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GreenFone

"An Innovative Green Solutions for Wireless Devices"

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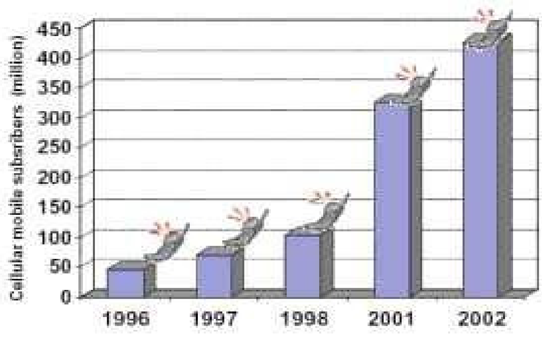
Abstract. The paper focuses on the redesigning of wireless devices with the ubiquitous cell phone being analyzed here. The focus is on eliminating e-waste and utilizing alternate sources of energy to power the device. The mobile phone is constructed maximizing the use of biodegradable components. Other non-biodegradable components are integrated with modular design techniques to improve recycling efforts. Distinctive features include 1) Circuit boards designed out of a composite of keratin from chicken feathers and soybean oil. 2) Soft keys that are made from banana fiber. 3) Central structure/Innovative power supply – arrays of zinc oxide Nano wires possessing piezoelectric property are encased in a semisolid gum resin that encases the entire structure. The resin structure also absorbs heat readily which can be used as an alternative power source to charge the battery. The casing is coated with photosynthetic protein based solar cells to convert ambient light into energy.

Keywords: e-waste, banana fiber, resin structure, biodegradable components, photosynthetic protein.

1. Introduction

Wireless devices have become ubiquitous in today's world. The rapid replacement cycle of around 18 months on an average and the limited or non-existent efforts by manufacturers to recycle these highly toxic devices poses a great challenge to environmentalists and engineers alike. The rapid increase in the number of mobile devices, an average individual possesses, has also led to rise in personal power consumption. Hence it is essential to create devices that are greener and utilize alternate power sources in order to reduce the destruction of our planet.

Cell phones are examined here because they are fast becoming the dominant mode of communication in developing and developed nations. Research groups predict that the number of mobile phone subscribers will peak at 2.5 billion by mid 2013. In Asia, the total number of mobile phone has increased form nearly 45 million in 2003 to over 420 million in 2006, and growing exponentially.



Trend in the use of mobile phone in Asia (selected 25 countries); Source: ITU (2004)

An added disadvantage is the rising cost of new models which keeps them out of reach of a large percentage of the populace in developing nations an innovative approach is presented here. The focus is on developing a cell phone that has these objectives: 1) Replacement of conventional component by biodegradable alternatives 2) Modular design techniques that make the refurbishment of cell phones easier. 3) Use of specialized greener power arrangements that are designed to supply the device with energy.

2. Need for a Greener Cell – The GreenFone

Although cell phones represent a small percentage of this total waste, due to their small size and rapid replacement cycle, they are more likely to end up in the waste stream and contribute a growing portion of the toxic materials that end up in our landfills. Future trends suggest that power consumption of wireless devices will also increase with the number of radio interfaces that each device is presumed to possess.

2.1. Hazards of Mobile Devices

Cell phones and their accessories contain a large number of hazardous substances known as Persistent, Bioaccumulative and Toxic Chemicals (PBTs). These chemicals linger in the environment for a long time and have adverse effects on the human body. They especially affect the umbilical cord, thyroid gland and pituitary gland leading to fertility and developmental problems.

Our project aims to replace bioaccumulative components like lead with biodegradable alternatives. A few of the rare earth minerals, used in cell phones, are indispensable. Hence our paper proposes modular design techniques in order to minimize frequent disposal of the entire device. This considerably reduces wastage of material resources.

2.2. Composition of Conventional Cell phones

2.2.1 PBT – LEAD

Lead is primarily utilized to attach various components to printed circuit boards and other components. It has long been known to be highly toxic to both physical and biological systems. In humans, it affects the central nervous system, immune and cardiovascular systems, kidneys, and the endocrine system, with serious effects on the development of children's brains and resulting intelligence quotients.

Our work aim to replace highly carcinogenic and toxic lead solders connectors by biodegradable and greener alternative - electrically conductive adhesives.

2.2.2. PBT – Brominated Flame Retardant.

Brominated flame-retardants (BFRs) are primarily found in the plastic housing and printed wiring boards of cell phones to prevent flammability. They are known to be highly hazardous to human health. To make matters worse, during incineration, if copper is present (as it is in printed wiring boards); it increases the risk that BFRs will create highly toxic brominated dioxins and furans. (PBDEs) are associated with cancer, liver damage, neurological and immune system problems, thyroid dysfunction and endocrine disruption.

