Electrostatics-Driven Hierarchical Buckling of Charged Flexible Ribbons

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We investigated the rich morphologies of an electrically charged flexible ribbon, which is a prototype for many belt like structures in biology and nanomaterials. Long-range electrostatic repulsion is found to govern the hierarchical buckling of the ribbon from its initially flat shape to its undulated and out-of-plane twisted conformations. In this process, the screening length is the key controlling parameter, suggesting that a convenient way to manipulate the ribbon morphology is simply to change the salt concentration. We found that these shapes originate from the geometric effect of the electrostatic interaction, which fundamentally changes the metric over the ribbon surface. We also identified the basic modes by which the ribbon reshapes itself in order to lower the energy. The geometric effect of the physical interaction revealed in this Letter has implications for the shape design of extensive ribbon like materials in nano- and biomaterials.

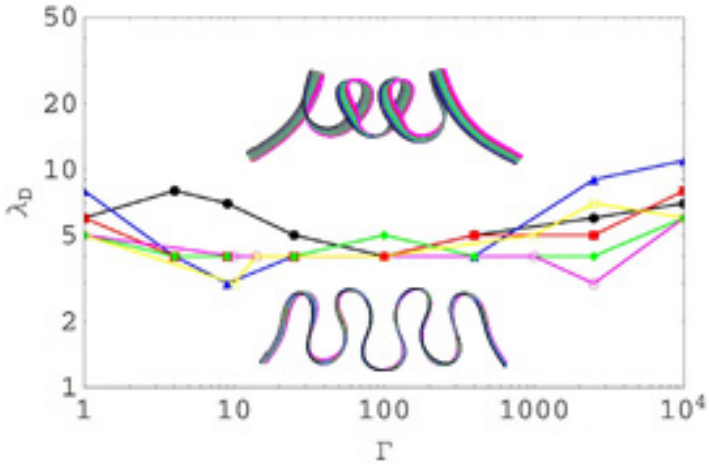

FIG. 4. The phase diagram of the low-energy shapes of the charged ribbon. The curves separate the undulated state (below the curve) and the twisted state (above the curve). For flexible ribbons with vanishing bending rigidity, M ¼ 6 and N ¼ 102 (black circles), 154 (blue triangles), 206 (red squares), and 258 (green diamonds). The two curves with empty symbols are for ribbons with bending rigidity κ=ðK0l20Þ¼ 0.1 (pink empty circles) and 0.01 (yellow empty squares) (see Supplemental Material [22]), with M ¼ 6 and N ¼ 258.

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