Efficient Solar Powered Smartphone for Nigeria's Telecom Advancement.

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Abstract.
This study is aimed at producing an efficient model design of a solar-powered Smartphone that can be used continuously without the need to recharge their batteries from electrical outlets. There has been recent significant advancements in the research aimed at developing solar powered Smartphones as against the Smartphones we have today that requires frequent recharge of their batteries from electrical outlets. But these advancements have only produced solar Smartphone with efficiency of less than 19%. This study is theoretical due to lack of fund to produce the empirical design of the efficient solar powered Smartphone. However, it is intended to provide a new direction for Researchers in solar powered Smartphone Design to enable them produce efficient models that can continuously work for years without recharging their batteries.

Keywords: Smartphone, Graphene, Photovoltaic, Supertransformer, Electrically-Doped Semiconductor, Solar

1. Introduction:

The term, Smartphone, was probably first used in 1997, when Ericsson described its GS 88 "Penelope" concept as a "Smart Phone". A Smartphone can be described as a mobile phone that is built on a mobile computing platform, and has a more advanced computing ability and connectivity than a regular phone. The first Smartphones mainly combined the functions of PDAs and a mobile phone or camera phone. Today's models combine the functions of portable media players, high-speed wireless data transfer, low-end compact digital cameras, pocket video cameras, video game consoles, GPS navigation units, high-resolution touch screens, web browsers that can access and properly display standard web pages rather than just mobile-optimized sites, and high-speed data access via Wi-Fi and mobile broadband.

There is no official definition for what constitutes the difference between Smartphones and feature phones. However, the advanced APIs on Smartphones can allow applications to better integrate with the phone's OS and hardware than what is obtainable on feature phones. These Smartphones are powered by rechargeable batteries. Due to the series of application running on Smartphones, the battery life tends to be short. And this requires a frequent recharging of the batteries by plugging to electricity sockets (Smartphone, 2012).

2. Solar power and solar powered devices and equipment:

Solar power is power derived from energy from the sun. Energy can be derived from the sun in a number of ways, but we will focus on energy derived from the sun using photovoltaic (PV) devices or solar panels. Solar panels are the major component of a solar power system. It converts light energy from the sun to direct current DC electric voltage. Solar panels are made up of arrays of photovoltaic cells (solar cells), connected in series and in parallel to deliver rated voltage and power.

The PV cell is the basic component of a solar panel. PV cells are made from semiconductor materials, like silicon, and doped with other elements, like Boron and phosphorus. These elements create an N-type layer and a P-type layer on the cell. The junctions between the N-type layer and P-type layer contains an electric field, which stops electrons from moving across the junction, effectively creating an open circuit. Some materials exhibit a photoelectric effect that causes them to absorb photons of light and release electrons. When a PV cell is exposed to sunlight, photons continuously strike the p-n junction area of the cell and are absorbed. Energy derived from these absorbed photons provides electrons on the cell with enough energy to overcome the potential barrier of the electric field in the p-n junction. When these free electrons are captured, an electric current results that can be used as electricity. (Okafor, 2009). Photovoltaics is the direct conversion of light into electricity at the atomic level. The photoelectric effect was first noted by a French physicist, Edmund Bequerel, in 1839, who found that certain materials would produce small amounts of electric current when exposed to light. The nature of light and the photoelectric effect on which photovoltaic technology is based, was described in 1905 by Albert Einstein. The first photovoltaic module was built by Bell Laboratories in 1954 as a solar battery and was too expensive to gain widespread use. In the 1960s, the space industry began to use the technology to provide power aboard spacecraft. Then the technology advanced, and became reliable and the cost began to decline. During the energy crisis in the 1970s, photovoltaic technology gained recognition as a source of power for non-space applications (Knier, 2011). Modules are designed to supply electricity at a certain voltage. The current produced is directly dependent on how much light strikes the module. PV modules are now used to provide electrical energy to various devices, equipment and structures. Some houses are built with Building-integrated photovoltaics (BIPV). BIVPs are photovoltaic materials that are used to replace conventional building materials in parts of the building envelope such as the roof, skylights, or facades. They are increasingly being incorporated into the construction of new buildings as a principal or ancillary source of electrical power, although existing buildings may be retrofitted with BIPV modules as well (Building-integrated photovoltaics, 2012). In Nigeria, PV modules are used to provide energy for street lighting, calculators, water boreholes projects etc. Two things hold back the mass adoption of solar energy as a source of sustainable energy. One is the need to store and transmit excess power, the other is the high cost of solar panels. One of the reasons solar panels are so expensive is that it is tricky to extract electric currents from semiconductors, the materials used to convert solar radiation into electrical energy (Finley, 2012).

