STRUCTURAL HEALTH MONITORING SYSTEMS

for composite structures in future airplanes

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Health Monitoring Systems – Vehicles & Aircraft

Safety issues in composite structures remain to be studied with cost-effectiveness and easiness of monitoring,but without degrading Structural performance

What's out there?

Visual

- Dual-Pass Light Reflection (D-Sight)
- Edge of Light TM (EOL)

Eddy Current

- Magneto-Optics Imager (MOI)
- Pulsed Eddy Current (PEC)
- Superconducting Quantum Interference Device (SQUID)

Radiography

- Compute Tomography Scan
- Reverse Geometry X-Ray (RGX) Imaging
- Microfocus X-Ray Microscopy

Ultrasonics

- Dry coupling techniques
- Air-Coupled transducers
- Electromagnetic acoustic transducer (EMAT)
- Laser induced ultrasound
- Oblique Insonification NDE of composites
- Portable Real-time images

Shearography

Thermography

Related research projects at CIMS

We are working on designing a set of new active and sensing materials and devices at Center of Intelligent Materials and Systems(CIMS)

1. Design of active and sensing nano-composites(AFOSR)
2. Design of active materials for use in actuators(Darpa)
3. Spark Plasma Sintering(AFOSR)
4. Energy absorbing materials(ONR)
5. High strain-rate deformation of smart materials(Honda)
6. Design of smart antenna based on electro-active polymer(NSF)
7. Design of electrochromic windows(Boeing)

Requirements of future SHM system for polymeric composite structures

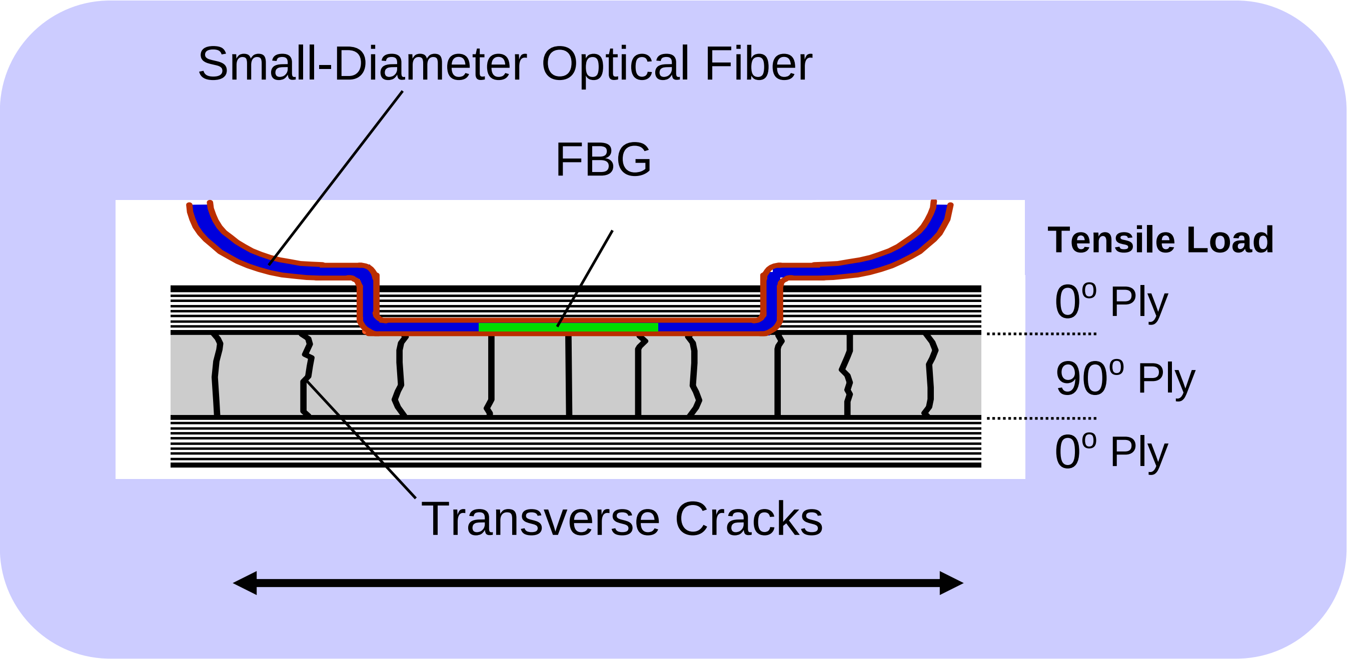
1. Monitoring only critical data set
2. Autonomous system with no connection wires
3. Power supply is self-generating
4. Monitoring can be done with a portable detector while an airplane is parked at airport
5. Stealth, and cost-effective and ultra lightness---detection via portable detector applied to nano-sensing particles embedded in a composite panel

What are the proposed SHM systems for Composite Structures ?

