School of Mechanical and Design Engineering

Creative Smart Systems

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1. INTRODUCTION

This report contains research in depth into existing products and business practices around smart materials. Smart technologies are now in the initial phases of development, with few effective and viable consumer applications in the realm of enabling smart components. The project's goal is to investigate applicable smart materials and develop a creative solution for a mass-marketable device, either unknown or proposed that employs the components in a realistic way to increase the product's value.

2. RESEARCH INTO DIFFERENT SMART MATERIALS

2.1 Smart Materials

Smart materials can respond to one or more environmental stimuli in a reversible manner (for example, chemical, electrical, light, temperature, and mechanical stimuli). Chemical and strain sensors, actuators, switches, robotics, artificial muscles, and controlled medication delivery are just a few of the applications that have been studied extensively. Metal alloys or inorganic compounds, polymers, and carbon nanomaterials are used in traditional smart materials.

Shape-memory alloys and piezoelectric ceramics, for example, have been widely employed to make actuators. However, because of their difficult working conditions and/or high operating voltages, their practical uses are limited. Polymer-based smart materials have the benefits of flexibility, light weight, and high transparency, but they also have the drawbacks of poor mechanical strength, delayed response, and poor environmental stability.

Carbon nanomaterials, on the other hand, are often inexpensive, stable, mechanically strong and flexible, as well as electrically and thermally conductive. As a result, they're excellent starting points for the development of high-performance smart materials and gadgets. Carbon nanotube (CNT)-based electromechanical actuators, for example, produced enormous strain deformations at low applied voltages, but the techniques for altering or treating CNTs to make them ‘smart' are costly and time-consuming

2.2 Types of Piezoelectric Materials

Natural or man-made materials can be used to make piezoelectric materials. Crystal materials like quartz (SiO2), Rochelle salt, Topaz, Tourmaline-group minerals, and bio things such as silk, wood, enamel, dentin, bone, hair, and rubber are examples of natural PEM. Crystals that are quartz analogues, ceramics, and other man-made piezoelectric materials are illustrations of man-made piezoelectric materials. Polymers and composites are two different materials. There are 32 different crystal classes, which are grouped into seven categories:

Triclinic, monoclinic, orthorhombic, tetragonal, trigonal, hexagonal, and cubic. The material's elastic nature is also represented by groups, with triclinic representing an anisotropic material, orthorhombic representing an orthotropic material, and so on.

In most cases, cubic materials are isotropic. Piezoelectric properties are recognized in just 20 of the 32 classes. Ten of these classes are polar, i.e. they polarize spontaneously. Fine powders of the component metal oxides are being used to make a piezoelectric ceramic. They are blended in precise amounts before being heated to make a homogeneous powder. The powder is combined with an organic binder and shaped into the desired shape structural parts (discs, rods, plates, etc.).

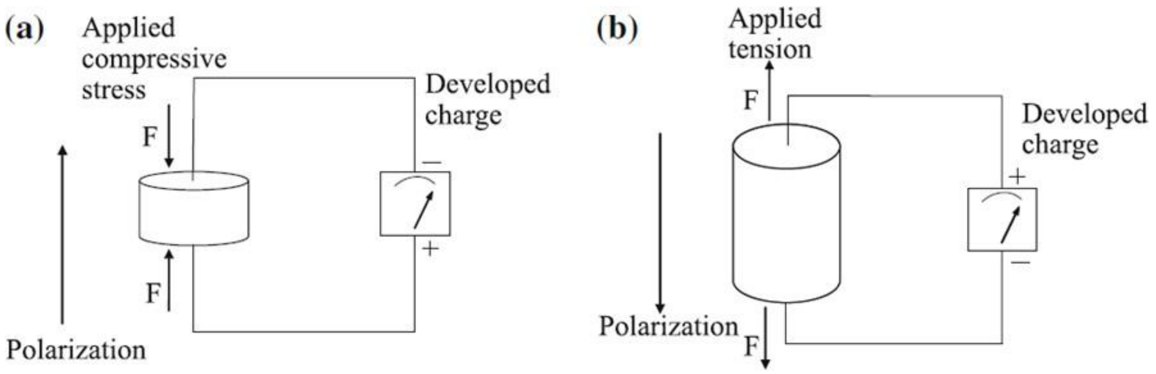

Figure 1: Direct piezo-effect: a at applied compressive stress, b at applied tension

