Determination of cellular viscoelastic properties from AFM stress relaxation data via SOM analysis

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Cells are complex viscoelastic systems whose mechanical properties are governed by the organization of semiflexible cytoskeletal filaments, their crosslinking, and the active remodeling of the cytoskeletal network. Atomic force microscopy (AFM) is a powerful tool for studying cell mechanics, as it enables time- and frequency-dependent measurements using nanometric tips or colloidal probes. When subjected to an external stress, cells exhibit time-dependent deformation behavior. In this study, we investigated the stress relaxation response of HeLa cells under conditions of constant strain. The applied force (1, 2, 4, and 8 nN) and the residence (pause) time (1, 10, and 60 s) were systematically varied to evaluate different linear viscoelastic models (1). The experimental data were fitted using the standard linear solid model, the five-element Maxwell model, and a power-law model. Our results indicate that the five-element Maxwell model provides the best description of the observed stress relaxation behavior. This work is intended to serve as an introduction and practical guide for performing AFM-based stress relaxation experiments on soft matter. To facilitate visualization and interpretation, the data were organized using self-organizing maps (2).

Keywords:
cell mechanics, linear viscoelasticity, relaxation time, elastic modulus, viscosity, atomic force microscopy, self-organized maps

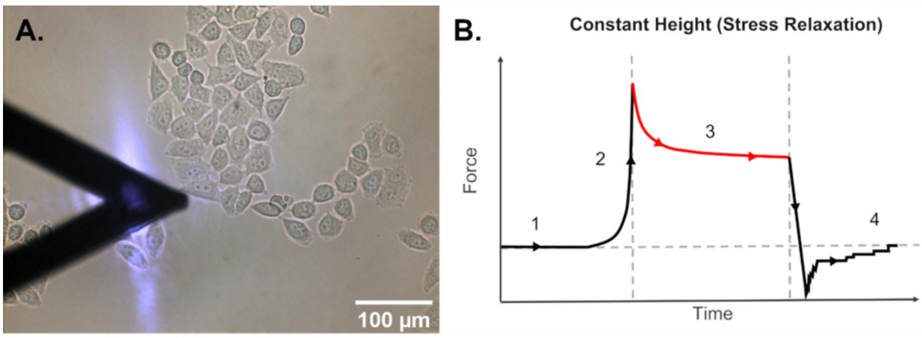

Figure. A. Schematic of the experimental setup illustrating the cell of interest, the AFM cantilever, and the detection laser spot. B. Representative force–time curve showing the relaxation of the applied force over time, with the stress relaxation phase highlighted in red.

References:

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