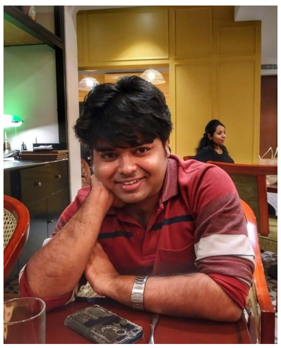
Indian Institute of Science

Centre for BioSystems Science and Engineering

BSSE Annual Work Presentation

27th January 2020 (Monday), 4:00 PM, CES Seminar Hall, 3rd floor, Biological Sciences Building

Role of Fiber Reinforcement in the Biomechanics of Cells and Tissues



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ABSTRACT

Fiber reinforcement is an important determinant in the structure and function of biological materials. Soft tissues like artery, heart tissues, skin etc. exhibit anisotropic material responses due to fiber reinforcement along specific directions. Fiber reinforcement in biological materials occur at multiple length scales via the organization of structural proteins into fibrillar structures embedded within a soft compliant matrix. In this study, we have investigated the role of fiber reinforcement in the form and function using two different problems. First, we study the role of stress fiber growth and remodeling in determining the cellular morpho-mechanical properties under uniaxial cyclic stretch. Stress fibers in the cytoskeleton are essential in maintaining cellular shape and influence their adhesion and migration. Cyclic uniaxial stretching results in cellular reorientation orthogonal to the applied stretch direction via a strain avoidance reaction; however, the mechanistic cues in cellular mechanosensitivity to this response are currently underexplored. We show that uniaxial cyclic stretch induces stress fiber lengthening, their realignment and increased cortical actin in fibroblasts stretched over varied amplitudes and durations. Higher amounts of actin and realignment of stress fibers were accompanied with an increase in the effective elastic modulus of cells. We modelled stress fiber growth and reorientation dynamics using a nonlinear, orthotropic, fiber-reinforced continuum representation of the cell. The model predicts the observed fibroblast morphology and increased cellular stiffness under uniaxial cyclic stretch. These studies are important in exploring the differences underlying mechanotransduction and cellular contractility under stretch.

Second, we studied the role of fiber orientations in the mechanics of bioinspired fiber reinforced elastomers mimicking the tissue microstructure. Few studies have explored the effects of differential fiber winding on the large deformation mechanics of fiber reinforced elastomers (FRE). We fabricated FRE materials in transversely isotropic layouts varying from 0-90° using a custom filament winding technique and characterized the nonlinear stress-strain relationships using uniaxial and equibiaxial experiments. We used these data within a continuum mechanical framework to propose a novel constitutive model for incompressible FRE materials with embedded extensible fibers. The model includes individual contributions from the matrix and fibers in addition to coupled terms in strain invariants, I1 and I4. The deviatoric stress components show inversion at fiber orientation angles near the magic angle (54.7°) in the FRE composites. These results are useful in soft robotic applications and in the biomechanics of fiber reinforced tissues such as the myocardium, arteries and skin.