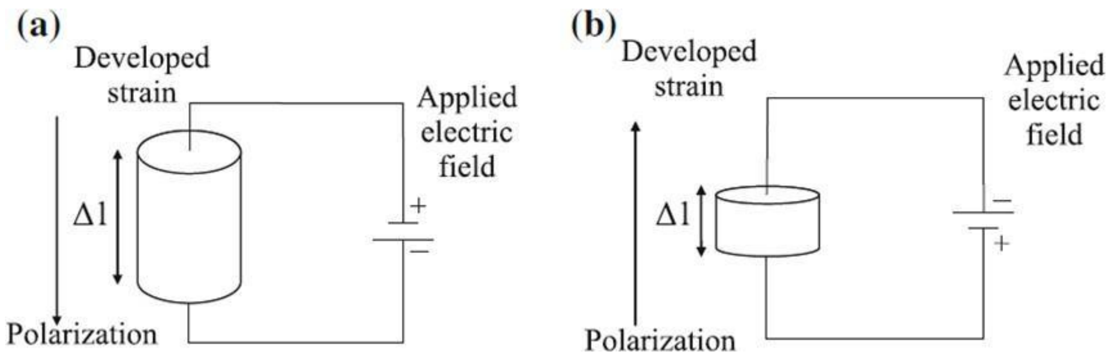

Figure 2: Inverse piezo-effect at applied electric field

2.3 Shape Memory Materials

When a certain stimulus is provided, shape memory materials (SMMs) have the potential to regain their original shape after a large and seemingly plastic deformation. The form memory effect is what it's called (SME). Under specific situations, super elasticity (in metals) or viscoelasticity (in polymers) are also frequent. From aerospace engineering (e.g. deployable structures and morphing wings) to medical devices, the SME can be used in a variety of applications like stents and filters.

2.4 Shape Memory Polymers

In terms of engineering, tailoring the material characteristics of polymers is far easier than tailoring the material qualities of metals/alloys. Polymers also have a lower cost (both material and processing cost) than metals. A wide range of SMPs have been developed and well-documented in the literature, and new ones are being developed every week, if not every day. SMPs are substantially lighter, have a lot larger (at least an order higher) reversible tension than SMAs, and can be activated for shape recovery by a variety of stimuli, including several stimuli at the same time. In addition to heat, light (UV and infrared light) and chemical (moisture, solvent, and pH change) stimuli exist. Moreover, many SMPs are biocompatible by nature.

