Using biodegradable material as electrical and electronic components

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Access to information and communication technology (ICT) has been identified as an indicator of a country's economic and social development. The rapid growth of the ICT sector has therefore led to an improvement in the capacity of electrical and electronic equipment, which has also led to a decrease in product lifetime, so that the volume of waste generated increases annually by 10% .

Many countries lack the infrastructure and resources needed to manage electrical and electronic waste (e-waste) in an environmentally sound manner. Some West African countries, including Benin, Côte d'Ivoire, Ghana, Liberia and Nigeria, now face huge challenges in e-waste management.

Public nuisance and health challenges that arise from e-waste disposal are of serious concern to humanity and the environment. The exposure to e-waste hazards in and around dismantling sites causes manifold health and safety risks for scavengers, recyclers and neighbouring populations (Basel Convention, 2011a). Hazardous substances are released during various e-waste dismantling and disposal operations, particularly during the burning of cables to liberate copper and plastic to reduce waste volumes.

The production and use of electrical and electronic equipment needs to be revisited through the application of technology frontiers that are environmentally compactable and safe.

Chemical composition of e-waste

Many components of electrical and electronic equipment contain aluminium, copper, lead, cadmium, zinc, mercury, ferrous metals, glassware/ceramics and thermoplastics. A personal computer (PC) comprises 26% silica or glass and 23% plastic. Metals constitute 51% of PCs. These materials normally biodegrade very slowly, with full degradation occurring in 500 to 1 000 years (Irimia-Vladu, Głowacki, Voss, Bauer and Sariciftci, 2012). Generally, e-waste, as a composite material, is not necessarily hazardous, but harmless natural substances become hazardous during the manufacturing process. For example, chromium becomes hexavalent chromium, which is a human carcinogen when inhaled.

Rising e-waste trends in Nigeria

The media has paid considerable attention to the trade of used electrical and electronic equipment in Nigeria. An estimated 500 containers of used electronics and computers are imported into Lagos ports daily. In 2010, containers of imported used electrical and electronic equipment in categories 2 to 4 were analysed between May and July by monitoring shipment manifests and providing shipping information for about 176 containers. The results revealed that almost 60% of the containers came from the United Kingdom (UK), with Felixtowe as the dominant exporting port. More than 75% of all containers came from Europe, approximately 15% from Asia, 5% from African ports (mainly Morocco) and 5% from North America.

In the light of this rising trend, the National Environmental Standards and Regulation Enforcement Agency (NESREA) recently ordered a vessel carrying e-waste at the Tin Can Island Port in Lagos to send its consignment back to the UK. NESREA cited the provisions of the Nigerian Harmful Wastes Act of 1988, which was promulgated after the Koko waste saga in 1988. Local Nigerian officials discovered the illegal toxic waste stored at the port of Koko. Some first-world countries saw Nigeria as an illegal dumping ground for e-waste and the waste was more toxic than many had realised. Many workers started to need hospitalisation, with problems ranging from chemical burns and nausea, to paralysis. By 2011, NESREA had intercepted five ships carrying e-waste destined for Nigeria.

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Technology frontiers

In order to mitigate the e-waste crisis, more biodegradable components should be included in electrical and electronic equipment. According to Irimia-Vladu et al. (2012), many organic materials, including natural compounds, have been shown to be biodegradable, safe and non-toxic. Biodegradation is a natural form of recycling. Until recently, legislations, policy, guidelines and standards merely governed the transboundary movement of hazardous waste and its disposal, together with take-back and extended producer responsibility (EPR) programmes for end-of-life electrical and electronic equipment, (Basel Convention, 2011b; NESREA, 2011). The application of organic field effect transistor (OFET) technology, organic thin-film transistors (OTFTs), organic light-emitting diodes (OLEDs) and organic photovoltaics (OPVs) in the manufacture of electronic devices promotes the sustainable management of e-waste.

Research conducted to find replacements for some of the inorganic components of electronic devices suggests that biodegradable components would be a better choice. Experimental tests have shown that the integration of active organic materials into e-devices has allowed the implementation of low-cost, lightweight and flexible sensing devices. Such usage is currently proposed in the field of environmental monitoring, military defence and preventative medical care.

