Piezo promises

Piezoelectric technology is over 120 years' old, but the changing nature of society's challenges has driven new research and applications. Markys Cain, a Director of the European Commission's Piezo Institute, discusses modern uses.

When brothers Jacques and Pierre Curie stumbled across piezoelectric properties in 1880, they could never have imagined how widely their findings would be used in decades to come. Their research uncovered piezoelectric properties in naturally occurring materials such as quartz and tourmaline crystals, and some rochelle salts. From the 1930s to the 50s, scientists developed new piezoelectric materials, such as barium titanate, which demonstrated enhanced properties. These materials boasted high piezoelectric performance in small packages, making them perfect for component applications in sonar and medical imaging. Barium titanate quickly became the archetypal material and paved the way for most piezoelectrics.

Advances in materials science enabled more complex piezoelectric materials to be developed, including man-made ceramics (such as lead zirconate titanate) and, more recently, polymers. Ceramics are particularly important to the design and development of piezoelectrics. Ceramic materials can be considered as all inorganic non-metallic materials. However, it is more useful to classify them as polycrystalline non-metallic materials that acquire mechanical strength through a sintering process.

Their inherent physical properties have made them desirable for a range of industries, such as electronics. However, these immediately apparent properties exploited in the first half of the 20th century are only the most obvious. As scientists discovered the unusually high dialectric constants of ceramics and began to link them to piezoelectric properties, the materials found their way into medical ultrasonic components, advanced sonar devices, televisions, boilers, and record players.