1. Fiber optics embedded in polymeric composites(Takeda et al,2004)
2. Metal core piezo-fibers embedded in polymer composites(Sekiya et al , 2003)
3. Piezo-sensor system attached on the surface of composite structure(Sato et al,2004)
4. Composite structure with sensing nano-particles embedded (UW-Toray)

1-3 are done as a part of NEDO project where UW(Taya) was involved as an active member of smart materials group.

Response of Fiber Bragg Grating Sensor to Strain

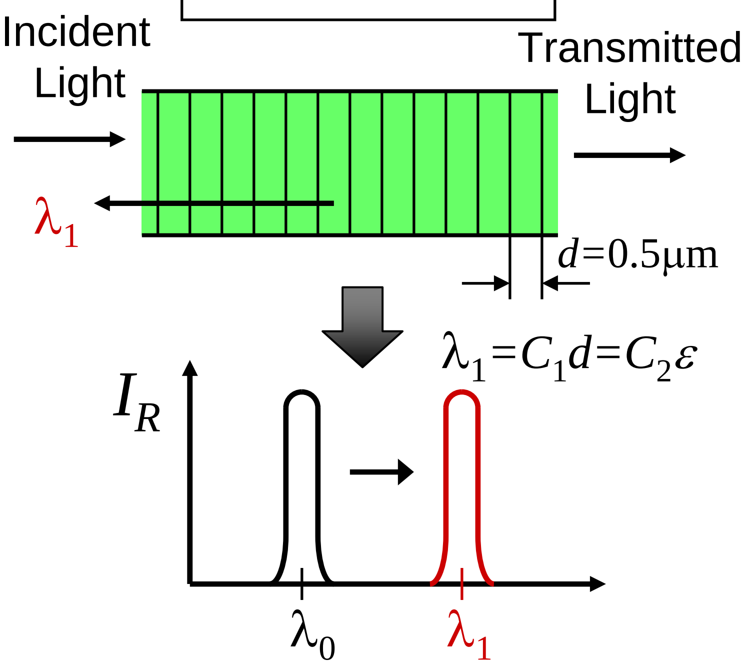


Small-diameter Fiber Bragg Grating (FBG) Sensors can be embedded close to transverse cracks without deteriorating the laminate.

Takeda, 2004

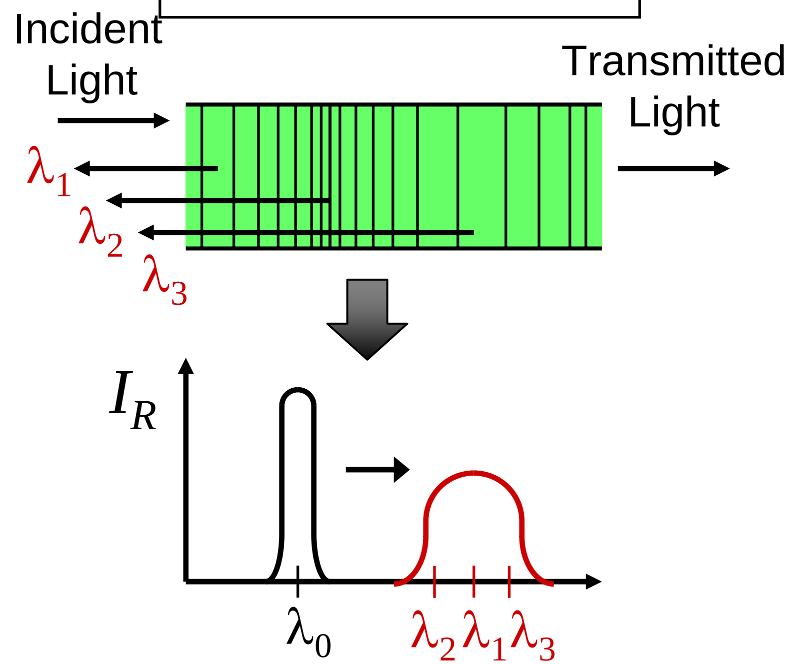
Response of FBG Sensor to Strain

Uniform strain



Reflection spectrum is *narrowband*.
Strain can be determined from the wavelength shift.

