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Piezoelectric Ceramic Drives Automobile Innovation

Piezoelectric ceramic components composed of Lead Zirconate Titanates (PZT) have enabled many recent technological innovations in the automobile industry. PZT components can be found throughout many state-of-the-art vehicles, enhancing safety, performance, energy-efficiency and comfort.

For example, you will find PZT sensors under the hood detecting engine knocking, PZT transducers in the gas tank measuring the fuel level, PZT actuators operating valves in pneumatically adjustable driver’s seats, PZT ultrasonic transducers on the front, rear, and side of the car as parking sensors, and PZT generators in the wheels harvesting energy that powers tire pressure monitoring systems.

Piezoelectricity is a property of certain classes of crystalline materials including natural crystals of Quartz, Rochelle Salt and Tourmaline as well as manufactured ceramics such as Barium Titanate and Lead Zirconate Titanates (PZT). When mechanical pressure is applied to these materials, the crystalline structure produces a voltage proportional to the pressure. Conversely, when an electric field is applied, the structure changes shape producing dimensional changes in the material.

As a result, piezoelectric materials are used in four functional applications:

* Passive Sensors (converting mechanical force or movement into an electrical signal) such as accelerometers, knock sensors, suspension load sensors, airbag impact sensors and intruder alarms

* Generators (converting mechanical energy into electrical energy) such as spark igniters
* Transducers and active sensors (converting electrical energy into mechanical energy to produce ultrasonic waves, and converting mechanical energy into electrical energy to detect the returning ultrasonic waves) such as fuel level sensors and parking aid reverse sensors
* Actuators (converting electrical energy into mechanical displacement) such as valves for fuel injection systems, and devices for positioning headlamps and mirrors

PZT has proven its robustness in industrial applications for more than a half century, and it has several key advantages for automotive applications. Compact, solid-state piezoelectric ceramic devices have no moving parts and offer long-term reliability, even in harsh environments.

One of the principal advantages of PZT is that physical, chemical and piezoelectric properties can be optimized to suit particular applications by adjusting the Zirconate-Titanate ratio. On the one hand, relatively “hard” formulations of PZT are suitable for high power applications that involve high levels of electrical and mechanical stress. On the other, relatively “soft” formulations of PZT are suitable for applications involving high sensitivity and permittivity, such as sensors, and high strain, such as high displacement actuators.

Relative to other piezoelectric materials, PZT has a high conversion efficiency and exceptional temperature stability, important attributes for automotive applications. Moreover, the design versatility of PZT is also an important advantage: it can be fashioned into almost any shape and combined into composite structures with polymer filler.

For applications requiring miniaturization, Morgan Technical Ceramics has developed PMN-PT28 single crystal piezoelectric material that is manufactured in a high temperature crystal grown process at its Bedford, OH facility. This new family of piezoelectric ceramic is formulated to exhibit very large electromechanical coupling coefficients as well as high dielectric constants and low dielectric losses, resulting in more sensitive sensors and more efficient transducers and actuators.

Fuel Level Sensors

One innovative new design incorporating PZT is the “ship-in-a-bottle” fuel tank technology developed by an automotive company. The blow-molded plastic tank encloses the fuel pumps, level sensors and other components. Originally introduced for the 2005 Ford GT, this first-of-a-kind solution reduces the number of openings, minimizing evaporative emissions and providing additional space for a larger amount of fuel such as that required by the GT’s 500-horsepower engine. The traditional float gauges have been replaced with an ultrasonic level sensor with PZT ceramics for greater accuracy.

The sensor is installed at the bottom of the tank’s interior. An electric current is sent to the PZT material, which responds by oscillating. The resulting sound wave passes through the liquid and rebounds off the surface and returns to the transducer, registering the current fuel level based on a ‘time of flight’

measurement. The proven corrosion resistance and temperature stability of the PZT material ensures consistent, reliable operation.
Automotive companies also use this sensor technology for additive reservoir use in diesel engines. The additives improve emissions in combination with diesel particle filters.

Car Seat Valve Actuators
Another interesting use of piezoceramic is in comfort systems of car seats that are now found in several luxury brand cars. These systems use piezoelectric bimorphs (benders) embedded in the seat to drive valves that inflate/deflate strategically positioned aircushions, creating a massaging effect. A personalized level of comfort can be set and memorized to perform varying functions, such as lower back massage or temporarily increased side support.

The bimorph consists of two active piezoceramic plates separated by an inactive inner layer composed of carbon fiber. The two piezoceramic plates are electrically driven, so that one plate expands in length while the other contracts, and the whole component bends, opening a valve. The layered design, using piezoceramic coupled with carbon fiber, causes 20-30% greater deflection, enabling the designer to create a more-compact, lower-weight product.

Future Innovations
Automobile manufacturers and their tier one suppliers are working with the material scientists and applications engineers to develop new uses of piezoelectric ceramics to further enhance automobile safety, performance, energy-efficiency and comfort. The industry continually implements technological innovations that make cars smarter, and therefore piezoelectric sensors, transducers and actuators will play an increasingly important role, as the critical input/output devices for many electronic systems.

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