited by ultrasonic wave.

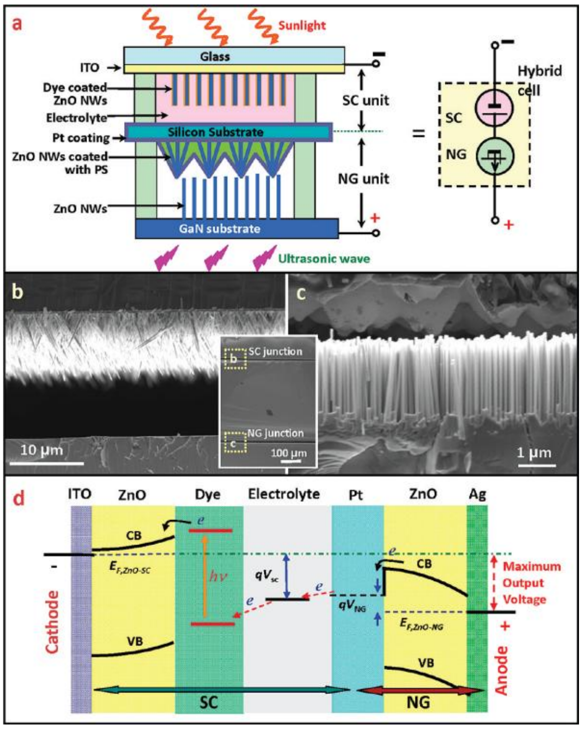
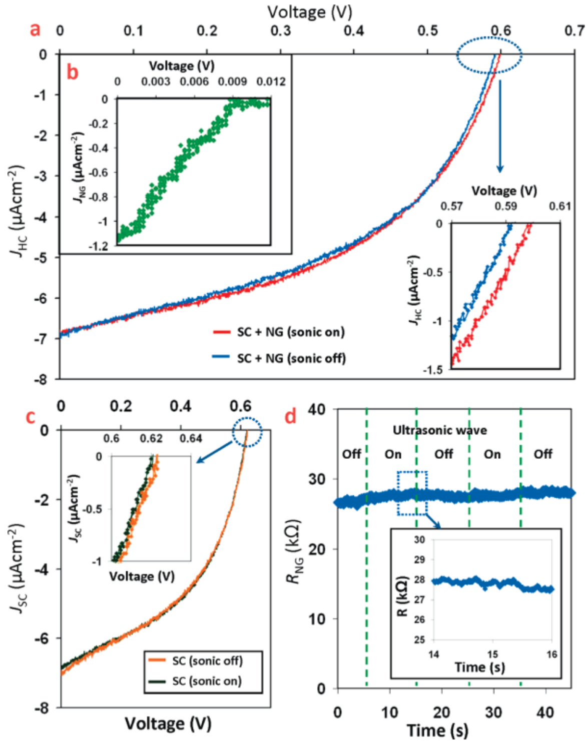


Figure 1: Design and structure of a hybrid cell (HC) composed of serially integrated solar cell (SC) and nanogenerator (NG) for raising the output voltage. (a) Schematic structure of a serially integrated HC, which is shined by sun light from the top and excited by ultrasonic wave from the bottom. The ITO layer on the SC unit and GaN substrate are defined as the cathode and anode of the HC, respectively. The symbol to represent the HC is shown at the right-hand Side. (b) SEM image of the SC unit. (c) SEM image of the NG unit. The SEM image inserted between (b) and (c) is a low-magnification cross-section view of the HC. (d) Electron energy band diagram of the s-HC, showing that the maximum output voltage is a sum of those produced by SC and NG. The abbreviations are as follows: conduction band (CB), valence band (VB), Fermic level (EF).

The working principle of the s-HC can be explained using the electron energy band diagram shown in figure 1d. At about the NG at the right-hand side, the maximum voltage output of the NG (v_{NG}) is determined by the differences between the Fermi level of the ZnONWs and that of the Pt that is "transiently" raised by the electrons "pumped in" under the driving force of the piezoelectric potential from the NWs and Ag bottom electrode. Once subjected to mechanical deformation under the driving of ultrasonic waves, for example, a compressive side of a NW, which drives the charge carriers located in the NW side close to the Pt-ZnO junction to move and injects them into the Pt electrode due to the forward biased schottky barrier.

