

Supplementary Information

Instabilities in dielectric elastomers: buckling, wrinkling, and crumpling

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Movie 1

Buckling (experimental observations): The top and oblique views of an unstretched dielectric elastomer clamped to a circular frame are shown in Movie 1. The video is accelerated by a factor of 8. The membrane undergoes the first-order buckling at 10kV. This is observed as a sudden increase in out-of-plane displacements of the membrane. The membrane undergoes the second-order buckling at 22kV. This is observed as a wavy pattern along the circumferential direction in the boundary of membrane. The membrane finally suffers dielectric breakdown at $\Phi = 26\text{kV}$.

Movie 2

Wrinkling (experimental observations): A circular dielectric elastomer membrane of prestretch $\lambda_{pre} = 5$ is shown in Movie 2. Voltage applied to the membrane is increased at a rate of 20V/s. The movie shows the states of the membrane starting from $\Phi = 5.37\text{kV}$ when the wrinkles nucleate near the edges. When the voltage reaches 5.96kV, the membrane is fully wrinkled. The membrane finally suffers dielectric breakdown at 5.97kV.

Movie 3

Crumpling (experimental observations): A circular dielectric elastomer membrane of prestretch $\lambda_{pre} = 6$ is shown in Movie 3. Voltage applied to the membrane is increased at a rate of 20V/s. The movie shows the states of the membrane starting from $\Phi = 5.86\text{kV}$. When the voltage reaches 5.92kV, the membrane bulges, exhibiting out-of-plane displacements. The membrane then further deforms, exhibiting singular vertices and curved ridges on its surfaces. It finally suffers dielectric breakdown at 6.31kV.

Movie 4

Buckling (finite element simulations): The top view of a circular dielectric elastomer membrane of prestretch $\lambda_{pre} = 1$ is shown in Movie 4. The dielectric elastomer membrane undergoes the first-order buckling at 1.5kV. This is observed as a sudden increase in out-of-plane displacements of the membrane. The membrane undergoes the second-order buckling at 9.9kV. This is observed as a wavy pattern along the circumferential direction in the boundary of membrane.

Movie 5

Wrinkling (finite element simulations): A circular dielectric elastomer membrane of prestretch $\lambda_{pre} = 5$ is shown in Movie 5. The movie shows the states of the membrane as the voltage is ramped up. When the voltage reaches 8.72kV, the wrinkles nucleate and then propagate across the entire membrane as the voltage increases.

Movie 6

Crumpling (finite element simulations): A circular dielectric elastomer membrane of prestretch $\lambda_{pre} = 6$ is shown in Movie 6. The movie shows the states of the membrane starting from $\Phi = 8.44$ kV. When the voltage reaches 8.52kV, the membrane crumples, exhibiting sudden out-of-plane displacements. Meanwhile, the membrane develops singular vertices and curved ridges on its surfaces.