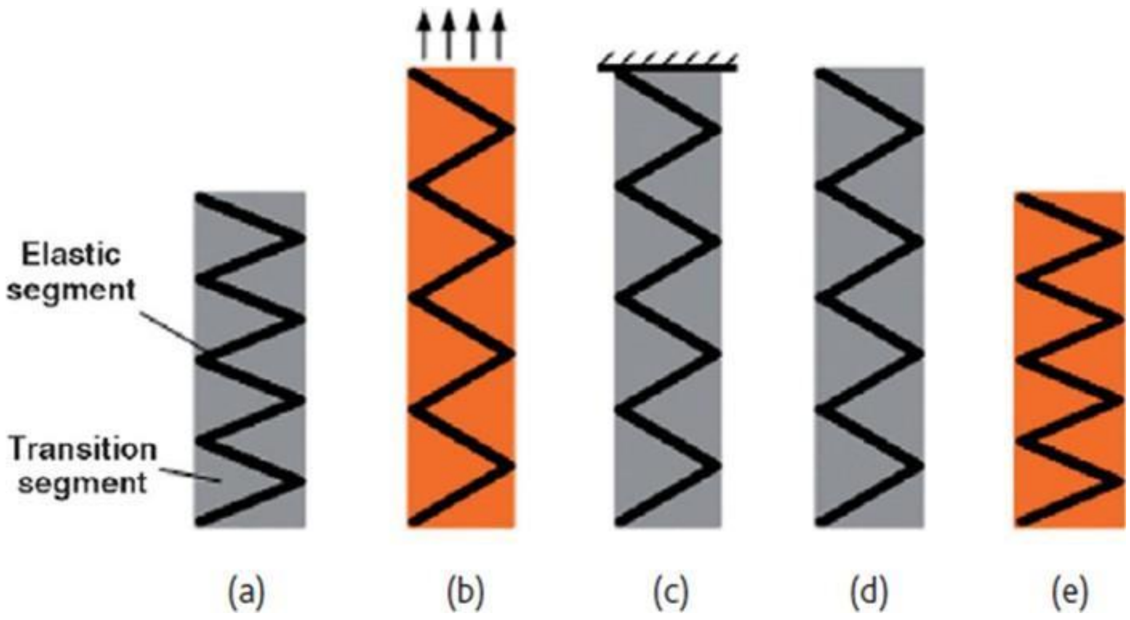

Figure 3: Illustration of the mechanism of the SME in thermo-responsive SMP. (a) Hard at low temperature (b) easily deformed at high temperature (c) hard again after cooling (d) temporary (deformed) shape after constraint removed (e) shape recovery upon

2.5 Thermoresponsive polymers

The development of thermo - sensitive macromolecules that can be sculpted into novel smart materials has sparked a great deal of interest in thermo - responsive polymers during the last few decades. Despite the fact that a wide range of different thermo - responsive polymers have exhibited similar promise for the development of adaptive materials, the overwhelming majority of previously published temperature-responsive polymers are centered on poly(N-isopropylacrylamide) (PNIPAM). Because of their higher biocompatibility and tunable reactivity, several of these (co)polymers promise apparent prospects for breakthroughs in growing biomedical and materials domains. Scientists intend to encourage the creation of new eras of smart materials by showcasing recent instances of newly created thermo - responsive polymer systems.

2.6 Graphene-based smart materials

Graphene's high specific surface area, as well as its superior mechanical, electrical, optical, and thermal properties, making it a desirable ingredient for high-performance stimuli-responsive or smart materials. Functionalization or hybridization, in addition to these intrinsic features, can increase the performance of all these materials. Mechanically exfoliated flawless graphene, chemical vapour deposited high-quality graphene, chemically modified graphene (for example, graphene oxide and reduced graphene oxide), and their macroscopic assemblies or composites are examples of graphene-based smart materials. Gas molecules or biomolecules, pH value, mechanical strain, electrical field, and thermal or optical excitation are all stimuli that these materials are responsive to.

Large specific surface areas, strong thermal and electrical conductivities, and outstanding mechanical qualities characterize graphene materials. Chemically modified graphene (CMG) materials, such as reduced graphene oxide (rGO), graphene oxide (GO), and their derivatives, can also be generated at a low cost on a wide scale. They could also be easily solution-processed into fibers, films, and porous frameworks, as well as changed or hybridized to expand their capabilities.

As a result, graphene and its compounds or composites hold a lot of promise for the development of high-performance smart materials. Despite the fact that graphene-based smart materials have been intensively explored in recent years 5–7, there is no comprehensive study that includes their manufacturing and practical applications.