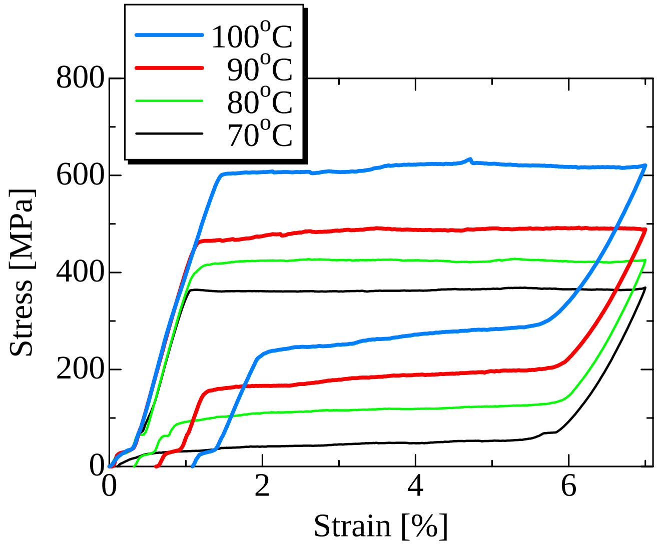
Non-uniform strain



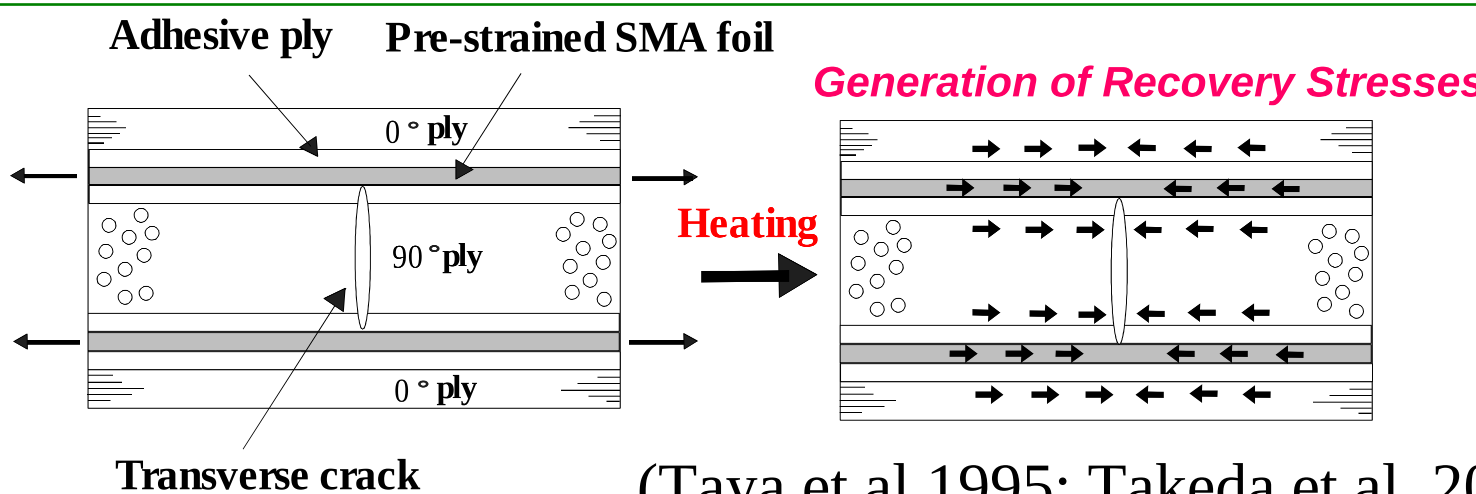
Reflection spectrum becomes *broadband*.
This phenomenon is applied to detection of damages.

Takeda, 2004

Suppression of Transverse Cracks in CFRP Laminates with Embedded Pre-Strained SMA Foils



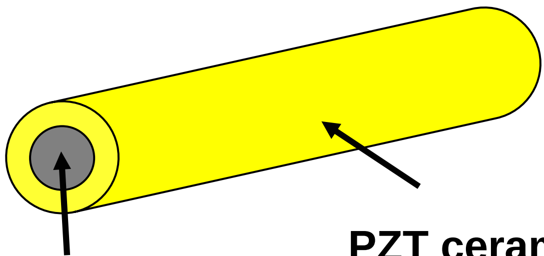
Load—Unload Stress-Strain Curves of SMA Foils



(Taya,et al,1995; Takeda et al, 2004)

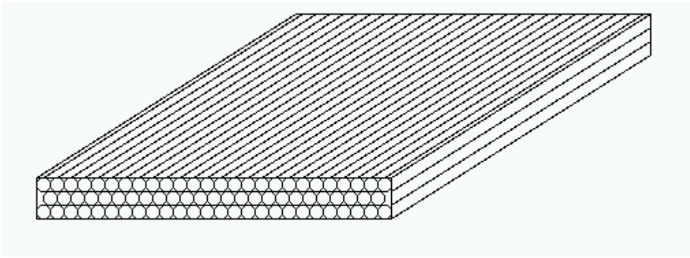
2. Metal core-Piezoelectric Fiber

Piezoelectric Fiber



•Hydrothermal Method
•Extrusion Method

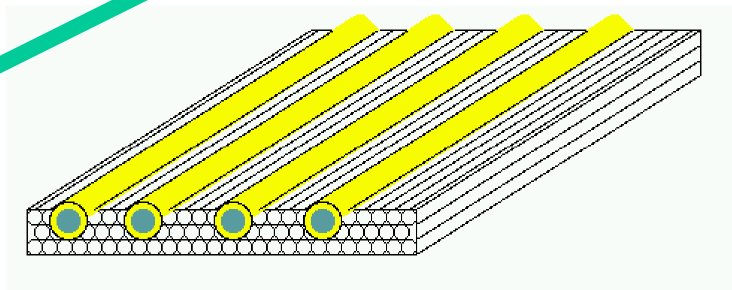
CFRP composite



CFRP (Carbon Fiber Reinforced Plastic)
The composite material between carbon fiber and epoxy resin.