3. Batteries:

Battery is a device that converts chemical energy into electricity. It consists of two or more cells connected in series or parallel, but the term is also used for single cells. All cells consist of a liquid, paste, or solid electrolyte and a positive electrode, and a negative electrode. The electrolyte is an ionic conductor; one of the electrodes will react, producing electrons, while the other will accept electrons. When the electrodes are connected to a device to be powered, called a load, an electrical current flows.Batteries in which the chemicals cannot be reconstituted into their original form once the energy has been converted , are called primary cells or voltaic cells. Batteries in which the chemicals can be reconstituted by passing an electric current through them in the direction opposite that of normal cell operation are called secondary cells, rechargeable cells, storage cells, or accumulators.

3.1 lead-acid battery:

The storage battery, which can be recharged by reversing the chemical reaction, was invented in 1859 by the French physicist Gaston Planté. Planté's cell was a lead-acid battery. Its major advantage is that it can deliver a strong current of electricity for starting an engine; however, it runs down quickly. The electrolyte is a dilute solution of sulfuric acid, the negative electrode consists of lead, and the positive electrode of lead dioxide. In operation, the negative lead electrode dissociates into free electrons and positive lead ions. The electrons travel through the external electric circuit, and the positive lead ions combine with the sulfate ions in the electrolyte to form lead sulfate. When the electrons reenter the cell at the positive lead-dioxide electrode, another chemical reaction occurs. The lead dioxide combines with the hydrogen ions in the electrolyte and with the returning electrons to form water, releasing lead ions in the electrolyte to form additional lead sulfate.

A lead-acid storage cell runs down as the sulfuric acid gradually is converted into water and the electrodes are converted into lead sulfate. When the cell is being recharged, the chemical reactions described above are reversed until the chemicals have been restored to their original condition. A lead-acid battery has a useful life of about four years. It produces about 2 V per cell. Recently, lead batteries with useful lives of 50 to 70 years have been developed for special applications.

3.2 alkaline battery:

Another secondary cell is the alkaline cell, or nickel-iron battery, developed by the American inventor Thomas Edison in the 1900s. The principle of operation is the same as in the lead-acid cell except that the negative electrode consists of iron, the positive electrode is of nickel oxide, and the electrolyte is a solution of potassium hydroxide. The nickel-iron cell has the disadvantage of giving off hydrogen gas during charging. This battery is used principally in heavy industry applications. The Edison battery has a useful life of approximately ten years and produces about 1.15 V.

Another alkaline cell similar to the Edison battery is the nickel-cadmium cell, or cadmium battery which produces about 1.15 V, and its useful lifetime is about 25 years.

