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Structure-function relations in cartilage under shear: Does fiber organization matter? MOUMITA DAS, School of Physics & Astronomy, Rochester Institute of Technology, JESSE SILVERBERG, Physics Department, Cornell University, ALIYAH BARRETT, POUL PETERSON, Department of Chemistry and Chemical Biology, Cornell University, LAWRENCE BONASSAR, Biomedical Engineering, Mechanical and Aerospace Engineering, Cornell University, ITAI COHEN, Physics Department, Cornell University — Confocal elastography have enabled spatially resolved measurements of soft biological tissues such as articular cartilage (AC). With this technique it was discovered that the AC shear modulus has a compliant region near the tissue surface that is 10-100 times smaller than the bulk. This region also dissipates $\sim 90\%$ of the energy absorbed during shear, suggesting a functional role protecting the underlying tissue. Though the mechanical properties have depth-dependent trends that parallel the stereotypical collagen fiber organization, we explore this observation with structural, compositional, and shear mechanical data. We show the fiber-reinforced interpretation of the collagen network is inconsistent with experiments at small strains. Instead, we find the shear modulus strongly correlates with cartilage matrix density leading to the result that a 50% variation in matrix density leads to a 10,000% variation in shear modulus. We interpret these results in terms of a biopolymer rheology model that is known to produce such trends. This scaling arises from a second-order mechanical phase transition known as rigidity percolation, and with the inclusion of a reinforcing medium to more closely mimic cartilage, the empirical trends are reproduced.

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