Embedded in CFRP composite

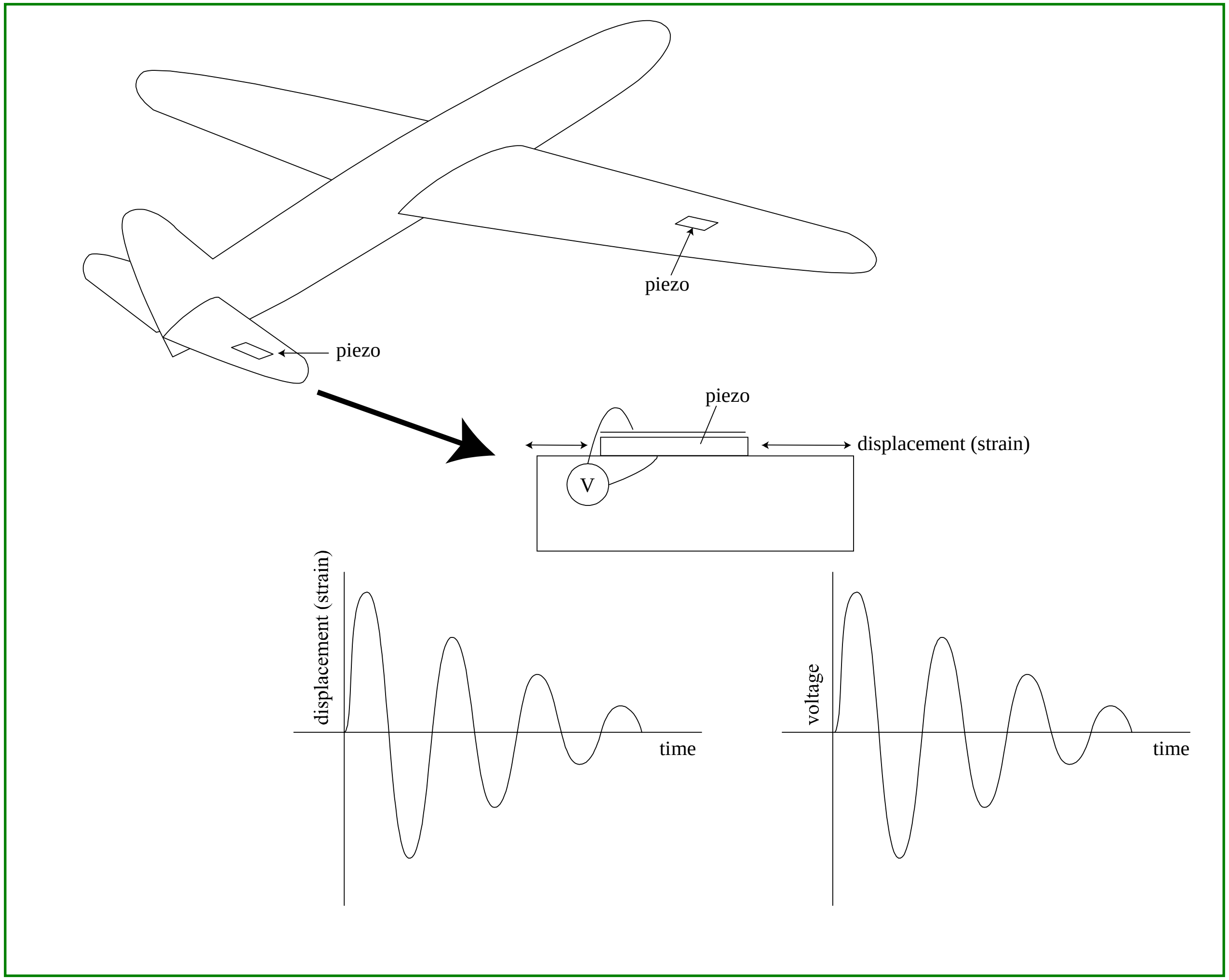
Smart board



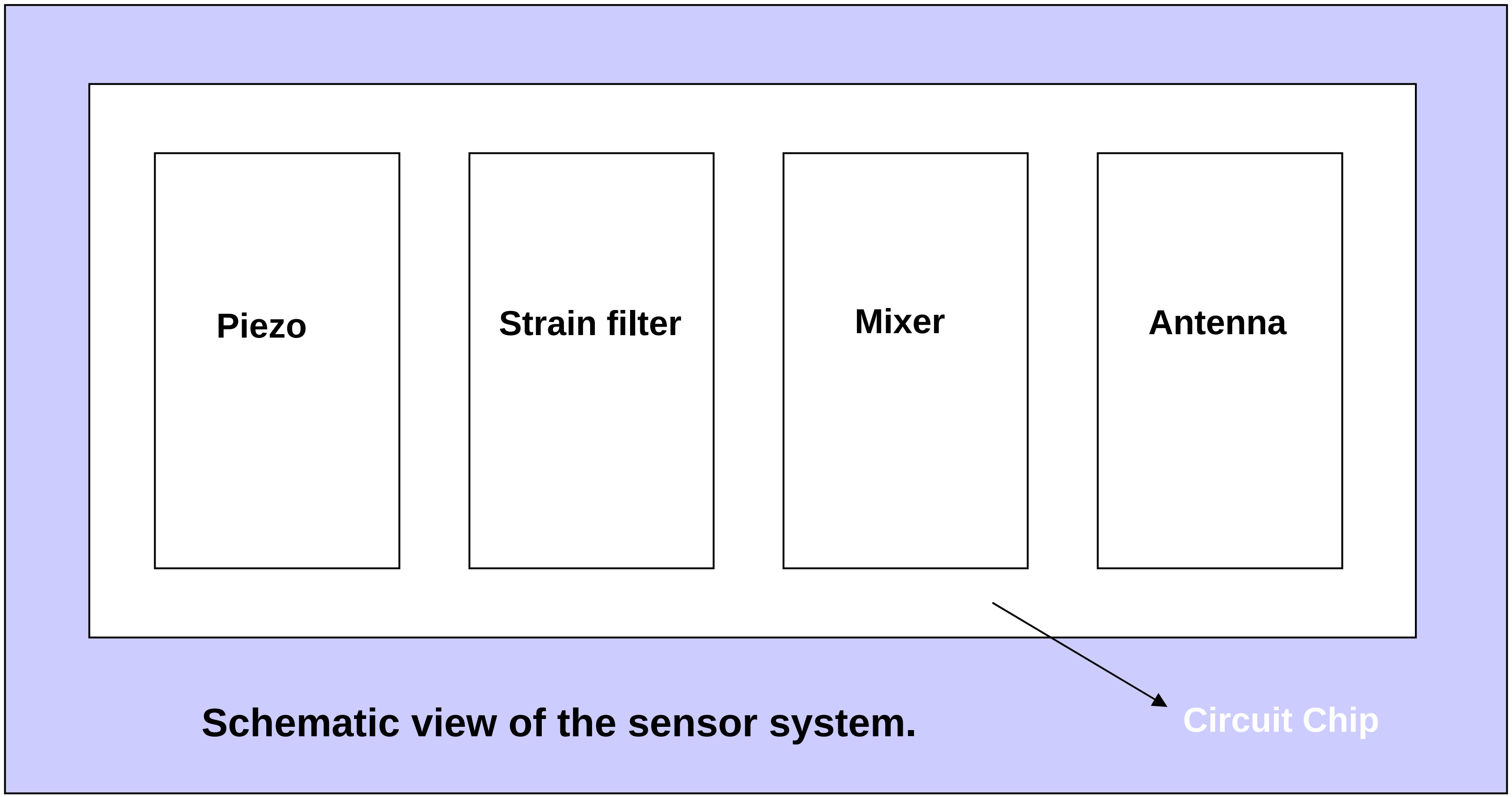
Sensor, Actuator, and vibration suppression

Sekiya, 2003

Piezo-sensor detecting spectrum of dynamic motion by using fatigue characteristics of piezo-sensor, where sensor system is attached on the surface of composite structure panel

