Optimization of large-scale fabrication of dielectric elastomer transducers - DTU Orbit

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Dielectric elastomers (DEs) have gained substantial ground in many different applications, such as wave energy harvesting, valves and loudspeakers. For DE technology to be commercially viable, it is necessary that any large-scale production operation is nondestructive, efficient and cheap. Danfoss Polypower A/S employs a large-scale process for manufacturing DE films with one-sided corrugated surfaces. The DEs are manufactured by coating an elastomer mixture to a corrugated carrier web, thereby imprinting the corrugations onto the elastomer. The corrugated elastomer is then sputtered with metal electrodes on the corrugated surface, and due to these corrugated surfaces the metal electrodes maintain conductivities up to more than 100% strain of the elastomer film. The films are then laminated in multiple layers to fabricate DE transducers. However, the current manufacturing process is not trouble-free, and two issues in particular have great influence on the performance of DE transducers. The first issue is the release of the corrugated elastomer film from the carrier web, due to the large surface area and flexible nature of the elastomer film, while the second issue relates to the lamination of DE films. Currently, the films are contacted without adhesion, in order to yield double-sided corrugations, which in turn causes friction between the layers and thus reduces the lifespan of the transducer. Furthermore, air can be trapped in the interface, thereby causing a decrease in electrical breakdown strength. Other issues may also arise, depending on how the elements are assembled. This thesis is based on optimising the large-scale manufacture of DE transducers. The hot embossing technology is used to impart corrugations onto elastomer film surfaces. Embossing, which was performed for samples with different r-values, showed that the process was applicable for different hardnesses of the material, while time intervals for the different materials were also determined. An attempt to solve the lamination issue was made by applying stronger adhesion methods when preparing monolithic elements. Due to the corrugations, the films were able to adhere in different configurations (back-to-back, front-to-back and front-to-front). The first approach involved adhering PDMS to PDMS (back-to-back), for which two routes were followed. The first route involved using an aminosilane as an adhesion agent after modifying the PDMS surface through plasma treatment, which demonstrated that the laminates were slightly stiffer and more fragile in respect to tearing. The other route involved modifying the surfaces through plasma treatment and by adhering the layers, which showed to be a suitable method and allowed high-strength laminates to perform as monolithic elements. For the front-to-back and front-to-front configurations, conductive elastomers were utilised. One approach involved adding the cheap and conductive filler, exfoliated graphite (EG) to a PDMS matrix to increase dielectric permittivity. The results showed that even at low concentrations, EG influenced the overall performance of the reinforced elastomer matrix, indicating that increasing the concentration further to make conductive elastomers would compromise the elastic nature of the elastomer due to large EG dimensions; consequently, EG-based elastomers as conductive adhesives were rejected. Dielectric properties below the percolation threshold were subsequently investigated, in order to conclude the study. In order to avoid destroying the network structure, carbon nanotubes (CNTs) were used as fillers during the preparation of the conductive elastomers and as received CNTs and modified CNTs were investigated. The unmodified CNTs were mixed with an ionic liquid, and two dispersion methods were investigated. The first method involved the ultrasonication of CNT/IL, which showed that conductivity increased in line with increasing CNT at concentrations lower than 5 wt% when CNTs were mixed with IL. The second method involved roll milling the composite, which decreased conductivity when concentrations exceeded 4 wt% for the CNT/IL composites. However, the obtained conductivities were increased for similar concentrations by roll milling. The modified CNTs were grafted covalently to the CNT surface with poly(methacryloyl polydimethylsiloxane), resulting in the obtained conductivities being comparable to commercially available Elastosil LR3162, even at low functionalisation. The optimized methods allow new processes for the production of DE film with corrugations and efficient DE transducers.

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