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A curvilinear high order finite element framework for electromechanics:  
From linearised electro-elasticity to massively deformable dielectric  
elastomers

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23 **Abstract**  
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25 This paper presents a high order finite element implementation of the convex multi-variable  
26 electro-elasticity for large deformations large electric fields analyses and its particularisation to  
27 the case of small strains through a staggered scheme. With an emphasis on accurate geometrical  
28 representation, a high performance curvilinear finite element framework based on an a posteriori  
29 mesh deformation technique is developed to accurately discretise the underlying displacement-  
30 potential variational formulation. The performance of the method under near incompressibility  
31 and bending actuation scenarios is analysed with extremely thin and highly stretched compo-  
32 nents and compared to the performance of mixed variational principles recently reported by Gil  
33 and Ortigosa [1, 2, 3]. Although convex multi-variable constitutive models are elliptic hence,  
34 materially stable for the entire range of deformations and electric fields, other forms of physical  
35 instabilities are not precluded in these models. In particular, physical instabilities present in  
36 dielectric elastomers such as pull-in instability, snap-through and the formation, propagation and  
37 nucleation of wrinkles and folds are numerically studied with a detailed precision in this paper,  
38 verifying experimental findings. For the case of small strains, the essence of the approach taken  
39 lies in guaranteeing the objectivity of the resulting work conjugates, by starting from the under-  
40 lying convex multi-variable internal energy, whence avoiding the need for further symmetrisation  
41 of the resulting Maxwell and Minkowski-type stresses at small strain regime. In this context,  
42 the nonlinearity with respect to electrostatic counterparts such as electric displacements is still  
43 retained, hence resulting in a formulation similar but more competitive with the existing line-  
44 arised electro-elasticity approaches. Virtual prototyping of many application-oriented dielectric  
45 elastomers are carried out with an eye on pattern forming in soft robotics and other potential  
46 medical applications.  
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54 *Keywords:* Monolithic & staggered electro-elasticity, high order curvilinear meshes, dielectric  
55 elastomers, material instability, wrinkling  
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