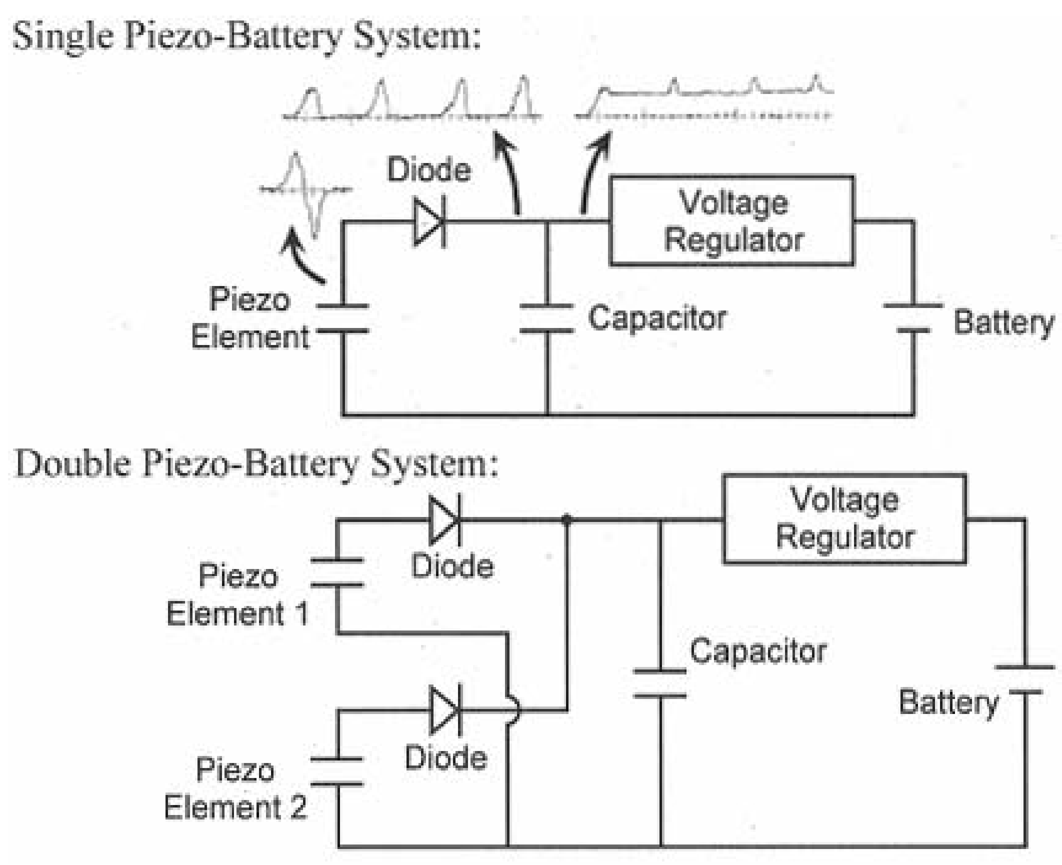


Piezo Sensing System



Schematic view of the sensor system.