3.3 Lithium storage batteries:
Perhaps most notable have been the entrance of lithium batteries into the commercial market and the development of nickel-hydrogen and nickel–metal hydride cells for use in spacecraft, computers, cellular telephones, and other applications. Rechargeable lithium–metal anode batteries show commercial promise, with theoretical energy densities that range from 600 to 2,000 watt-hours per kilogram. Even after allowance is made for the inactive parts of such cells, the net energy density is still competitive with aqueous systems. Commercially available systems of this type include lithium–cobalt oxide, lithium–nickel oxide, lithium–manganese dioxide, and lithium–molybdenum disulfide. Much current research is devoted to developing better oxide and sulfide structures and better solvent combinations, as well as to preventing the unsafe formation of finely divided lithium during the recharging of the cells.
3.3.1 lithium-ion cell:
Major commercial success for rechargeable lithium-based batteries came with the development of lithium-ion cells. The difficult problem of preventing lithium dendrite formation on charging was solved in these cells by using specially selected carbon powders as a base in which to insert lithium ions to form a weak compound that functions as a high-voltage, high-energy-density anode. While the energy density is lower than for lithium–metal anode batteries, their added safety is well worth the sacrifice. These batteries are available for portable computers, Smartphones, and other devices. The usual cathode is an expensive special cobalt oxide. Even with all of the added safety of the lithium-ion form, it is still a critical requirement to have precise electronic controls for charging and discharging.
3.4 Solar battery:
Solar batteries produce electricity by a photoelectric conversion process. The source of electricity is a photosensitive semiconducting substance such as a silicon crystal to which impurities have been added. When the crystal is struck by light, electrons are dislodged from the surface of the crystal and migrate toward the opposite surface. There they are collected as a current of electricity. Solar batteries have very long lifetimes (Battery, 2008).

4. **PVC DESIGN AND STRUCTURE:**
4.1 Solar cell structure and operation:
Solar cells, whether used in a central power station or a calculator, have the same basic structure. Light enters the device through an optical coating, or antireflection layer that minimizes the loss of light by reflection; it effectively traps the light falling on the solar cell by promoting its transmission to the energy-conversion layers below. The antireflection layer is typically an oxide of silicon, tantalum, or titanium that is formed on the cell surface by spin-coating or a vacuum deposition technique.

The three energy-conversion layers below the antireflection layer are the top junction layer, the absorber layer, which constitutes the core of the device, and the back junction layer. Two additional electrical contact layers are needed to carry the electric current out to an external load and back into the cell, thus completing an electric circuit. The electrical contact layer on the face of the cell where light enters is generally present in some grid pattern and is composed of a good conductor such as a metal. Since metal blocks light, the grid lines are as thin and widely spaced as is possible without impairing collection of the current produced by the cell. The back electrical contact layer has no such diametrically opposed restrictions. It simply functions as an electrical contact and thus covers the entire back surface of the cell structure. Because the back layer also must be a very good electrical conductor, it is always made of metal.

Semiconductors in thicknesses of about one-hundredth of a centimeter or less can absorb all incident visible light; since the junction-forming and contact layers are much thinner, the thickness of a solar cell is essentially that of the absorber. Examples of semiconductor materials employed in solar cells include silicon, gallium arsenide, indium phosphide, and copper indium selenide. When light falls on a solar cell, electrons in the absorber layer are excited from a lower-energy ground state, in which they are bound to specific atoms in the solid, to a higher excited state, in which they can move through the solid. In the absence of the junction-forming layers, these free electrons are in random motion, and so there can be no oriented direct current. The addition of junction-forming layers induces a built-in electric field that produces the photovoltaic effect. The electric field gives a collective motion to the electrons that flow past the electrical contact layers into an external circuit where they can do useful work.

The materials used for the two junction-forming layers must be dissimilar to the absorber in order to produce the built-in electric field and to carry the electric current. These may be different semiconductors, or the same semiconductor with different types of conduction, or they may be a metal and a semiconductor. The photovoltaic process bears certain similarities to photosynthesis, the process by which the energy in light is converted into chemical energy in plants. Since solar cells obviously cannot produce electric power in the dark, part of the energy they develop under light is stored, in many applications, for use when light is not available. One common means of storing this electrical energy is by charging electrochemical storage batteries. This sequence of converting the energy in light into the energy of excited electrons and then into stored chemical energy is strikingly similar to the process of photosynthesis (Solar cell, 2012).

The structural design of a PV cell depends on the limitations of the material used in the PV cell. The four basic device designs are:

4.1.1 Homojunction Devices:
Crystalline silicon is the primary example of this kind of cell. Single crystalline silicon is altered so that one side is p-type, dominated by positive holes, and the other side is n-type, dominated by negative electrons. The p/n junction is located so that the maximum light is absorbed near it. The free electrons and holes generated by light deep in the silicon diffuse to the p/n junction and then separate to produce a current if the silicon is of sufficiently high quality.
In this homojunction design, these aspects of the cell may be varied to increase conversion efficiency:

- Depth of the p/n junction below the cell's surface;
- Amount and distribution of dopant atoms on either side of the p/n junction
- Crystallinity and purity of the silicon.

