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Triboluminescent Sensor for Distributed Damage Monitoring in Composites: Wind Turbine Blade Application

ABSTRACT The in-situ triboluminescent optical fiber (ITOF) sensor combines the highly desirable features of polymer optical fibers (POF) such as lightweight, smaller sizes, immunity to electromagnetic interference and capacity for distributed sensing, with the triboluminescent property of ZnS:Mn. Trboluminescence is the emission of light when certain crystals are subjected to mechanical impact, rubbing and fracture. The ITOF sensor has an integrated sensing and transmission component that converts the energy from damage events like impacts and crack propagation into optical (light) signals that are indicative of the magnitude of damage in composite structures. The bio-inspired and proprietary ITOF sensor acts as a triboluminescent optical nerve network that can be easily weaved into carbon or glass fiber during manufacture or composite fabrication to provide in-situ damage monitoring capabilities for composite structures like airplanes and wind turbine blades. While other fiber optic sensors require external light sources with complex and expensive interrogation systems, the ITOF sensor generates its own light as induced by the damage-causing stimuli. This reduces system complexity, cost and required data analysis. The sensor is also uniquely designed to successfully couple the damage-induced light signals all along its length thereby possessing distributed damage sensing capability throughout its length. The 2012 claims data for GCube, the leading provider of renewable energy insurance services, shows that blade damage and gearbox failure account for the greatest number of losses, accounting for 41.4% and 35.1% of the total claims reported. Gearbox claims typically cost the industry $380,000, while turbine blade claims cost on average, $240,000, per claim. The majority of wind turbine blade damage can be attributed to lightning strikes. Delamination and improper handling during the construction and installation phase are also frequent. In addition, poor maintenance has been reported as a leading cause for these. While vibration analysis and oil analysis are commonly used for condition monitoring of the gearbox and generator, the wind blades usually have to be inspected. The high cost and difficulty associated with inspecting these huge turbine blades make their maintenance very difficult. The ITOF sensor when integrated into the wind blade during manufacture will provide real time, in-situ and distributed damage monitoring from cradle to death. This will enable effective maintenance planning. Timely detection and repairs will prevent catastrophic failures and expensive system downtime thereby reducing operations and maintenance costs. The wind energy sector is very promising. Wind generation has quadrupled since 2007, growing by more than 30 percent per year. The drive to promote green (eco-friendly) energy and energy independence is fueling this growth and is expected to be sustained. There is also the pressure on wind farm operators to lower their operations and maintenance cost so as to be competitive with fossil fuel and be profitable. In addition, there is a strong push from wind farm insurance companies encouraging the use of monitoring systems to ensure safe and prolonged use of wind turbines. The ITOF sensor will therefor meet a crucial need by providing cost-effective in-situ damage monitoring capabilities to large composite structures like wind turbine blades.

PRIMARY AUTHOR
David O. Olawale, PhD, PMP
Postdoc. Research Fellow
High-Performance Materials Institute
Dept of Industrial and Manufacturing Engineering
Florida State University
doo07@my.fsu.edu

CO-AUTHORS
Tarik J. Dickens
Assistant Professor, FAMU-FSU College of Engineering
Okenwa I. Okoli
Professor/Chair, FAMU-FSU College of Engineering
Emily C. Hammel
Graduate Research Assistant, FAMU-FSU College of Engineering

ADDITIONAL INFORMATION The bio-inspired and proprietary ITOF sensor is being developed as a triboluminescent optical nerve network analogous to the nerves in mammals. The goal is to provide large composite structures like airplanes and wind turbine blades with in-situ and distributed damage monitoring capabilities. This will enable timely damage detection thereby promoting timely and inexpensive repairs. This will also prevent catastrophic failure and costly downtime. While other fiber optic sensors require external light sources with complex and expensive interrogation systems, the ITOF sensor generates its own light as induced by the damage-causing stimuli. This reduces system complexity, cost and required data analysis. The sensor is also uniquely designed to successfully couple the damage-induced light signals all along its length thereby possessing distributed damage sensing capability throughout its length. The ITOF sensor is moving us closer to developing smart composite structures and systems with in-situ damage monitoring capabilities similar to that in mammals.

Focus Area(s)
Alternative Energy (Solar; Wave; Wind); Architectural; Infrastructure; Power Generation