Piezoelectric Sensors and Transducers for Advancing Structural Health Monitoring Technologies

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The current industrial revolution demands decentralized intelligence that helps create smart and interactive objects networking. In the emerging generation of manufacturing and product applications, machinery will no longer simply process the product, but that real-time communications among the machinery, product or structure, and operator are becoming essential to tell exactly what is happening and what to do for the next step. As the crucial technologies for enabling an interconnected intelligent system, sensors and transducers that effectively detect and transduce various stimuli and signals are desired to be highly distributed, in a large quantity, and with online functional interactions in the system.

However, the implementation of existing sensors and transducers technologies, such as those for structural health monitoring including machine condition monitoring, is mainly based on installation of bulky, discrete and electrical wired sensors and transducers at specific locations. This is often not reliable or cost-effective in the desired cyber-physical system, and is becoming a bottleneck for advancing smart manufacturing and integrated system, because of the inconsistency of manual installation, tedious point by point testing with human factor errors, and complex wiring connection for signal communication and power supply for the individual components in the network.

With the multiple inherent mechanisms involving signal and energy conversion and storage, our analyses show that ferroelectric materials possess the great potential to create novel sensors and transducers with distributive real-time monitoring functions, and the advantages for realizing unique energy autonomous functions. In our experimental work, piezoelectric coatings, as the materials with inherent active ultrasonic signal transduction functions, are deposited and patterned directly on the mechanical structures to be monitored. Direct-write piezoelectric vibration sensors and Lamb mode ultrasonic transducers with reduced weight and profile are integrated on parts of manufacturing machinery and aircraft structure. We have also designed and demonstrated several unique wireless and energy autonomous sensors and transducers by utilizing and combining multiple signal conversion and storage functions of piezoelectric materials, including wireless accelerometers, energy-autonomous optical and vibration monitoring sensors. The results and analyses here show that innovations in piezoelectric sensors and transducers from ferroelectric materials have the great values for advancing structural health monitoring technologies as highly demanded currently and for the future.