The Power and Potential of Piezoelectric Energy Harvesting

The process of piezoelectric energy harvesting – that of converting mechanical energy into electrical – has rapidly gained momentum in recent years for a number of reasons, primarily due to its energy efficiency and environmental benefits. There has been considerable development in applications utilising piezoelectric innovations, alongside advances in ultra low power electronics, meaning energy harvesting is no longer viewed as being a potentially unreliable source of energy transfer, capable of only low power output. While alternative energy harvesting technologies are available, such as thermoelectric or electromagnetic energy, some have a reputation for unreliability and are not always capable of providing the consistent source of energy needed. **Fred Pimparel, Technical Manager, Morgan Technical Ceramics, Stourport, UK**

The process of piezoelectric energy harvesting – that of converting mechanical energy into electrical – has rapidly gained momentum in recent years for a number of reasons, primarily due to its energy efficiency and environmental benefits. There has been considerable development in applications utilising piezoelectric innovations, alongside advances in ultra low power electronics, meaning energy harvesting is no longer viewed as being a potentially unreliable source of energy transfer, capable of only low power output. While alternative energy harvesting technologies are available, such as thermoelectric or electromagnetic energy, some have a reputation for unreliability and are not always capable of providing the consistent source of energy needed. Fred Pimparel, Technical Manager, Morgan Technical Ceramics, Stourport, UK

Piezoelectric energy can be harvested by converting mechanical vibrations into an electrical charge, or by placing a material under significant strain through heavy pressure. These harvesters (Figure 1) generate electricity based on the amount of force used in compressing or deforming a material, as well as the amount and type of deformation on the material's crystal structure and the speed or frequency of compressions or vibrations to the material (Figure 2). The potential for piezoelectric energy harvesting is therefore much greater than alternative energy harvesting technologies, with the components capable of delivering up to 70 % of their charge.

Huge market opportunities

In terms of market opportunities in the future, independent research from IDTechEx found that the energy harvesting market is expected to grow from £450 million in 2012 to more than £950 million by 2017 [1]. Tests are already being carried out for piezoelectric energy harvesters to be used in an extensive variety of

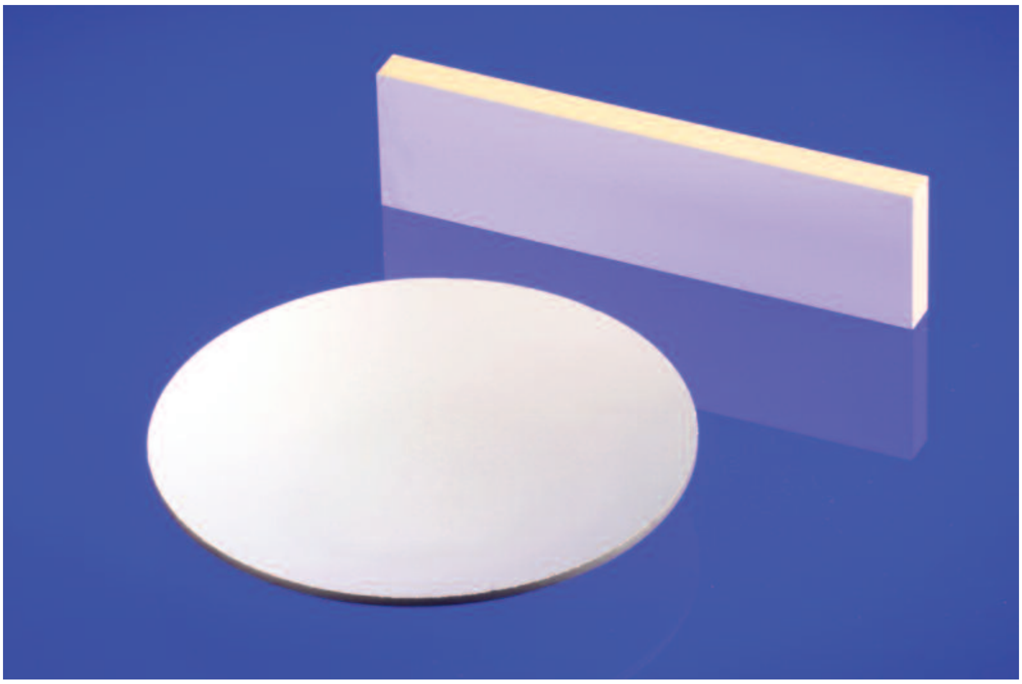

Figure 1: Pressure harvesters generate electricity based on the amount of force used in compressing or deforming a material

