Accepted Manuscript

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PII: S0022-5096(18)30266-7
DOI: 10.1016/j.jmps.2018.07.001
Reference: MPS 3378

To appear in: *Journal of the Mechanics and Physics of Solids*

Received date: 31 March 2018
Revised date: 29 June 2018
Accepted date: 1 July 2018

Please cite this article as: Yipin Su, Hannah Conroy Broderick, Weiqiu Chen, Michel Destrade, Wrinkles in soft dielectric plates, *Journal of the Mechanics and Physics of Solids* (2018), doi: 10.1016/j.jmps.2018.07.001

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Wrinkles in soft dielectric plates

Yipin Su[a,b], Hannah Conroy Broderick[a], Weiqiu Chen[b], Michel Destrade[a,b]

[a] *School of Mathematics, Statistics and Applied Mathematics, NUI Galway, University Road, Galway, Ireland*

[b] *Department of Engineering Mechanics, Zhejiang University, Hangzhou 310027, P.R. China*

Abstract

We show that a smooth giant voltage actuation of soft dielectric plates is not easily obtained in practice. In principle one can exploit, through pre-deformation, the snap-through behavior of their loading curve to deliver a large stretch prior to electric breakdown. However, we demonstrate here that even in this favorable scenario, the soft dielectric is likely to first encounter the plate wrinkling phenomenon, as modeled by the onset of small-amplitude sinusoidal perturbations on its faces. We provide an explicit treatment of this incremental boundary value problem. We also derive closed-form expressions for the two limit cases of very thin membranes (with vanishing thickness) and of thick plates (with thickness comparable to or greater than the wavelength of the perturbation). We treat explicitly examples of ideal dielectric free energy functions (where the mechanical part is of the neo-Hookean, Mooney-Rivlin or Gent form) and of dielectrics exhibiting polarization saturation. In addition to the expected buckling mode coming from the purely elastic case, we discover a second mode occurring at large voltages in extension. We find that plates always wrinkle anti-symmetrically, before the symmetric modes can be reached. Finally we make the link with the classical results of the Hessian electro-mechanical instability criterion and of Euler buckling for an elastic column.

Keywords: dielectric plates, large actuation, snap-through, wrinkling instability

1. Introduction

When a soft dielectric plate is put under a large voltage applied to its faces, it expands in its plane. At first, the expansion increases slowly and almost linearly with the voltage until, typically, a local maximum is reached. Then in theory, the voltage drops suddenly, until it reaches a local minimum, rises again, to reach the

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