Distributed Sensing Methods for Structural and Human Health Monitoring

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Both human systems and structural assets are susceptible to "damage" caused by fatigue, deterioration, changing operating conditions, and/or unexpected extreme events. This presentation outlines how multifunctional nanocomposites can be engineered for characterizing issues encountered by the warfighter and damage in structural assets. The development of carbon nanotube and graphene nanosheet thin film strain sensors, along with different fabrication approaches, will be first discussed. In addition to using them as discrete or point sensors, they can be coupled with tomographic methods to achieve spatial sensing. The second part of this presentation will demonstrate how densely distributed 2D sensing can be realized using an electrical impedance tomography (EIT) measurement strategy and algorithm applied to the aforementioned carbon-nanomaterial-based thin films. Specifically, smart socket prostheses instrumented with fabric-based nanocomposite pressure sensors were fabricated and tested. The results showed that pressure hotspots could be successfully characterized, which can help amputees prevent pressure ulcers and help guide prosthesis fitment. Similarly, by applying EIT and these thin films to physical structures, damage, such as cracks, strain fields, and pH/corrosion, could be identified and localized. Finally, the last part of this presentation will discuss the development of a noninvasive and field-deployable tomographic imaging system based on electrical capacitance tomography (ECT). Unlike EIT that applies electrical current to a conductive body, ECT leverages propagating electric fields and boundary capacitance measurements for reconstructing the electrical permittivity distribution of its sensing domain. Different materials and their changes (e.g., due to damage) can be readily imaged using ECT. Furthermore, subsurface structural sensing could also be achieved. Cross-sectional images of targets could be performed to image both human health issues (e.g., infection or fracture) and structural defects (e.g., voids or cracks). The presentation will conclude with a discussion of a modified planar ECT system, which was demonstrated for imaging subsurface damage such as delamination in fiber-reinforced polymer composites.