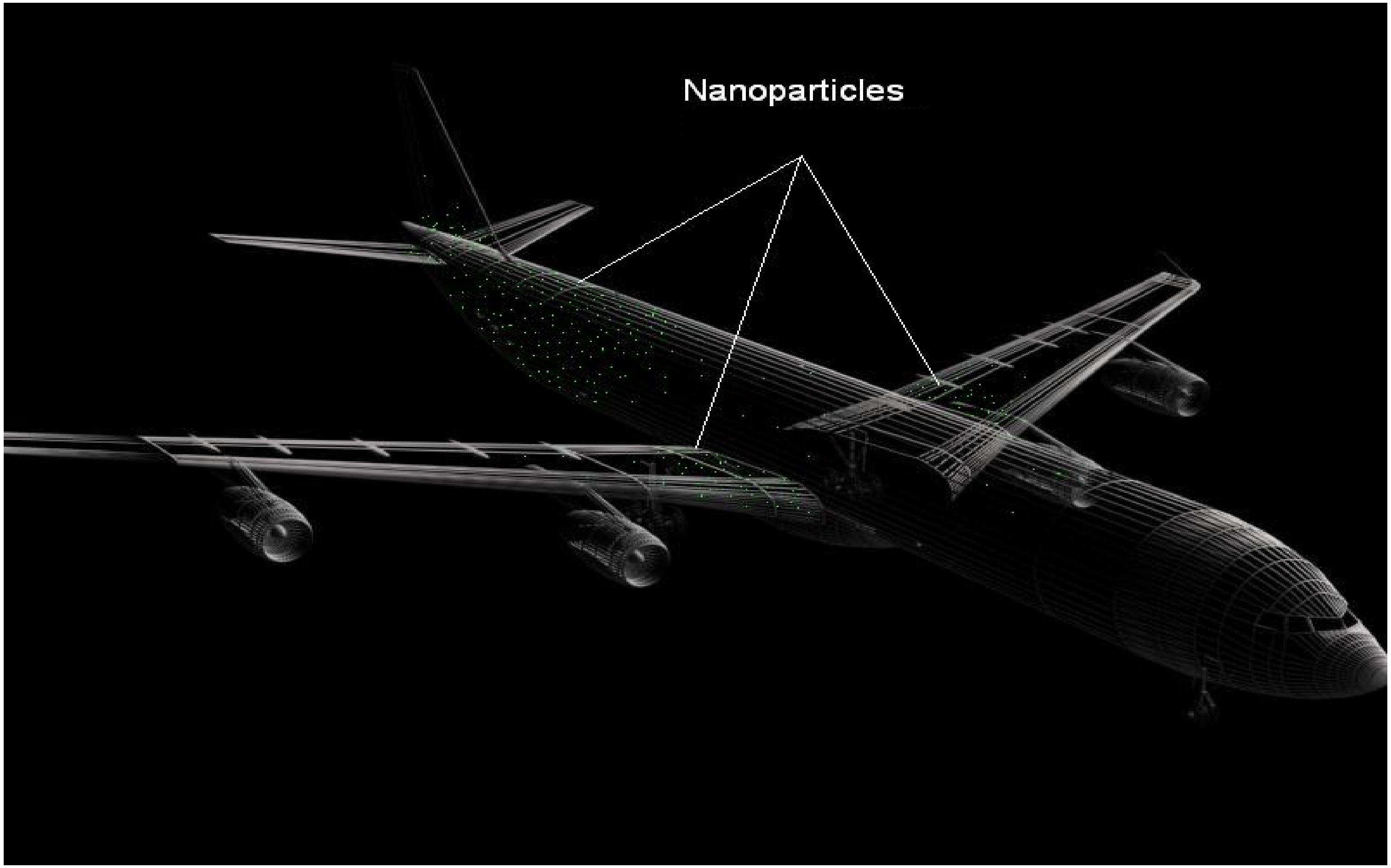
Battery charging unit schematic



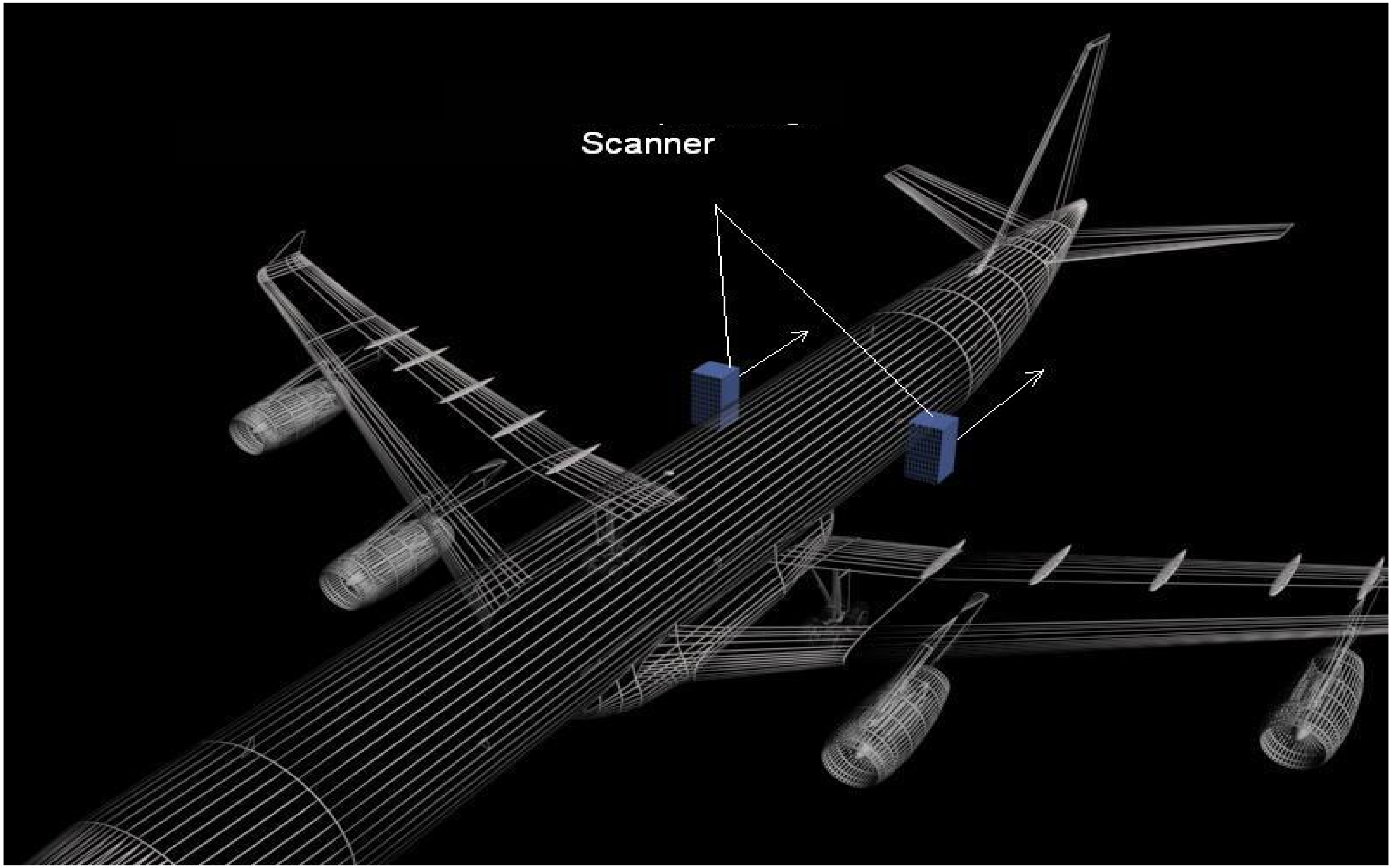
4. A Future Structural Health Monitoring for polymeric composite structures by embedding nano-sensing particles

