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Load Transfer in Abalone Shell

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Beamline(s): X14A

Introduction: Understanding the mechanical behavior of mineralized tissues (bones, teeth, shells, etc.) is crucial both to the design of better implants, prostheses, and dental restoration materials and to protecting against traumatic injuries. Very little is known about the distribution of stresses between the organic and mineral phases in these tissues under various kinds of loading. The nacre layer of abalone shell consists of an organic network containing aragonite platelets. The average distribution of applied strains within the aragonite platelets of the nacre layer of abalone shell was determined by applying controlled loads and x-ray residual stress analysis.

Methods and Materials: X-ray diffraction was used to quantitatively measure residual and applied elastic strains/stresses in crystalline materials as these strains change interplanar spacings. A strain gage was mounted to an nacre bar/sample, which was wet cut from a large dry abalone shell. The sample was placed in four point flexure, and the applied load was calibrated to the strain gage reading from the compressive face. Later the sample was mounted in four point flexure on the goniometer, and x-ray strain measurements were made on the aragonite phase as a function of tilt angle, psi, and load.

Results: The XRD data revealed that the polycrystalline aragonite within the nacre possessed a strong (001) fiber texture. Consequently, the (373) and (513) reflections, observed at nominally 132.7° and 142.2°, respectively, were chosen due to there continued presence over several psi tilts. A $\sin^2$ psi analysis was used.[1] Figure 1 indicates that less than 50% of strain is transferred to the aragonite platelets at the tensile surface of the nacre sample via four-point flexure. A significant amount of tensile residual stress appears to be present in the sample prior to loading, which may be due to the prior proof testing. This suggests that the elastic limit of the sample was exceeded causing inelastic deformation.[2] The factor of two difference between the two reflections is puzzling, as the Young's moduli were calculated and found to be similar ($E_{<373>}$= 87.8, $E_{<514>}$= 76.5 GPa).

Conclusions: X-ray diffraction can be used to quantitatively measure residual and applied elastic strains/stresses in mineralized tissues.

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References:

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[2]A.G. Evans, Z. Suo, R.Z. Wang, I.A. Aksay, M.Y. He, and J.W. Hutchunson, "Model for the Robust Mechanical Behavior of Nacre," J. Mater. Res. **16** 2475 (2001).

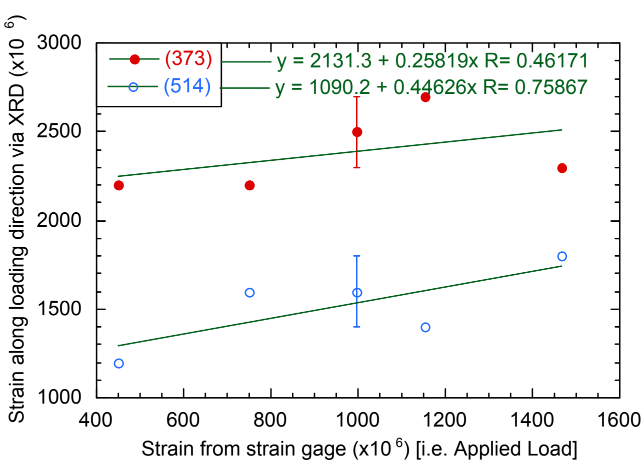

Figure 1. The strain determined from XRD as a function of the applied strain for the two aragonite reflections examined.