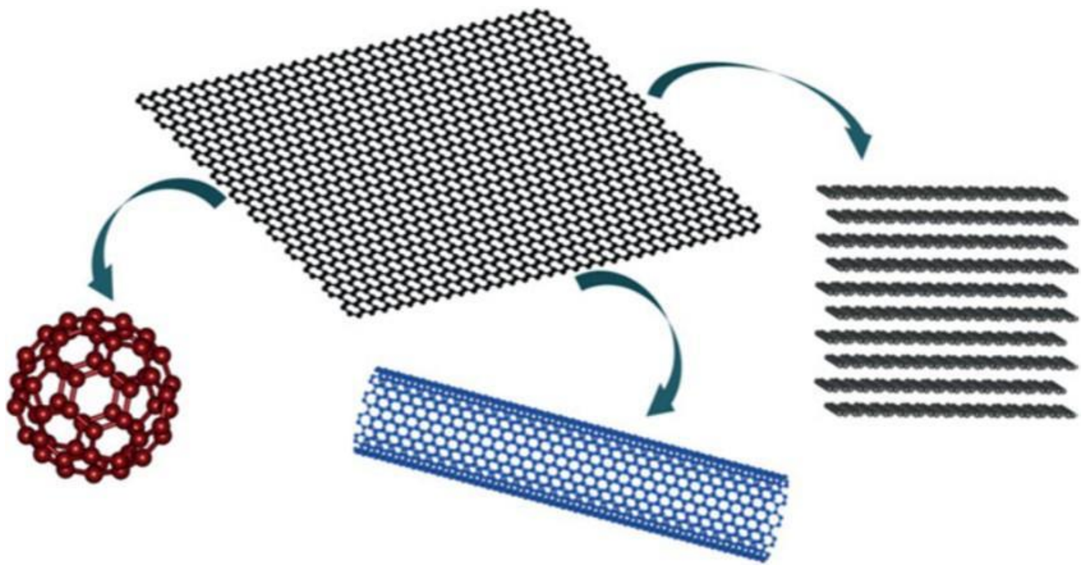

Figure 4: Graphene, the building block of all graphitic forms

3. EXISTING PRODUCTS

3.1 Carbon-based Materials

Carbon materials are frequently employed as Nano-fillers in composite materials, with applications in a variety of sectors (biology, pharmaceutics, energy storage, optoelectronics, medicine and many others). For example, fullerenes are utilized as electron acceptors in the construction of organic solar cells based on semiconducting polymers like poly-3-hexyl thiophene, which has greatly enhanced the efficiency of the corresponding devices, reaching levels comparable to inorganic solar cells. Graphene-based biosensors with high detection efficiencies for highly specific molecules have also been developed by taking advantage of graphene's excellent electrical and optical capabilities, even at very low concentrations. CNTs' large specific surface area, low electrical resistance, and great charge transport abilities have enabled the development of elevated supercapacitors with higher energy storage, power delivery, and a relatively extended life cycle as compared to traditional batteries.

3.2 Graphene produced products

- When graphene is mixed with rubber, the rubber becomes stronger and more elastic. The rubber shoes are shielded from everyday wear and tear thanks to the graphene in them. This essentially means that graphene-enhanced footwear is more durable, comfortable to wear, and attractive.

- Durable, lightweight, and most importantly, signal-oriented fishing rods are made from graphene and Toray carbon fiber.

- Heat will be distributed more quickly with graphene-enhanced light bulbs. As a result, the light bulb may produce light while using less energy. Because graphene-enhanced light bulbs consume less energy, there's a good chance your electric bills will go down. Graphene-enhanced light bulbs are economical and long-lasting, and they help consumers save more money.

Figure 5: Graphene shoe

Figure 6: Graphene fishing rods and graphene light bulb

4. PROPOSED IDEAS

4.1 Design Concept 1

Graphene-based bicycle:

Throughout history, bicycles have almost always maintained the same basic shape, but innovations began to come with the discovery of new materials. For many years it was thought that the use of iron or steel for the frame of the bicycle was unbeatable, until aluminum came along, which was a huge breakthrough. The same thing happened years later with the discovery of carbon fiber, and now it's happening again with graphene.

Graphene was discovered in the search for lighter and stronger materials, like almost all innovative materials, it went hand in hand with the aerospace industry, and so far it has been used mainly for this, but the future is here as it is a material 100 times more resistant than steel and 5 times more lightweight than aluminum. Graphene also provides rigidity and flexibility. Graphene Bikes are 2x stronger and 30% lighter than traditional bicycles. Graphene combined with improved carbon fiber allows for the creation of lighter, thinner, and tougher tubes than standard carbon.

Figure 7: Graphene bike concept

4.2 Design Concept 2

Graphene-based headphones:

Many scientists have become interested in graphene in past years. Its remarkable properties make it appealing for use in electrical equipment, such as mechanical strength, thermal conductivity, ultra-high mobility, and transparency. Graphene was originally used in audio devices due to its thermal acoustic effect. Traditional speakers utilize mechanical transmission components to build pressure and produce acoustic signals.