Embedded nanoparticles

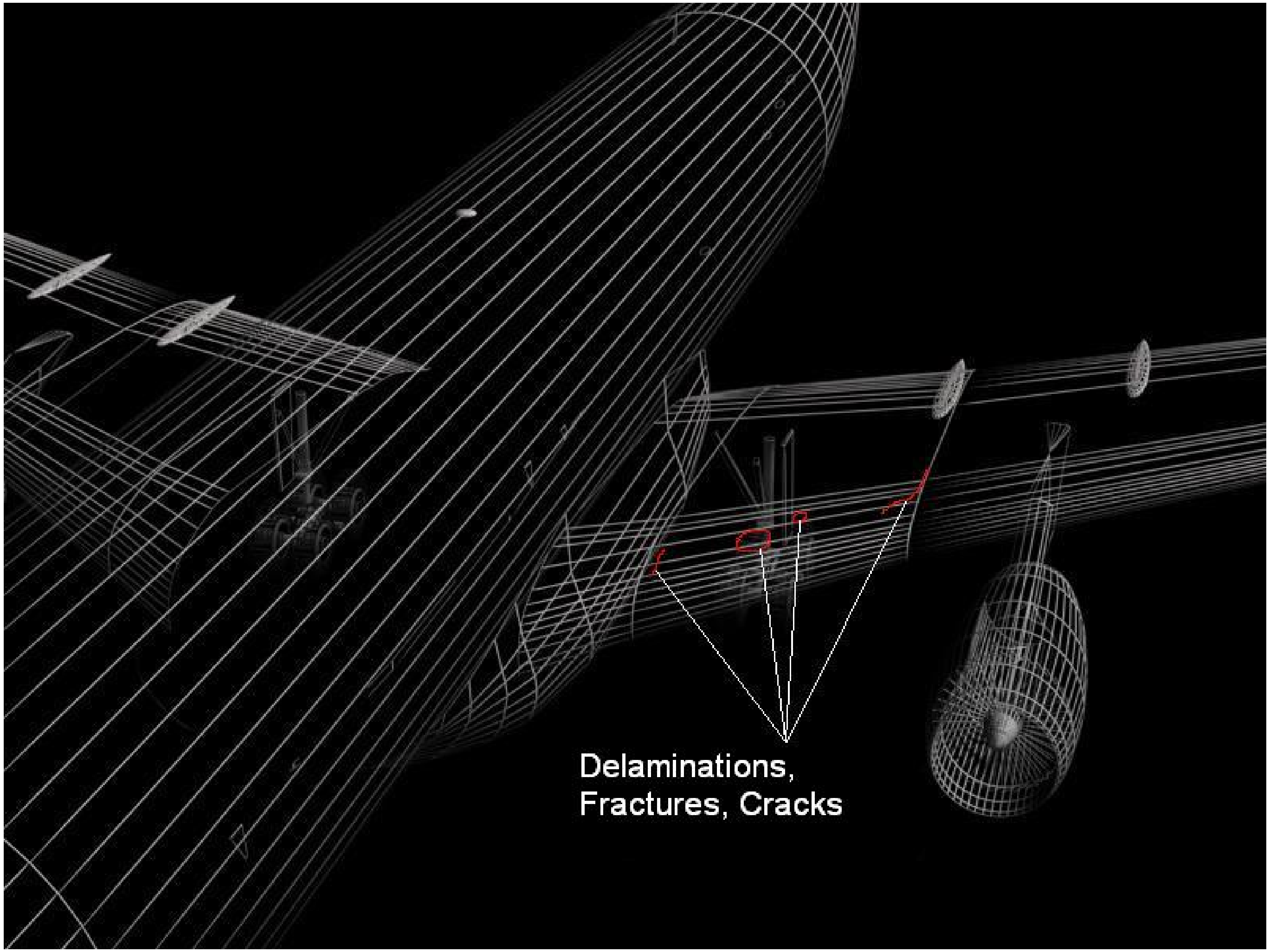
Tagged Composites



Scanner for monitoring damage from outside composite fuselage



Failure Detection



Where do we go in the future for SHM ?

Short-term goal:Design of a cost effective and autonomous sensing unit for monitoring a spectrum of flight loading history, mainly critical loading data set , where the sensor unit is attached to surface of a structural component. The goal of this is to reduce the operational cost while maintaining the maximum safety of the overall flight operation.

Long-term goal: Design of a new composite with sensing nano-particles which can be monitored easily by a scanner while an airplane is parked at airport.

Hierarchical modeling to optimize
The nanostructure of sensing composites
is summarized in a new book
(Taya,2005)