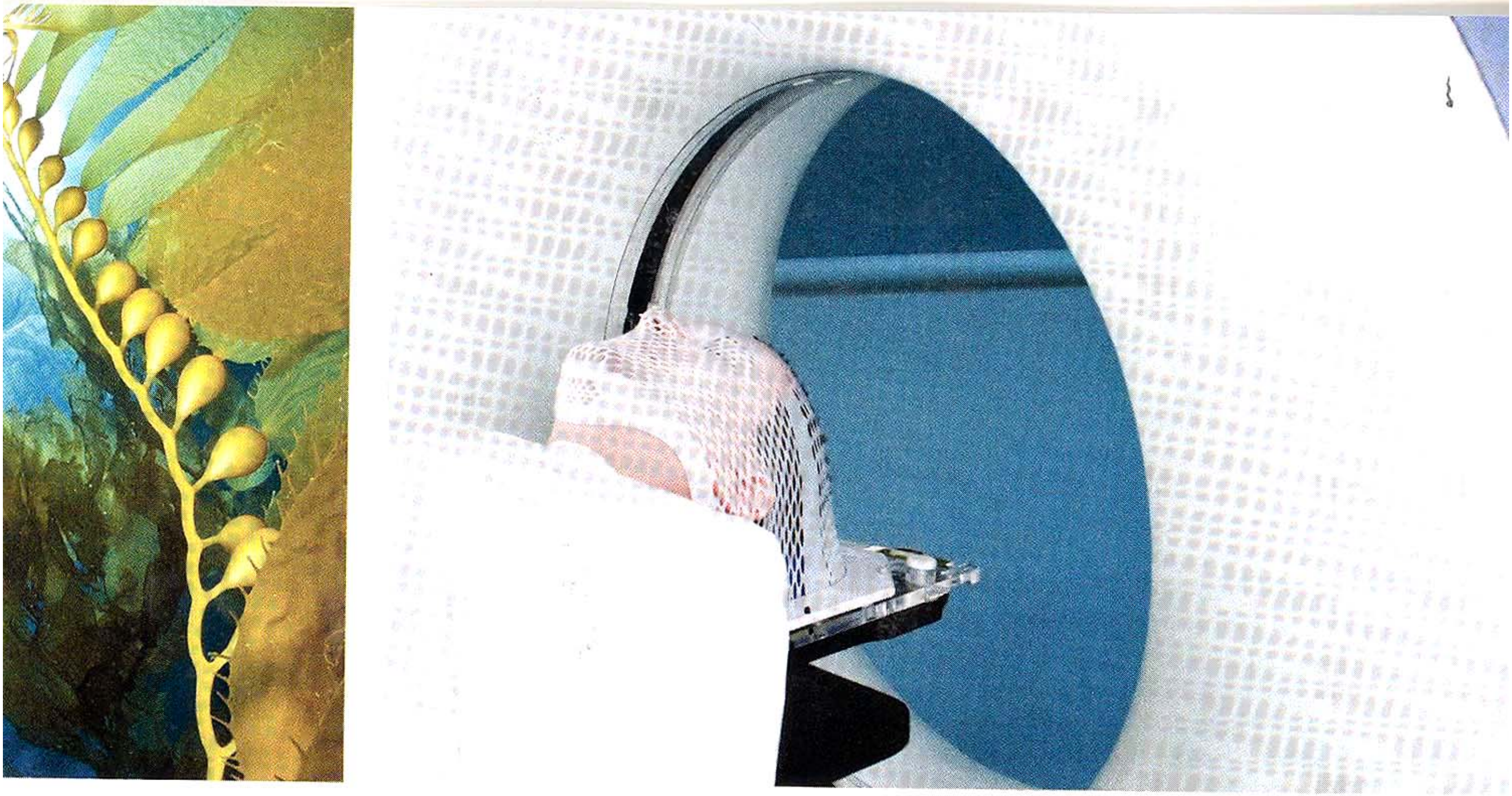
Further forward

Today's applications are considerably more advanced, but it is the potential applications that offer the greatest insight into how these materials may change the way we live and work.

Energy harvesting is a key example. This has become increasingly interesting in light of dwindling natural resources and the need to identify new sources of clean energy. The ability to generate power from small movements and vibrations offers new ways to run minute devices. It is realistic to imagine joggers powering their iPods as they run, or soldiers charging their communication packs as they march.

We are already starting to see some novel applications. A nightclub in The Netherlands has embedded piezoelectric crystals in its dancefloor so that clubbers power the lights as they dance (see *Materials World*, August 2008, p13). A similar

A medical transducer



Left: The University of Pittsburgh's piezoelectric 'seaweed' Right: An MRI scanner

principle has been applied to roads in Israel where a spinout company from the country's Technicon University has developed a system enabling cars to power streetlights as they drive past.

Most novel is the USA-based University of Pittsburgh's approach. It has created fake seaweed made from piezoelectric material. This is embedded in the estuary of a local river where the 'seaweed' generates electricity by flexing and bending in

Piezoelectricity

Piezoelectricity is the ability of certain materials to generate an electric charge in response to mechanical stress. The opposite effect also occurs – the application of electric voltage causes mechanical strain. These effects make piezoelectric materials effective in sensors and transducers.

tidal currents. Pittsburgh scientists estimate that the local town of Vandergrift could draw up to 40% of its power from this project.

Monitoring medicine

Piezoelectric materials are also commonly used in medical equipment, such as transducers in hearing aids, and for medical imaging. In the most advanced devices, materials science has delivered new ceramics that are improving our ability to spot diseases.

Piezoelectrics are critical to new imaging technologies that identify the resurgence of tumours that have been operated on. They are also helping medical physicists measure the 'hardness' of human tissue. Different densities are often the first sign of a problem.

At St James' hospital in Dublin, Ireland, medical physicists are using piezoelectricity to monitor coma patients' eye movements and explore their relation to consciousness. An individual's state of awareness can be detected by tiny involuntary tremors in their eyes. It is constant in healthy people but slows in a coma, rising again if they are likely to regain consciousness. A probe armed with a piezoelectric material is placed into the white of a patient's eye, similar to placing a needle onto a record. The eye's movement shifts the piezoelectric probe and generates a small current that can be monitored.

However, there is still much to do to make the most of the opportunities that piezo presents. Ceramics have exemplary properties, but the way they are designed and processed (including refining and tailoring composition to ensure suitability for applications) can have a significant impact on how they perform as piezoelectric materials.

A key challenge is the development of ceramics using 'domain engineering'. Ceramics are made of multiple grains of material. Within each grain a series of 'domains' exist, each of which has a different orientation and is irregularly packed together. Their co-operative motions impart a lot of the piezoelectric properties researchers want to enhance. Being able to engineer the order and orientation of these domains could produce specific properties. Advances in this area will make it easier to manufacture piezoelectrics that do exactly what we need and want.

The development of piezoelectric materials as thick and thin films as well as ceramics, is another area gaining traction. The ability to print, spin or fabricate these items would increase the flexibility of use, provide new ways to embed properties, and remove reliance on the existing structure of ceramics.

Scientists are also investigating 'single crystal' structures for piezoelectric materials to create a ceramic with a single domain – a crystal that offers an absolute theoretical value. This has been pioneered by the US Navy and offers up to 10 times the piezoelectric value of existing ceramics, but is extremely expensive to produce.

Further information

Piezo Institute, c/o Konstantin Astafiev, Ferroperm Piezoceramics A/S, Hejreskovvej 18A, DK 3490, Kvistgaard, Denmark. E-mail: info@piezoinstitute.com. Website: www.piezoinstitute.com.