→ *The search for biodegradable material for use in computer components is a vital step towards curbing e-waste and the impact it has on human health.*

> The best technologies yield multiple gains in the field of environmental protection, working conditions and employment creation.

Advancements in biomaterial processing and organic electronic device fabrication have allowed the potential integration of biomolecules as active components in all the materials employed in the realisation of an organic transistor, including the bulk substrate, dielectric interface, active semiconducting layers and electrodes.

Irimia-Vladu et al. (2012) suggest that silicon-based electronics can also be fabricated onto silk, and the silk can be used as a bioresorbable carrier. Silk has also been used as a substrate for passive radio frequency identification (RFID) circuits that can be integrated directly onto food, such as apples and eggs as sensors of food quality. In addition, silk can be fully biodegradable and can be engineered to degrade under chosen conditions, allowing selected drug storage and delivery.

These findings also identify gelatine, which is commonly used for oral medication capsules, as a good substance for electronic components. Electronics built on hard gelatine could easily be ingested for specific biomedical applications that target a short examination time. The placement of organic field effect transistor components directly onto hard gelatine capsules has also been demonstrated.

In addition to electronic conduction, several biological materials are ionic conductors (Irimia-Vladu et al., 2012). The earliest organic electronic “device”, a resistive switching element, was based on melanin, a biological polymeric material that is responsible for brown-black skin pigmentations in animals and humans (Angione, Pilolli, Cotrone, Magliulo, Mallardi, Palazzo, Sabbatini, Fine, Dodabalapur, Cioffi and Torsi, 2011). It has been employed in several sandwich diode devices. Proton-conducting materials, which have been extensively researched for fuel cell applications, have recently been documented as a huge prospect in biocompatible electronics. Many conducting polymers are uniquely suited as bioelectronic interfaces, because they can conduct both ionic and electronic currents. Both modes of conduction have potential application in biodegradable electronic products and biomedical devices. These common conducting polymers have been shown to be non-toxic and remarkably biocompatible (Schwabegger, Mujeeb, Irimia-Vladu, Baumgartner, Kanbur, Ahmed, Stadler, Bauerb, Sariciftci and Sitter, 2011; Angione et al., 2011).

Policy direction towards biodegradable electronic components

In the field of waste management, EPR is a strategy designed to promote the integration of environmental costs associated with electrical and electronic equipment throughout their life cycles into the market price of the products. It is an environmental protection strategy to decrease the environmental impact of electrical and electronic equipment by making the manufacturer of the product responsible for its entire life cycle.

Manufacturers are now advised to enclose information leaflets on e-waste management and the best strategy to involve business and industry in corporate citizenship responsibility programmes, including the EPR and buy-back mechanism (Basel Convention, 2011a). In Nigeria, the introduction of a buy-back mechanism has yet to gain ground because of government uncertainty in enforcing a sound EPR programme in terms of e-waste (NESREA, 2011). However, Nokia, the mobile phone manufacturer, has embarked on the collection of used mobile phones in 83 buy-back centres in Nigeria (Osibanjo, 2009).

Samsung, another electrical and electronic equipment firm, produced 45 million OLED displays in 2011, and aims to produce up to 600 million units by 2015 (Irimia-Vladu et al., 2012).

Conclusion

The best technologies yield multiple gains in the field of environmental protection, working conditions and employment creation, as well as in general economic terms.

Such practices encourage the formal application of the five Rs of e-waste: reduce, repair, reuse, recycle and recover (NESREA, 2011), minimise occupational and environmental hazards, and promote economic benefits.

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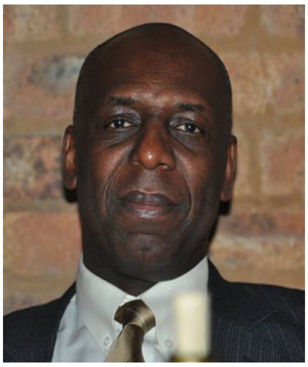

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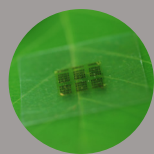

More bio-degradable components should be included in electrical and electronic equipment.