Polymer-Clay nanocomposites which are biodegradable and possess flame retardant properties are to be used as a replacement here.

2.2.3. PBT – Cadmium

Cadmium is a rare metal, typically found in very low concentration in nature. It is used in some contacts and switches and in Ni-Cd batteries. It is highly toxic to plants, animals and humans. Exposure can result in bioaccumulation of cadmium in humans and animals. Some food crops such as grain, rice and vegetables can accumulate cadmium. We propose the usage of Organic radical batteries that are ecologically safe and avoid the usage of toxic chemicals.

3. GreenFone – Way To Greener Electronics

The first part of our methodology is to do a careful study of existing wireless devices and replacement of non biodegradable toxic component by innovative biodegradable/natural electronic materials thereby paving a way for a greener tech revolution.

3.1. TechTalk – Printed Wiring Board

Printed wiring boards are the brains of any cell phone, controlling and co-coordinating its functions. Conventional boards are composed of several toxic and hazardous materials which we propose to replace by natural and greener alternatives in GreenFone.

3.1.1. Flying Boards

Existing circuit boards consist of two or more pieces of dielectric material with circuitry that are stacked up and bonded together. The dielectric commonly used is either fiber glass or an epoxy resin substrate. Cell phone circuit boards commonly use the FR4 composite mainly due to its relatively low dielectric constant of 3.9.Feathers are a by product of the chicken industry which pose recycling problems. These feathers can however be used to create a greener circuit board which has been found to be quite promising. The new boards are made from a composite of keratin from chicken feathers and resin from commercially available soybean oil. The quill of the chicken feather is stripped and discarded leaving behind the air filled down. The soft fiber is then pressed into thin mats. These thin mats are then coated with the Soya based resin. The resin is based on the oil's natural make up of triglycerides: three fatty acids joined at a glycerol juncture. The fatty acid distribution is varied using modern genetic engineering techniques to produce a natural epoxy resin that can adhere to almost any substrate. The final product has a composition of 30% keratin and 70% epoxy resin. It has a lower dielectric constant of 1.8, this means that electrons can move twice as fast on the surface of these boards. The hollow feather fiber used is both light and tough enough to withstand mechanical and thermal stresses.

3.1.2. Graphite Circuit

Conventionally circuit patterns are produced by overlaying a copper foil on the circuit board. The pattern is then etched using acid. Copper is extracted by an expensive and highly hazardous process and has a current price of $9800 per tonne. The circuit patterns of cell phone can be substituted by a new graphene nanofabric.The nanofabric belongs to the family of fullerene molecules (buckyballs and nanotubes); this is the first truly two-dimensional fullerene. The nanofabric sheet is highly flexible and strong, and remarkably conductive. They also suffer little energy loss, making graphene an ideal candidate for GreenFone. A single wafer of silicon carbide when heated in a high vacuum leaves behind a thin continuous layer of grapheme. This layer is then coated with photo-resist material and the pattern is drawn using electron-beam lithography. Then conventional etching is done to remove unwanted grapheme.

3.1.3. Green Contacts

The components on a normal circuit board are attached using lead based solder and acid based fluxes. The solder used in mobile electronics is usually an alloy that is composed of 60% tin and 40% lead. Rosin based fluxes are used to remove metal oxides from the surfaces to be joined and to prevent the reoxidiation of joints.

The fumes produced during the solder process are a dangerous health hazard. As already mentioned, the lead used in the solders can leach into the environment and cause considerable damage. The alcohol solvent base used in Rosin based fluxes also poses considerable threat to the environment. It has been classified as a hazardous waste and is also highly flammable.

We plan to embed sacrificial metals with lower potential in the adhesive to prevent corrosion. Furthermore, self-assembled minelayers with very high conductivity can be combined with these adhesives to further improve electrical performance. The advantages of these adhesives are manifold – 1) Avoiding usage of toxic and dangerous lead based solders. 2) Eliminating need for acid based fluxes and cleaning reagents for the same. 3) The adhesives have a lower curing temperature of around 150 degrees versus the 230 degree melting point of Pb/Sn alloy, thereby reducing thermal stress on components. 4) The adhesives are organic in nature and prove to be biodegradable.

