Attachment on the rocks: the adhesion system of *Anomia*

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Biological organisms attach to substrates using a wide range of strategies. Amongst these, that of the bivalve *Anomia* is particularly intriguing. The animal attaches to the substrate through a single heavily mineralized byssal 'plug' that connects the substrate to the top shell through a large hole in the bottom shell [1].

We characterize the byssus at length scales all the way from the atomic to the mm. The byssal plug contains aragonite and calcite organized in spatially distinct regions: a lamellar aragonitic region and a porous calcitic region [1, 2, 3]. High resolution synchrotron powder X-ray diffraction showed that the calcitic part consists of calcite with a range of degrees of magnesium substitutions, while the aragonite phase displayed organic matrix induced lattice distortions in a pattern different from those seen in shells [2]. The polymorph distribution was unraveled by diffraction scattering computed tomography [3] that allows tomographical reconstruction of powder diffraction patterns *inside* a sample in a non-destructive manner [4,5]. On larger length scales, a highly hierarchical structure is observed [1, 6]. The organic phase contains chitin, sulfur in various oxidations states and phosphorylated biomolecules. The mechanics of byssus design was investigated by nanoindentation and finitie element modelling. The lamellar design allows efficient redistribution of load from the soft musculature to the substrate. The complex structure of this system highlights how designs with multiple phases can result in tailored materials with advanced function.

[1] Eltzholt & Birkedal (2009) *J. Adhesion* **85**, 590-600. [2] Leemreize *et al.* (2014) *Eur. J. Mineral* **26**, 517-522. [3] Leemerize *et al.* (2013). J. Roy. Soc. Interface **10**, 20130319. [4] Birkbak *et al.* (2015) *Nanoscale* **7**, 18402-18410. [5] Leemreize *et al.* (2014) *Proc. SPIE* **9212** 92120C. [6] Frølich *et al.* (2015) *Key Eng. Mater.* **672**, 71-79.