Executive Summary

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Project "New approaches to shape and stiffness changing materials"

In the present project we have investigated the use of variable stiffness/variable strength structural elements in semi-active adaptive structures taking a dual approach to the problem. While in the project funded by the NFP 62, we have investigated dielectric materials for the implementation of the electrostatic lamination of multi-layer structures, in a parallel project, funded by ETH's Centre of Structure Technologies we have identified structural concepts that can take advantage of the above mentioned elements to realize new and useful functionalities in aircraft structures, specifically wing structures with variable bending-twist coupling. The efforts of these two parallel projects have been coordinated from a quite early stage and where aimed at the implementation of Electro-Bonded Laminates (EBLs the object of the present project) in a structural demonstrator of a high performance, light weight structure.

The first achievement of the present project was the detailed investigation of the properties of polymer films that are relevant for the application at hand: Dielectric constant, dielectric strength and volume resistivity. This first step was decisive in creating the framework needed for the investigation of dielectric materials for their qualification for EBL applications. It became soon clear, also from research conducted on dielectric materials also for other applications, that a concurrent increase of dielectric strength and dielectric constant would be unlikely to be achieved, even if material synthesis had been included in the scope of the project.

Our attention was soon directed to the investigation of layered dielectrics, based on the hypothesis, corroborated by observations made by other groups, that dielectrics consisting of multiple layers would offer an increased dielectric strength due to the reduction of the size of defects (whose presence is inevitable in real materials and should always be considered as given) and due to charge trapping mechanisms that can be expected if more than one material is used to prepare the multi-layer dielectric. The question about the effective dielectric properties of the material arose soon and the knowledge of the dielectric and insulating properties of candidate materials at high near-DC fields acquired in the first phase of the project clearly indicated that a textbook approximation of the materials as perfect dielectric with infinite volume resistivity would not appropriately represent the problem. A model describing the dielectric response of multilayer films that also considers finite volume resistivity of the components was thus developed and experimentally verified. The developed analytical model represents the base for the optimization of high performance dielectric films for high energy density applications at different frequencies. The relevance of these findings goes far beyond the optimization of dielectrics for EBL applications. Future developments of high voltage DC power grids will require the development of reliable solid insulation materials. Multi-layer dielectrics could well represent an interesting class of dielectric and insulating elements for such applications. Furthermore, the understanding of the dependence of the electrostatic field effectively impinging on the layers of a multilayer insulator as a function of time is clearly necessary in order to understand the mechanism that lead to the failure of such materials systems at high fields.

In the last part of the project, the mechanical properties of EBL elements were investigated in detail with respect to load cases relevant to the structural applications envisaged in the framework of the cooperation with the structural branch of the project. Such kind of investigation had never been carried out before in this detail. The results, also with respect to the

effect of charge injection into the dielectric, due to the high applied fields and voltages have made a significant contribution to the understanding of EBL interfaces and represent a solid foundation for the future development of materials and structures.

As part of some related activities, carried out in cooperation with another SNF funded project, the experimental setup for the measurement of dielectric and insulating properties of polymer films was used to investigate the properties of another class of adaptive materials, i.e. dielectric elastomer actuator (DEA) materials. This investigation clearly indicated that also in this type of materials, under operational conditions, the assumption that the materials can be regarded as perfect insulators is far from correct. The implications of these findings in terms of power consumption of DEAs and most notably in terms of their long-term reliability are obvious and have been presented to the DEA community. An in-depth pursuit of this topic was beyond the scope of this project.