3.1.4. Flame Retardants

Flame retardants are materials that reduce the potential flammability of the underlying petroleumbased plastic ase or circuitboard. Conventionally polymers with flame suppressing substances like bromine were utilized. The halogen molecules retard the chemical action of a fire by mopping up reactive molecules as and when they are released. However as described earlier, the toxic nature of these brominated flame retardants renders them unsuitable for our GreenFone project.

We propose the usage of polymer-clay nanocomposites - nylon-montmorillonite composite. The nano particles of montmorillonite embedded in the nylon effectively increases the inflammability of the substrate circuit board.

The retardant works by burning to form a residue that contains alternating layers of silicate and carbon char that provides flame resistance. We note that pure nylon forms almost no char and is highly flammable but the combination provides different levels of flame resistance with different percentages of the clay nano particulate matter.

Heat release rate curves of three samples with varying percentage composition of clay are shown in the above figure. The results show that the Nan composite samples slightly increase the ignition delay time and significantly reduce the peak heat release rate in comparison to pristine nylon. The greater the clay contents the lower the heat release rate.

3.2. TechTalk – Display Screen

The L.C.D screen used in mobile phones and other wireless devices are made up of liquid crystals that are embedded between sheets of glass. An array of transistors provides power to the crystals and a backlight is used for illumination purposes.

GreenFone will employ a display screen that is an organic light emitting diode array (OLED) which proves to be a cheaper and greener alternative to existing LCD screens. It consists of an electroluminescent organic material sandwiched between two electrodes. It is not toxic. The electroluminescence of the organic material makes it unnecessary to have an expensive backlight for illumination this reduces power consumption and cost. The OLED is highly flexible thereby reducing the number of breakable components in the cell phone which ensures longer life.

3.3. TechTalk – Flower Covers

The cell phone casing is usually made of non bio- degradable plastic that is coated with BFRs. We plan to replace this casing by one made from a bioplastic material. Bioplastics are a form of plastics derived from vegetable matter and are truly biodegradable. The polymer to be used is derived from oil present in orange peels – Limorene in combination with CO_2 present in the atmosphere and certain catalysts.

The external casing is to be made transparent and soft to facilitate the delivery of power by both greener mechanisms to the cell phone. A flower seed is embedded in the casing. Once the cell phone is discarded in a compost heap, the bio plastic will break down releasing the seed. The bio plastic also acts as a natural fertilizer promoting the growth of the seed. This feature thus proves to be aesthetic and natural

We plan to extend our green solutions even to the keypads. The keypads will be designed using a banana fibre and polymer composite.

4. GreenFone– EcoPower

The complexity of current wireless devices has led to a surge in power needs of such devices. Cadmium based rechargeable batteries are in vogue due to their longer life time and reduced charging times. The environmental impact of such batteries is not only a function of their composition but also their lifetime. GreenFone provides an integrated solution to this problem by 1) Utilizing three greener sources of energy to power the wireless device. 2) Use of an organic radical battery. 3) Employing alternate radio interfaces depending on the requirements to minimize power consumption.

4.1 PowerTalk– Green Storage

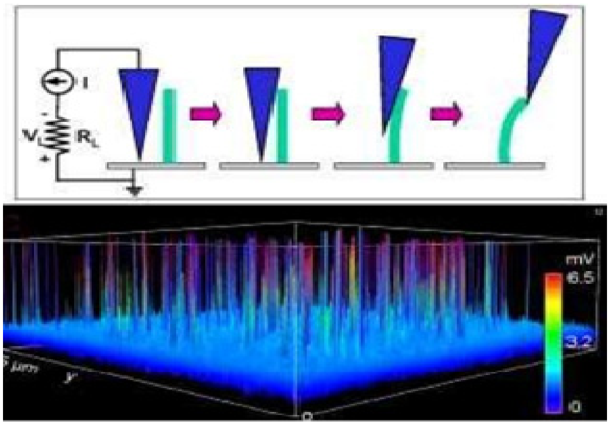
Organic Radical Batteries (ORB) are utilized as a power storage device. ORBs have a typical width of 300 microns and exist as a gel that is mainly composed of an organic radical polymer. Inherent advantages include 1) Charging time of 30 seconds mainly due to fast electrode reactions and the gel state polymer, which allows supporting salts to migrate easily. 2) Very high energy density – about 1 mWh per cm squared, thus making the GreenFone compact. 3) Lasts longer with a lifetime of over 1000 cycles. 4) Flexible aiding in better design.

Another main advantage is that these batteries are very similar in structure to Li ion based batteries, so existing assembly lines can be utilized for manufacture, reducing prices.