This is the one chosen as the final idea for the concept. The industry of wireless headphones made of smart materials is not developed yet, so it is a good opportunity to enter the market with a unique and innovative product, such as a headphone made of graphene. Since graphene gives:

- Instant improvement in sound quality
- Extension of battery up to 70%
- More volume from small speakers
- Unrivalled high frequency response for improved localization cues

Figure 8: Graphene headphones concept

5. PDS

5.1Aesthetics

The final design of the concept will include a closed-back headphone that will work through Bluetooth to make it wireless and will have a noise cancelling function. It will be flexible thanks to the material it is made of (graphene) and will therefore be able to adapt easily to the shape of the user's head.

5.2Cost

The average price of 1 square centimeter of graphene on copper foil is £1.03. The estimated area of material in the headphones is 372 square cm, which works out to about £383 of material. The average price for headphones with Bluetooth and noise cancelling is about £150. Adding about £15 per product for profit, the final estimated price is £548, which rounds up to £550.

5.3 Customer and consumer

The final product is primarily aimed at professional gamers. Within this industry, graphene headphones would be highly valued, due to their light weight, strength and durability as well as their conductivity and flexibility that allows a good grip and a good adaptation to the user's head. Apart from the gaming sector, it can be a very useful product for cybersecurity and IT companies as well as for music studios and producers.

5.4 Environment

Product manufacturing will try to get as close to zero emissions as possible. No leftover material will be thrown away as it will be recycled to re-produce headphones during the manufacturing process. We will refund a part of the money if they send us back the headphones that they no longer want to use or that have broken, in order to recycle the material that is no longer in the factory.

5.5 Size

The headphones will have a standard size: 200mm high, 186mm at the base, 85mm wide in the ear cup area and 30mm wide in the headband area.

5.6 Function

The overall function of the product is to be able to listen to clear, high quality sound without the need for other people in the same room to hear it. The headphones will have a Bluetooth connection so that there are no cables in the way, as well as an external noise cancellation function.

5.7 Material

The final product will be composed almost entirely of graphene, a very strong and lightweight material that will undoubtedly make the product unique in the world. It has a great ultra-high mobility quality as well as a great thermal acoustic effect. The material is expensive at £1.03 per square centimeter but it is well worth it.

5.8 British Standards

5.8.1 General

Overall latency between the analogue input to the analogue output shall not exceed 10 ms.

5.8.2 Frequency response

The overall interpreting system shall correctly reproduce audio-frequencies between at least 125 Hz and 15000 Hz ± 3 dB, high-pass with attenuation of at least 12 dB per octave for frequencies below 125 Hz in order to improve speech intelligibility.
The microphone and the headphones shall correctly reproduce audio-frequencies between 125 Hz and 15000 Hz ± 10 dB.

5.8.3 Amplitude nonlinearity

The system shall be free of perceptible distortion; total harmonic distortion (THD) should be less than 1%.

5.8.4 Noise and hum

The system shall be free of perceptible noise and hum, with an end-to-end signal-to-noise ratio of at least 95 dBA at maximum level.

5.8.5 Hearing protection

An audible hearing-damage warning shall be activated when the average sound pressure level is higher than 80 dBA for more than 1 minute.
The system shall limit loud sounds, with a maximum output level of 94 dBA for any duration longer than 100 ms.

5.8.6 Level consistency across channels

The volume of each channel should be automatically adjusted to minimize the volume difference between channels, as well as between channels and the floor assuming that the input level varies between nominal and ±12 dB

5.8.7 Characteristics

- Mass: ≤100 g.
- Ear contact pressure: ≤2,5 N
- Headband: adjustable in length and should be sufficiently flexible to adapt to individual ear pressure requirements.
- A lead approximately 1,50 m long and terminating in a non-locking TRS plug of 3,5mm.

6. Conclusion

Summarizing, the results of the report have showed that using a smart material to sense and respond instead of traditional mechanisms can simplify systems, decreasing weight and the risk of failure. Smart materials detect changes in their surroundings and react in a predictable way. The project's goal to investigate applicable smart materials and develop a creative solution for a mass-marketable device have been met successfully. As stated above the final design/concept will include a noise cancelling closed-back headphone connected via Bluetooth. Furthermore, the product would be composed almost entirely of graphene, a very strong and lightweight material that will undoubtedly make the product unique in the acoustic industry.

7. References

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