These charge carriers continue transport in the electrolyte through a redox couple process into the SC. At the left-hand side of figure 1d, the band structure of a ZnO-based DSSC is shown, where the maximum voltage output (V_{sc}) is dictated by the gap between the ZnO's Fermi level and the electrochemical potential of the electrolyte. When a light is applied on the glass side of the HC, electrons are excited to a high energy state of the dye molecules and subsequently transferred to the conduction band of ZnO and then collected by ZnONWs and finally exported through the cathode at the energy of the energy of the Fermi level. In the entry s-HC, the electron energy is promoted twice by NG and SC so that the overall maximum output voltage is the sum of V_{sc} and $V_{NG.}$



Performance of the HC composed of serial integrated SC and NG

The serially integrated SC and NG can work independently. A HC has also been designed that is composed of parallel integrated SC and NG for raising output current. As schematically shown in figure 3a, the anode of DSSC and NG were integrated together on a single piece of silicon substrate by an around surface Pt coating. The anode of the NG is a Pt-coated zigzag electrode fabricated by etching solution. The cathodes of DSSC and NG were connected together by external wiring: thus this device can be simplified as a parallel connected SC and NG.

The working principle of a p-HC is illustrated in figure 3b. As discussed previously, for an NG working independently, the output voltage (V_{NG}) is determined by the shift in transient Fermi level of the Pt electrode in reference to that of the ZnONWs Once the electrode are pumped in by piezoelectric potential, as shown in the red dashed box on the top right-hand side of figure 3b.

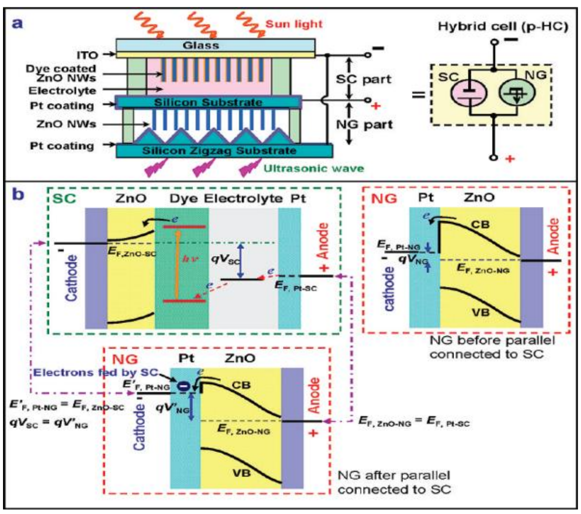
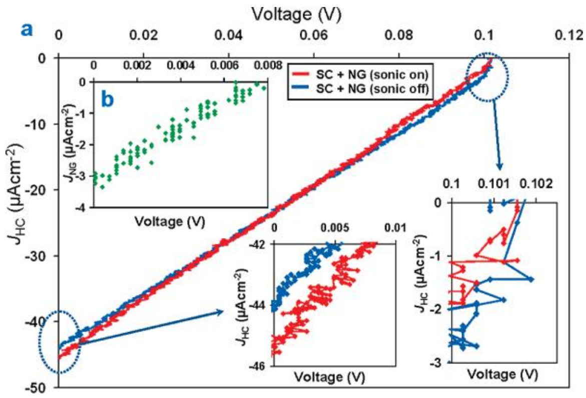


Figure 3: Design of a hybrid cell composed of parallel integrated solar cell and nanogenerator for raising the output current. (a) Schematic structure of the HC design. The central Pt-coated silicon substrate is defined as the anode, and the ITO layer electrically integrated to zigzag electrode is defined as the cathode of the HC. A symbol of the HC

structure is shown in the right-hand side. (b) Electron energy band diagram of the p-HC and its working principle. The top two diagrams are the band structures of SC and NG before parallel integration respectively. The bottom diagram are the band structures of the NG after being parallel integrated to the HC with realignment of Fermi levels at the cathode and anode respectively. The maximum voltage approximately the voltage output of the SC

When the NG is parallel integrated/connected to a SC, the band structure of which given in the green dashed box on the top left side of figure 3b, Fermi levels will realign at the anode and cathode, respectively. When the Pt electrode of NG is integrated to the ITO electrode of SC, extra electrons are fed from the SC side into the Ng side because the SC side has a higher Fermi level.



