Shaping the future of sports

The sports and leisure sector is becoming increasingly important in society, and with the UK market for sports equipment valued at around £4.2 billion there is real potential for smart materials and systems to take a significant share of the market. Based on the Materials Foresight report 'Smart materials for the 21st Century', Dr Chris Bowen provides an overview of how smart materials and systems are making an impact on the sports and leisure area.

Game, set, match – with the UK market for sports equipment valued at around £4.2 billion there is real potential for smart materials and systems to make their mark, from tennis rackets and baseball bats to golf clubs and sports clothing

The sports sector has always embraced new and novel structural materials such as aluminium alloys, titanium alloys, advanced polymers, glass and carbon composites. These materials are rarely developed by the sports industry and tend to originate from those developed for military, aerospace and transportation applications. A similar pattern is emerging in the field of smart materials whereby piezoelectric fibres and shape memory alloys, developed for other sectors such as medical and aerospace, are being incorporated into sports based equipment – although novel textiles are often developed purely for the leisure market.

Smart materials are often used to construct smart systems and include a wide range of materials such as piezoelectrics, magnetostrictives, shape memory alloys and polymers, thermo and electro-chromic materials, and conductive polymers. The piezoelectric tennis racket manufactured by Head is a good example of a smart system in sport.

Making a racket

Modern rackets have been designed to be stiff to maximise the energy returned to the ball, which results in the racket transmitting large amounts of shock and vibration to a player's arm.

In an attempt to reduce vibration, piezoelectric fibres, which generate a charge under the application of a force, or develop a strain under an applied electric field, are embedded around the racket throat. When the ball is hit the racket frame deflects slightly, bending the piezoelectric fibres and generating a

equipment

charge that is collected by the patterned electrode surrounding the fibres. The charge and associated current is carried to an embedded circuit, which is then returned to the fibres out of phase to reduce the vibration by destructive interference. The manufacturer claims a 50% reduction in vibration compared with conventional rackets, although no published evidence exists. Similar technology is also used in K2 skis developed in the US with the aid of ACX (Active Control eXperts). Piezoelectric materials have been incorporated into snow skis, baseball bats, snowboards and water skis that passively damp vibration by converting them into an electric charge that is dissipated through a resistor.

Taking the strain

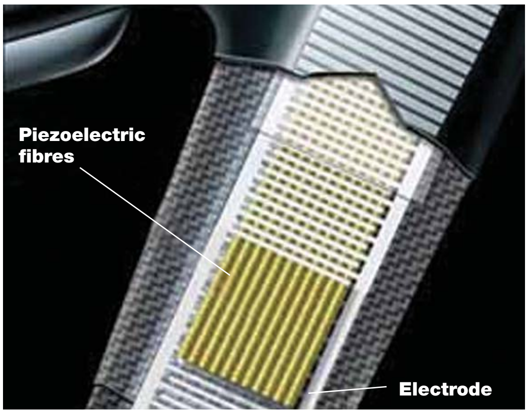
Another important area of development in the sports and leisure sector is in the application of shape memory alloys (SMAs), which are capable of recovering permanent strains as a result of a phase transition when they are heated. The alloys have been used for applications such as eyeglass frames and bra under wire supports because of their super elastic properties. Golf club faces have also used SMAs due to the high damping properties associated with the phase transition of this material. Grado Zero Espace has even used shape memory alloys to manufacture a shirt with memory.

The garment is made from a fabric consisting of nylon, woven with a nickel-titanium shape memory alloy. If the fabric is creased, the former shape can be restored using hot air. The company has also used a membrane material, Diaplex, produced by Mitsubishi Heavy Industries for cold weather clothing that can self-regulate its internal temperature and moisture content. The membrane is laminated from a shape memory polyurethane polymer whose permeability to water vapour and heat increase with temperature. This enables the fabric to be waterproof, windproof and breathable. In a similar fashion to the SMAs, the polymer changes structure at a transition temperature. After strenuous activity, or due to an increase in the external temperature, the garment reaches the transition temperature and becomes permeable to water vapour and heat, so cooling the user. As the internal temperature falls the material returns to a less permeable structure, keeping the user warm.

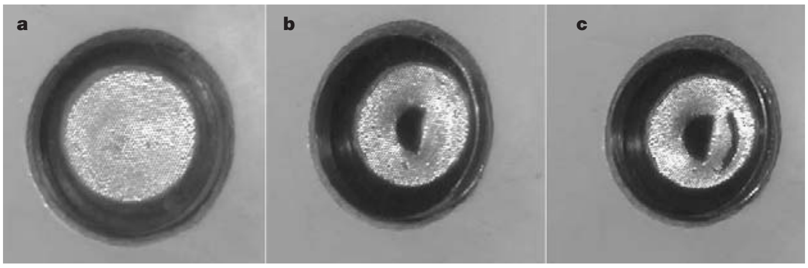
On the ball – opportunities for UK manufacturers

Many of the larger sports equipment manufacturers are often based outside the UK. However, there are many opportunities for UK manufacturers to increase their market share and competitiveness by developing products that incorporate smart technology.