Some homojunction cells have also been designed with the positive and negative electrical contacts on the back of the cell. This geometry eliminates the shadowing caused by the electrical grid on top of the cell. A disadvantage is that the charge carriers must travel farther, all the way to the back of the cell, to reach an electrical contact. The silicon must be of very high quality, without crystal defects that cause electrons and holes to recombine.

4.1.2 Heterojunction Devices:
This type of device structure includes copper indium diselenide cell, in which the junction is formed by contacting different semiconductors, cadmium sulfide and copper indium diselenide. This structure is often chosen to produce cells made of thin-film materials that absorb light better than silicon. The top layer, or window layer, is a material with a high bandgap selected for its transparency to light. The window allows almost all incident light to reach the bottom layer, which is a material with low bandgap that readily absorbs light. This light generates electrons and holes very near the junction, which separate the electrons and holes before they can recombine.Heterojunction devices have an inherent advantage over homojunction devices, which require materials that can be doped both p- and n-type. Many PV materials can be doped either p-type or n-type but not both. Again, because heterojunctions do not have this constraint, many promising PV materials can be investigated to produce optimal cells.
Also, a high-bandgap window layer reduces the cell's series resistance. The window material can be made highly conductive, and the thickness can be increased without reducing the transmittance of light. As a result, light-generated electrons can easily flow laterally in the window layer to reach an electrical contact.

4.1.3 p-i-n and n-i-p Devices:
Amorphous silicon thin-film cells use a p-i-n structure, while cadmium telluride (CdTe) cells use an n-i-p structure. A three-layer sandwich is created, with a middle intrinsic (i-type or undoped) layer between an n-type layer and a p-type layer. This geometry sets up an electric field between the p- and n-type regions that stretches across the middle intrinsic resistive region. Light generates free electrons and holes in the intrinsic region, which are then separated by the electric field.
In the p-i-n amorphous silicon (a-Si) cell, the top layer is p-type a-Si, the middle layer is intrinsic silicon, and the bottom layer is n-type a-Si. Amorphous silicon has many atomic-level electrical defects when it is highly conductive, so very little current would flow if an a-Si cell had to depend on diffusion. In a p-i-n cell, current flows because the free electrons and holes are generated within the influence of an electric field rather than having to move toward the field.
4.1.4 Multijunction Devices:

In the multijunction cell, individual cells with different bandgaps are stacked on top of one another. The individual cells are stacked in such a way that sunlight falls first on the material having the largest bandgap. Photons not absorbed in the first cell are transmitted to the second cell, which then absorbs the higher-energy portion of the remaining solar radiation while remaining transparent to the lower-energy photons. These selective absorption processes continue through to the final cell, which has the smallest bandgap.

A multijunction cell can be made two ways. In the mechanical stack approach, two individual solar cells are made independently, one with a high bandgap and one with a lower bandgap. Then the two cells are mechanically stacked, one on top of the other. In the monolithic approach, one complete solar cell is made first, and then the layers for the second cell are grown or deposited directly on the first.

Much of today's research in multijunction cells focuses on gallium arsenide as one (or all) of the component cells. These cells have efficiencies of more than 35% under concentrated sunlight, which is high for PV devices. Other materials studied for multijunction devices are amorphous silicon and copper indium diselenide (Photovoltaic Cell Structures*,* 2011*)*.

4.1.5 Transparent and Translucent Photovoltaics:

Transparent solar panels use a tin oxide coating on the inner surface of the glass panes to conduct current out of the cell. The cell contains titanium oxide that is coated with a photoelectric dye.Most conventional solar cells use visible and infrared light to generate electricity. In contrast, the innovative new solar cell also uses ultraviolet radiation. Used to replace conventional window glass, or placed over the glass, the installation surface area could be large, leading to potential uses that take advantage of the combined functions of power generation, lighting and temperature control. Transparent photovoltaics is also called translucent photovoltaics, they transmit half the light that falls on them. Inorganic and organic photovoltaics are capable of being translucent (Building-integrated photovoltaics, 2012).

