Developing the Framework for Predicting Viscoelastic Properties of Reconstituted Biopolymer Networks Controlled by Molecular Motors

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INTRODUCTION

- Molecular motors use ATP to convert chemical energy to mechanical work
- Biopolymer networks cross-linked with molecular motors generate forces that determine their mechanical behavior
- Axonemal dynein is a molecular motor that provides motility to cilia and flagella

Viscoelasticity measures loss modulus ($G''$) and storage modulus ($G'$)

Objectives: To model the viscoelastic properties of dynamically cross-linked actin filament networks

Overarching goal: To ultimately predict the viscoelastic properties of reconstituted microtubule networks controlled by axonemal dynein

BACKGROUND/METHODOLOGY

Semi-phenomenological models reproduced using Wolfram Mathematica

Viscoelastic response for actin-rigor-HMM network

- $G'(f) = G - a \cdot \frac{N_{CHMM}}{a^2 \cdot f^4} + b \cdot (f^4)^{3/4}$
- $G''(f) = c \cdot \frac{N_{CHMM}}{a^2 \cdot f^4} + d \cdot (f^4)^{3/4}$

Koff = 0.3 s

N = $3 \times 10^{14}$, Number of crosslinks formed

G₀ = 12 Pa, Static network elasticity of cross-linked semiflexible polymer networks

F₀ = 1.5, Scaling factor; function of the solvent viscosity

a = 5 $\times 10^{-10}$, $\pm$ s, c = 2 $\times 10^{-10}$, $\pm$ s, Amount of energy dissipated due to unbinding

b = 0.4 $\pm$ s, $\pm$ s, d = 0.7 $\pm$ s, Fluctuation of filaments in semiflexible polymer networks

RESULTS

Elastic Response ($G'$) of Actin-Rigor-HMM-Network

- As N and F₀ increase, G' increases

Viscous Response ($G''$) of Actin-Rigor-HMM-Network

- As N and F₀ increase, G'' increases

CONCLUSION

- Increasing the concentration of molecular motors increases $G'$ and $G''$ of a dynamically cross-linked actin filament network
- Increasing the breaking rate at zero force, K₀, decreases the detachment force, F₀
- Increasing the bond force, F₀, increases the detachment force, F

FUTURE WORK

- Develop DPD approach to determine the role of Koff
- Crosslink bond breaking rate as a function of force
- Use linear oscillatory microrheology to determine G' and G''

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REFERENCES