4.2 PowerTalk– Piezo Power

The Greenfone converts the mechanical energy spent in squeezing or handling the cell phone into electrical energy which charges the ORB. Nanowires made from Zinc Oxide possess piezoelectric property. The idea is to grow nanowires on a zinc oxide substrate and embed the substrate in the resin/gel based outer structure (described below) of the cell phones. This current is filtered to make it D.C and transferred to the battery.

As shown in the figure below, When pressure is exerted on the nanowires, electricity is generated which can be transferred via an electrode to the battery. If the density of NWs per unit area on the substrate is $20/\mu m^2$, the output power density is around $10 pW/\mu m^2$.These nanowires are non toxic and can be bent up to fifty degrees without breaking thus proving to be ecologically friendly.



Energy Conversion Efficiency Sketch

4.3 PowerTalk – Popeye Power

Solar cells that use photosynthetic proteins to generate electricity have been found to be highly efficient when compared to normal solar devices. We propose to integrate these photosynthetic proteins onto the outer surface of the central resin based structure. Photosynthetic proteins are naturally found in the cell membranes of plants like spinach. The aqueous environment in which the proteins normally reside in, is replaced by one created by synthetic peptides that self replicate to form structures that mimic the cell membrane of the plants.

The starch based resin structure is coated with indium tin oxide to make it slightly conducting. The photosynthetic membrane complex is placed on this structure and it is topped by a layer of organic semiconductor and a silver electrode. Ambient light falling on the cell phone passes through transparent ‘Flower Cover’ and falls on the casing.

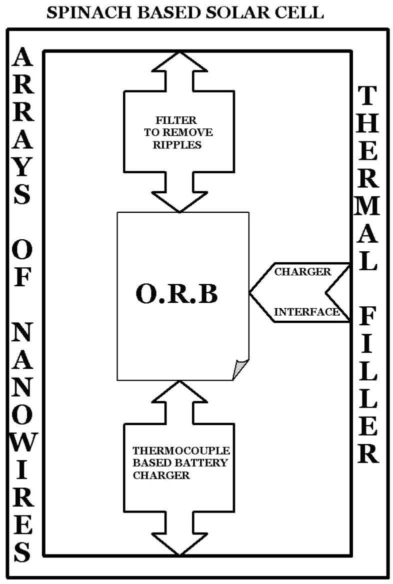


Diagram of Power Structure Block

5. GreenFone – LegoPhone

Rapid technological changes have led to the development of newer cell phones crammed with new features. This has led to the average cell phone to have a market lifetime of less than year. However the advantages in this process are manifold namely 1) the possibility of upgrading a cell phone by just replacing a relevant part by a newer more hi-tech version. 2) Recycling becomes easier as clearly marked nonbiodegradable components can be sent back to the manufacturers while the greener components can be conventionally disposed of. 3) The life time of a cell phone increases as it becomes easier to just locate and replace defective parts in such a device. 4) The user can customize a cell phone adding components that he requires thereby reducing cost of the overall device.

6. GreenFone – Future Scope

The main aim of GreenFone is design a mobile communication device that is both greener as well as cheaper. With these points in mind, we propose some additional enhancements.

6.1. BioSuit

The arrangement described in the section 4 to power the Greenfone can be used to provide power for any number of wireless devices. Since it may not be cost effective to use such an arrangement for miniature devices such as ipods or hearing aids. We propose the use of a BioSuit. The biosuit would be made up of the same starch based resin which can be tailored to give the appearance of normal clothing. The array of nanowires embedded in the resin can convert mechanical energy expended in moving the muscles into electrical energy which can be stored in a battery unit that charges all the other devices. The thermally conductive filler material and external coating of spinach based solar cells help in maximizing the production of greener power. The use of this

6.2. Linux Freeware

Cell phones currently use symbian or UIQ operating systems that are proprietary and add to the cost of the device.We propose the usage of linux as an alternative low cost software access mechanism.

7. GreenFone - Challenges

There are a few challenges involved in bringing the project to reality.These include 1) Problems associated with mass production of graphene based circuitry using lithographic technique. 2) Currently available electrically conductive adhesives cannot withstand temperatures above 150 degrees celsius. 3) Further research required in making Zinc Oxide nano wire arrays based power delivery mechanisms commercially viable. 4) Discharge time of O.R.B is significantly lower hence necessitating the need to stack arrays O.R.Bs and providing requisite heat sinks for the same.

8. Conclusion

"We do not inherit the earth; we borrow it from our children"

There are many innovative green solutions in our proposal. Even partial adoption of the various solutions given here, can reduce E-waste and power consumption to a greater extent.

9. Acknowledgement

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