Effect of Ionizing Radiation on the Modulus and Residual Strains in Bone

Anjali Singhal[1], Alix C. Deymier-Black[1], Jonathan D. Almer[2], and David C. Dunand[1]

[1]Northwestern University, Materials Science and Engineering, Evanston, IL 60208
[2]Argonne National Laboratory, Advanced Photon Source, Argonne, IL 60439

Biological tissues like bone are subject to a wide range of radiation doses during medical treatments such as cancer therapy (~ 60kGy) and terminal sterilization (~ 30kGy) [1]. During these treatments, not only are the surrounding healthy tissues affected, but also their mechanical properties are found to degrade. Since these tissues are often located in areas which are load bearing, it is important to understand how the mechanical properties of these tissues are affected by such treatments. Also, of great relevance is the increasing use of synchrotron x-rays in scientific studies to determine the structure and mechanical properties of these tissues, where radiation doses of 0.2 kGy/s are imparted to the sample, depending on the x-ray beam flux density. The mineral phase is less susceptible to such radiation damage; however the properties of the collagen phase have been found to change due to mechanisms such as increased cross-linking or chain scission [2]. The collagen-mineral interface has also been shown to degrade due to de-carboxylation of the collagen side-chains from the surface of the mineral phase [3]. To investigate the effect irradiation on the elastic properties of bone, samples are subjected to a combination of mechanical loading (0 to -60 MPa) and varying levels of radiation doses (5 to 3800 kGy). High-energy x-rays are employed to study the evolution of the apparent modulus and residual strain in the collagen fibrils and the mineral phase. The apparent moduli of the mineral (26±1.2 GPa) and fibrils (13±1.9 GPa) do not exhibit a systematic change with increasing radiation doses as high as 3800 kGy, indicating that the rate of load transfer to the mineral phase via the collagen phase remains unchanged at the radiation levels applied here. This is possible since the elastic modulus of the material is mostly dependent on the mineral phase which is more resistant to damage, and changes in the collagen phase do not significantly affect these properties. However, the residual strains in the mineral phase are found to become less compressive and those in the fibrils become more compressive with increasing radiation dose and loading cycles. This would indicate that de-bonding has taken place during mechanical loading, allowing the mineral platelets to relax, which re-bond on unloading the sample. Thus upon re-loading, the rate of load transfer does not significantly change from the previous cycle. It is thus important to impart as low a dose as possible to these biological tissues during experimentation and clinical therapy.

Use of the Advanced Photon Source was supported by the U.S. Department of Energy, Office of Science, Office of Basic Energy Sciences, under Contract No. DE-AC02-06CH11357.

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