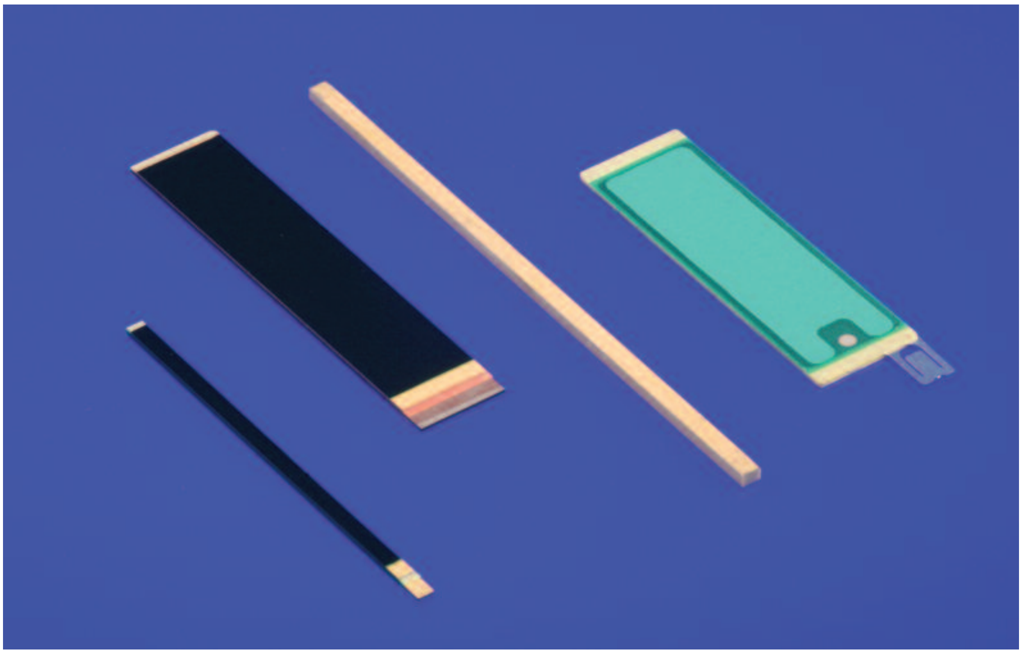

Figure 2: Example of vibration harvesters

applications. For instance, modules can be installed on roads or rail networks that react to heavy vehicles passing overhead, to generate energy that can be used to power LED lighting in signs or traffic lights. Industrial applications undoubtedly represent the biggest opportunity for piezoelectric energy harvesters, with electrical charge harnessed from vibrations in an engine shaft being just one key example. Industrial environments, such as oil and gas and manufacturing, will find energy harvesting a cost-effective alternative to wired infrastructure, which can be expensive. One of the greatest future challenges for piezoelectric energy harvesting is the ability to convert energy from broadband frequencies, harnessing a number of different sources of vibrations at various frequencies to produce a consistent supply of electric charge.

Choice of materials

The piezoelectric effect was discovered by Jacques and Pierre Curie in 1880. The French brothers learned that by subjecting certain crystals to mechanical strain, they became electrically polarized, with the degree of polarization proportional to the applied strain. The Curies also realized that these same materials deformed when exposed to an electrical field, which is now known as the inverse piezoelectric effect.

While quartz and ferroelectric crystals, such as tourmaline and Rochelle salt, are good examples of piezoelectric materials, ceramic lead zirconate titanate – more commonly known as PZT – is the most widely-used piezoelectric material used for energy harvesting. A key advantage of PZT materials is that they can be optimized to suit specific applications through their ability to be manufactured in any shape or size. Furthermore, PZT materials are resilient, chemically inert and resistant to high temperatures and other atmospheric pressures – all key benefits considering the greatest opportunity for piezoelectric energy harvesting is in industrial applications. PZT products can be deformed repeatedly to generate energy and power devices, with typical applications being sensors and industrial equipment.

But how do piezoelectric ceramic materials generate power through the conversion of mechanical energy into electrical? The smallest of deformations can produce a measurable charge. As a result, a PZT cylinder can generate voltages that are high enough to draw a spark across an electrode gap. The energy created can then be stored in a capacitor and used to power a circuit or another application. However, there are a range of factors which govern the performance of any power generated in this way, including the shape of the PZT transducer, the style in which the transducer has been installed and the nature of the electrical load.

For instance, a PZT disc that is compressed between two metal surfaces will never be able to expand as readily as a long, narrow PZT cylinder, which is only constrained at its flat top and bottom ends, resulting in greater potential for the straight parallel sides to expand. Essentially, it is important to allow the material some freedom to expand radially, since energy generation is directly proportional to deformation. If the force that can be applied is limited, then the energy converted can be optimized by ensuring it is applied to a particular area where the material has the freedom to expand outwardly.

Another important consideration is the impedance – the measure of opposition to the flow of an alternating current – of the load. When the current is created, it is important to match the electrical impedance of the piezoelectric component to the electronic recovery system, in order to maximize the energy transfer to the reservoir capacitor. The charge must be allowed to flow away quickly, otherwise the electrical field generated will tend to dissipate through the electronic components. As a result, applications subjected to a heavy pressure must be exposed to a fast 'impulse' to ensure the charge does not dissipate quickly. Furthermore, the choice and design of the electronic recovery circuit is of equal importance. It is essential to carefully consider components to minimize leakage currents and increase energy transfer efficiency.

Conclusion

The advantages to piezoelectric energy harvesters are numerous. The process offers some of the highest efficiencies and power outputs by size and cost, and is therefore extremely appealing to those in search of an effective, high-performance solution. The environmental benefit is to substitute batteries and other means of charging, and their associated replacement costs, rather than solely focusing on saving energy.

Literature

[1] IDTechEx report, 'Energy Harvesting and Storage for Electronic Devices 2012-2022: Forecasts, Technologies, Players', http://www.idtechex.com/research/reports/energy-harvesting-and-storage-for-electronic-devices-2012-2022-000316.asp