Performance of the HC composed of parallel integrated SC and NG

III. RESULT AND DISCUSION

Yet these electrons cannot flow through the NG because of the existence of a schottky barrier at the interface between the Pt electrodes and ZnONWs; instead they tend to accumulate at the Pt side close to the schottky barrier, resulting in a rise of the local Fermi level to $E2_{F,\ Pt\text{-}NG}$ until it matches that of the cathode of the SC, $E2_{F,\ Pt\text{-}NG.}$ On the other hand, the connections of the two anodes lead to the alignment of the Fermi levels at the anode side: $E_{F,\ ZnO\text{-}Ng=}\ E_{F,\ Pt\text{-}SC.}$ The resultant voltage output of the p-HC is

$$V_{p\text{-}HC} = V_{sc} = V_{2NG} = E_{2F,\ Pt\text{-}Ng} - E_{F,\ ZnO\text{-}NG}$$

This relationship indicated that the output voltage of the NG can be raised to the same level as that of the SC under the parallel integration configuration. This is possibly due to their existence of a reversely biased schottky barrier in NG which has a high enough resistance that blocks the flow through of the electrons fed by the SC. This discussion holds if the barrier height is higher than the SC output; otherwise, the SC outputs will break through the NG. The electron affinity of bulk ZnO is 4.5eV and the work function of bulk Pt is 6.1 eV; the barrier height is estimated to be ~1.6eV. In reality, the typical voltage output of a DSSC is ~0.7-0.8V. Therefore parallel integrating SC to a NG may effectively boost the output voltage of a NG from several millivolts to several hundred millivolts. This provides a new approach for storing the charges generated by the NG with an assistance of an external power source such as a battery.

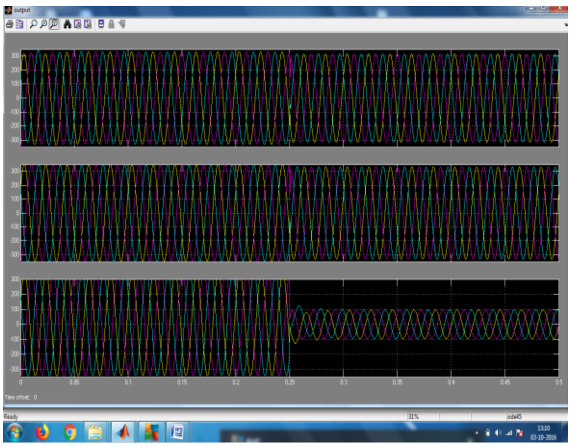


Fig: 4.**WITHOUT DVR**

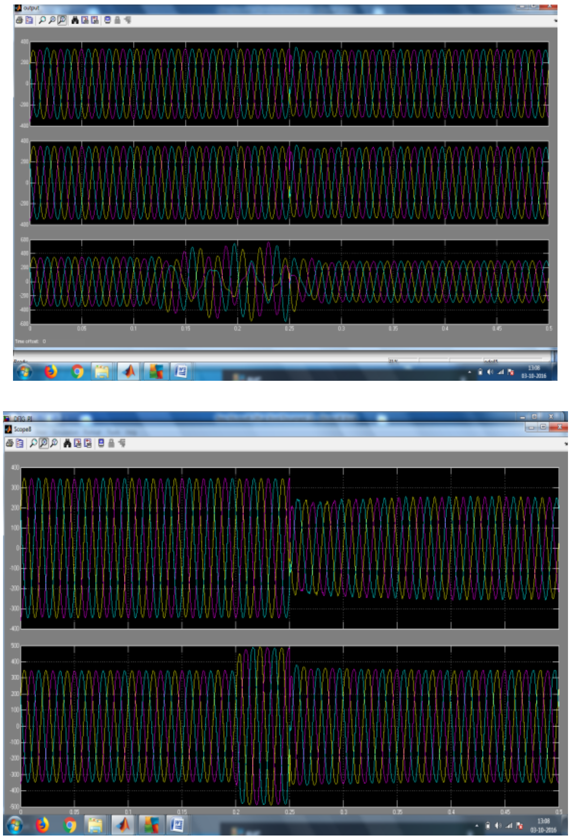


Fig: 5. **WITH DVR**

IV. CONCLUSION

In summary, conversion cells for harvesting solar energy and mechanical energy are usually separate and independent entities that are designed and built following different physical properties. Developing a technology that harvests multiple-type energies in forms such as sunlight and mechanical around the clock is desparately desired for fully utilizing the energies available in our living environment. We report a hybrid cell that is designed for simultaneously harvesting soalr and mechanical energies. Using aligned Zno nanowire array a grown on surfaces of a flat substrate, a dye-sensitized soalr cell is built on its top surface, and a piezoelectric nanogenerator is built on its bottom surface. The former harvests ultrasonic wave energy from the surrounding. The two energy harvesting approaches can work simultaneously or individually and they can be integrated in parallel and serial for raising the output currwnt and voltage respectively as well as power. Our study demonstrates a new approach for concurrently harvesting multiple types of energies using integrated hybrid cell so that the energy resources can be effectively and complementary utilized whenever and whereever one or all of them is available.

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