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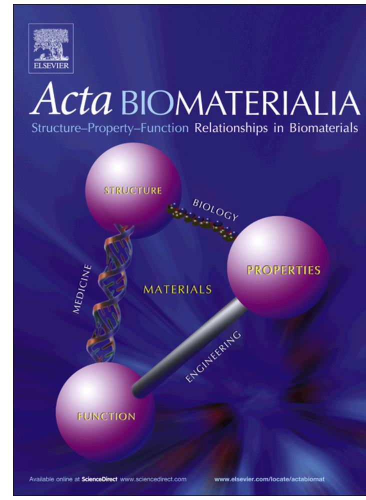

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Viscoelastic properties of α-keratin fibers in hair

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Abstract

Considerable viscoelasticity and strain-rate sensitivity are a characteristic in α-keratin fibers, which can be considered a biopolymer. The understanding of viscoelasticity is an important part to the knowledge of the overall mechanical properties of these biological materials. Here, horse and human hairs are examined to analyze the sources of this response. The dynamic mechanical response of α-keratin fibers over a range of frequencies and temperatures is analyzed using a dynamic mechanical analyzer. The α-keratin fibers behave more elastically at higher frequencies while they become more viscous at higher temperatures. A glass transition temperature of ~55 ^{o}C is identified. The stress relaxation behavior of α-keratin fibers at two strains, 0.02 and 0.25, is established and fit to a constitutive equation based on the Maxwell-Wiechert model. The constitutive equation is further compared to the experimental results within the elastic region and a good agreement is obtained. The two relaxation constants, 14 s and 359 s for horse hair and 11 s and 207 s for human hair, are related to two hierarchical levels of relaxation: the amorphous matrix-intermediate filaments interfaces, for the short term, and the cellular components for the long term. Results of the creep test also provide important knowledge on the uncoiling and phase transformation of the α-helical structure as hair is uniaxially stretched. SEM results show that horse hair not only has a rougher surface morphology and damaged cuticles, but also exhibits a lower strain-rate sensitivity of 0.05 compared to that of 0.11 in human hair. After the horse and human hairs are chemically treated and the disulfide bonds are cleaved, they exhibit a similar strain-rate sensitivity of ~0.05. FTIR data confirms that the human hair is more sensitive to the -S-S- cleavage, resulting in an increase of cysteic acid content. Therefore, the disulfide bonds in the matrix are experimentally identified as one source of the strain-rate sensitivity and viscoelasticity in α-keratin fibers.