5. Recent Advancement in Solar powered phone:

Although Smartphone technology has advanced rapidly over the last few years with the advent of multi-core mobile processors, high fidelity displays and a wider breadth of multimedia applications, power consumption remains a persistent issue. Many models require recharging before reaching a full day's worth of use, but with a new OLED display technology that can actually recharge itself as it is being used, the days of keeping a charger close at hand may be numbered (Scott, 2012).

Researcher Arman Ahnood has developed a method to capture light otherwise wasted by OLED displays and convert it into energy that can be used to recharge a device's central battery unit. According to Ahnood, only 36-percent of the light produced by OLED displays is projected outward, while the rest is pointed toward the sides and rear. He applied a thin film of hydrogenated amorphous silicon that is designed to sit within the phone's screen. The layer of film containing photovoltaic cells gather the wasted energy, as well as capture ambient light from both man-made sources and the sun. Ahnood's findings offer a small amount of supplemental energy, but with further research it could reach higher efficiency levels. Making the device work required sidestepping another problem: fluctuations in the voltage provided by the solar cell, which could have damaged the phone’s battery. The researchers, designed a thin-film transistor circuit to smooth out voltage spikes and extract electricity more efficiently. And instead of charging the battery directly, which would have involved adding complex circuitry, they integrated a thin-film supercapacitor for intermediate energy storage. This combination of photovoltaics, transistors, and supercapacitor yielded a system with an average efficiency of 11 percent and peak efficiency of 18 percent. If the PV array converts 5 percent of ambient light to electricity, the energy-harvesting system can generate as much as 165 microwatts per square centimeter under the right lighting conditions. There are existing CMOS-based switch mode voltage regulators that offer higher efficiency, but they are not compatible with the thin-film technology used in Smartphone displays. The thin-film devices can be fabricated at temperatures below 150 °C on lightweight plastic, making them much more attractive for use in mobile phones. (Savage, 2012).

6. Proposed Design of Efficient solar powered Smartphone:

A PV module should replace the entire back cover of the Smartphone. The usual chemically doped semiconductor should not be used to design the PV cells, instead an electrically doped semiconductor (using Graphene (Finley, 2012), a highly conductive one-atom-thick sheet of carbon, as a transparent electrode), will be more suitable. The PV cells can then be miniaturized and translucent. The cells should be arranged in series and parallel to form a thin-film module with a relatively higher voltage than that of a chemically doped semiconductor. The PV module should be connected to several miniaturized supertransformers that have been connected in series to achieve the rated voltage. The supertransformers should be integrated into the circuit panel of the Smartphone or the rear side of the PV module. The supertransformers should then be connected to a thin-film supercapacitor as an intermediate storage and thin-film transistors to check any voltage fluctuation. The supercapacitor should then be connected to terminals to recharge the miniaturized lithium-ion battery. The rated voltage produced at the end of the supercapacitor should be sufficient to recharge the lithium-ion battery and resulting in an acceptable efficiency.

7. Conclusion:

The PV module should replace the entire cover case of the Smartphone. It can be a single-back case when using models like the Nokia® 5800 xpressmusic or Samsung® Galaxy series, or a double-back case in models like Nokia® Communicator. It can even serve as case in smaller-sized Smartphones. In Nigeria where the people are blessed with abundant natural resources, including sunlight, the solar energy should be used for greater productivity. The temperature in Nigeria averages between 25^{o}C and 28^{o}C annually, using such solar powered Smartphone will be a positive option in the right direction. During the day, the Smartphone will run on solar power, while at night, the lithium-ion battery will sustain it till the next daylight. Thereby providing a twenty four (24) hours uninterrupted power supply to the Smartphone.This proposed design is theoretical because lack of fund and tools has limited us from producing the empirical design of the solar powered Smartphone. We hereby urge Researchers trying to produce an efficient solar powered Smartphone to look in this direction.

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