Piezoelectric 0-0-3 Composites

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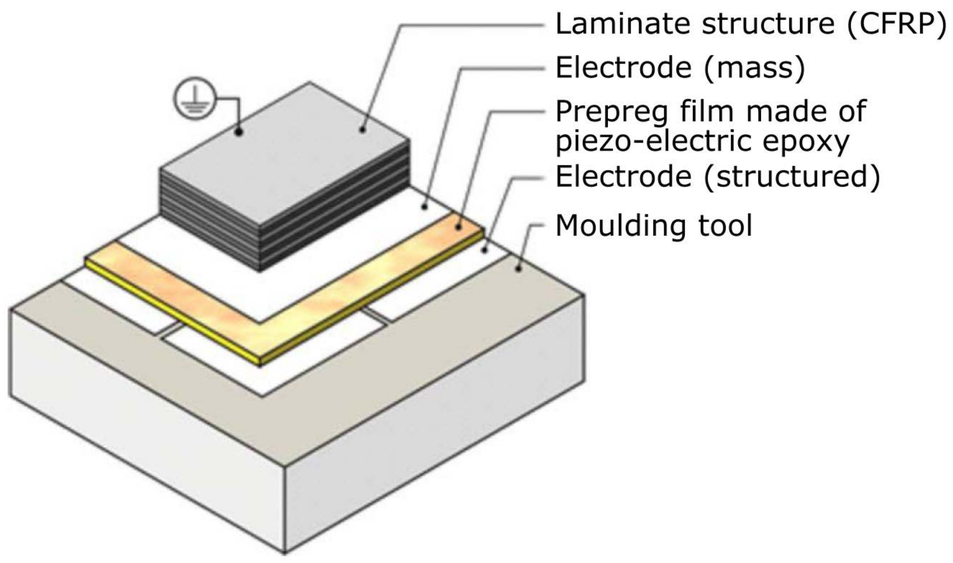
Motivation

Structural Health Monitoring (SHM) systems improve safety of lightweight composite structures and contribute to a higher economic efficiency through adapted maintenance intervals. Lamb waves can be used to monitor health of lightweight polymer composites but they must be excited and measured. Piezo-ceramic based transducers can be embedded in the structure, however they interact with the Lamb waves, reduce load carrying capabilities of the structure and increase weight.

For these reasons piezo-ceramic raw materials are mixed with the epoxy and will be used as an integrated active layers in lightweight composite structures. In such structures piezo-ceramic based active layers would become a part of the structure with actuating, sensing and energy harvesting capabilities.



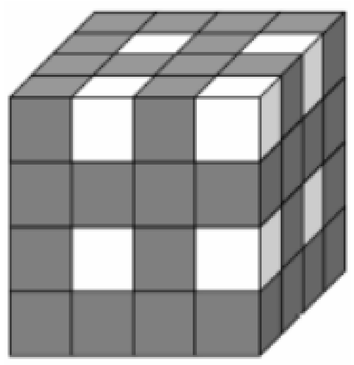
Preliminary configuration of the final structure

Aims

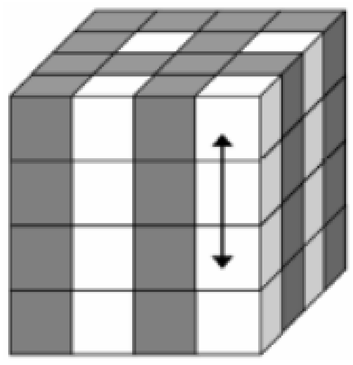
- Enhanced understanding of piezo-electric polymer composites and their usage for SHM applications.
- Experimental improvement of piezo-electric polymer composites by addition of the third phase (filler) in order to enhance the piezo-electric properties of the composites.
- All relevant piezoelectric properties of the modified piezoelectric composites (permittivity, charge constants, coupling factors) and mechanical properties must be thoroughly investigated.
- Alternative polarization techniques applicable to FRP composites with an integrated piezo-electric layer must be found.

Piezo-electric composites

Bulk ceramics exhibit excellent piezoelectric properties but are brittle and heavy. Combination of piezo-electric ceramics together with low density polymers promises many advantages. Adding filler as a third phase creates structures with 0-0-3 connectivity. These structures can be further structured by electric field to obtain quasi 1-3 connectivity.



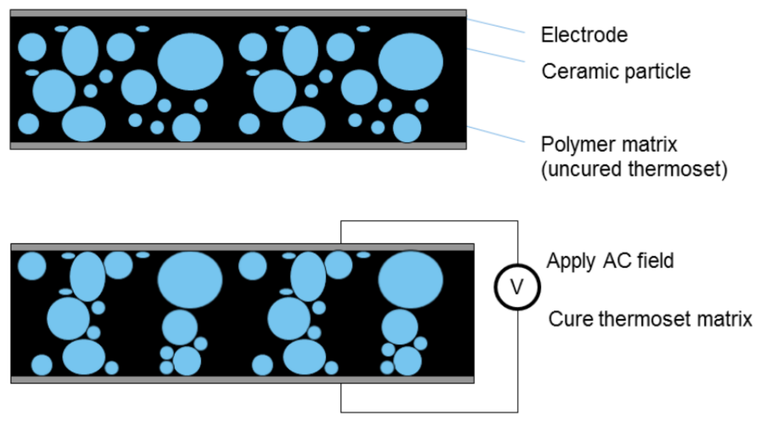
0-3 Connectivity



1-3 Connectivity

Structuring of ceramic particles in the composite

- A method to induce increased connectivity between ceramic particles while retaining flexibility of 0-3 composites is called dielectrophoresis (DEP).
- Small additional step in manufacturing process allows to almost double piezo-electric properties and achieve quasi 1-3 composites which has outstanding piezo-electrical properties.



Unstructured (top) vs structured (bottom) composites

Challenges

- PZT based ceramic composites are used only as a reference point and main focus is on lead-free ceramics.
- Various fillers (for a third phase) and ceramic configurations must be investigated and characterized.
- Agglomeration of ceramic particles and fillers must be solved by proper mixing or additional particle covering methods.
- Structuring of the ceramics by electric field have to be investigated.
- Method to measure thin piezo-electric composites must be developed.
- Manufacturing technique for composites with piezo-ceramic layer must be developed.
- Applicability of Corona poling for FRP structures must be investigated in details.

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