Molecular- To Macro- Energy Absorption Mechanisms in a Biological Body Armour Illuminated by *in-situ* Diffractive Pseudo-Tomographic X-ray Imaging

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Determining multiscale, concurrent strain and deformation mechanisms in hierarchical biological materials is a crucial engineering goal, to understand structural optimization strategies in Nature. However, experimentally characterizing complex strain fields within a 3D hierarchical composite, in a multiscale full-field manner, is challenging. Here, we present a pseudo-tomographic X-ray scanning diffractive imaging method, to measure strains in micro, meso and macro levels *in-situ* simultaneously of the stomatopod cuticle, an extreme example of biological tissue with high impact resistance. The results demonstrate the method, using the mineralized 3D α-chitin fibre networks as strain sensors, can capture sub-micron deformation of a single lamella (mesoscale), can extract strain information of multiple constituents concurrently, and shows that α-chitin fibre networks deform elastically while the surrounding matrix deforms plastically before systematic failure under compression. Further, the results demonstrate a molecular-level pre-strain gradient in chitin fibrils, resulting from different mineralization degrees in the exo- and endo cuticle.