In the UK, QinetiQ has been active in the development of smart material systems for the sports and leisure marketplace, and has examined a range of concepts and prototypes. They are currently working with Mitre on a visual ball pressure sensor based on the deflection of a diaphragm placed inside a football. As the ball is inflated, a column attached to the diaphragm moves closer to a viewing window made from a reflecting elastomer film. At low pressures the film obscures the moving column. When the ball is inflated to the correct pressure the column makes contact with the film and becomes visible by the user. By using a range of column heights, with each one becoming visible at different pressures, the correct operating pressure range can be easily obtained. This allows the ball pressure to be accurately and easily monitored, allowing greater consistency between balls. QinetiQ is also developing a damping unit situated between the handle and the rigid pole of skiing equipment. The unit is designed to remove unwanted vibrations and jarring, giving the user a greater degree of comfort.



A good example of the use of smart materials in sport – this tennis racket manufactured by Head is embedded with piezoelectric fibres connected to electrodes, which aim to reduce vibration to the player's arm (image: Reproduced from the Materials Foresight report 'Smart materials for the 21st century')



On the ball – QinetiQ's smart ball pressure window during inflation (a) low pressure (b) medium pressure (c) high pressure

Functional clothing – Grado Zero Espace has used Shape memory alloys to manufacture a shirt with memory

Functional fabrics

It is not only sports equipment where UK manufacturers are making an impact and taking a market share. SOFTswitch Ltd has developed the use of a pressure sensitive textile that consists of conductive metallic particles covered by a polymer insulator aimed at the sports clothing market, which accounts for almost 50% of the total UK market for sports products. Since the coating is extremely thin, the resistance of the material is sensitive to deformation, allowing it to be used as a switch or pressure sensor. The fabric has enabled electronics, audio devices and mobile phones to interface with clothing, in particular snow sports clothes manufactured by Burton Snowboards, Nike, The North Face and O'Neill.

The increased interest in novel textile materials has led to the development of an EPSRC UK Network initiative on 'Smart Textiles for Intelligent Consumer Products', based in the Innovation Centre at Central Saint Martins College of Art and Design, London. A principal aim of the network is to improve the development in smart textiles and systems, with textile users and designers being brought together with materials developers. Workshops are to be held during the three-year period of the network, each of which will cover a specific technology area, including sensors and actuators, display materials, circuits, antennas, and switches.

Overcoming potential barriers

Many of the smart materials discussed are readily and commercially available, driven by a need to:

- improve the performance of existing equipment and add value to the product and increase competitiveness with other manufacturers
- increase the functionality of an existing product, such as the use of conducting or colour changing textiles
- develop new products
- use smart materials as a marketing tool to increase consumer interest.

In addition to the materials, technologies such as active and passive vibration damping are being heavily researched in other sectors such as transport and aerospace.

While the materials and the technologies are clearly available, a potential barrier to the future development and commercial exploitation of new products in this sector is a lack of awareness and understanding of the properties and applications of smart materials by those working in the sports and leisure industry. However, encouragingly while traditional engineering and physical sciences degrees are finding undergraduate and postgraduate recruitment increasingly competitive, degrees in sport and exercise science (which concentrate on human performance), and sports engineering/technology/materials (which concentrate on equipment) are increasing in number. The Engineering and Technology Board is also using a lecture tour based on 'Engineering in the Olympics' to generate increased interest in engineering, science and technology across UK schools, so these potential barriers could soon be overcome by the next generation

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Further reading

- The aim of the Materials Foresight report on 'Smart materials for the 21st Century' was to carry out a comparative review of the status of smart materials technology, to identify the key drivers and barriers to commercial exploitation, and to recommend a strategy for future UK government funding support. The report considered areas such as aerospace, transportation, consumer packaging, construction, energy, white goods, healthcare and sports & leisure. Further Foresight report details can be found at www.iom3.org/foresight/reports.htm
- 'Review of state of art of smart structures and integrated systems', I Chopra, AIAA Journal, 40, pp2145-2187, 2002.
- 'Smart Fibres, Fabrics and Clothing', X Tao (ed), Woodhead Publishing in association with the Textile Institute, 2001, ISBN 1855735466.
- 'Electroceramics Materials, Properties, Applications, 2nd Edition' A J Moulson and. J M Herbert, John Wiley & Sons, 2003, ISBN 0471497487.