Micro & Nano StructuresInspired by Nature

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As long as we have existed on the planet, natural foods have been derived form locally available plant and animal sources. Many of these raw materials have become commodities and are used globally. However what we do not appreciate often is that Nature evolved plants and animals to breed more plants and animals and not necessarily to provide convenient food for mankind. Thus there is a technical challenge for the industrial scientists to understand and manipulate and/or mimic the functionality of these complex natural materials in order to provide nutritious, healthy and good tasting offerings with functional health benefits. For example its is well known that fiber (rod like) particles dispersions have structuring advantage over spheroidal dispersions, since the amount of material need to create a given structural strength decreases with the increase of particle aspect ratio and fiber structures break easily in shear. Nature also uses this approach when it needs to achieve great structural strengths with less material. Indeed the structural strength in plants is due to crystalline cellulose fibers. In animals, both bones and muscles get their strength form fiber like building elements. What is interesting that often these fiber like materials are also very important components of our diet by proving us with source of proteins, minerals and dietary fibers. In the processed products however this dual, multi-scale functionality is often lost and/or not fully utilised. Thus the challenge is how we can keep and even enhance or mimic the structuring potential of natural materials, while fully preserving and even enhancing their nutritional and health benefits.

This talk will give three examples, where learning from Nature can be applied in designing novel shape anisotropic functional biomaterials that can be used for structuring of foods, personal care and/or pharmaceutical products. The first example is based on a study of how plants structure water internally and to use these natural structures to improve the structuring of water in low fat mayonnaise, which allow us to make it healthier product, without compromising its taste. To fully utilize the potential of these natural fibers, one need to understand and use via clever processing the multi-length scale of plant cell structure and cellulose fibril, which spans from molecular to mesoscale level. In the second example we will try to mimic the structure of plant cell walls by using surface modified calcium carbonate rods, which allows them to self-assemble around air bubble surface and thus producing super stable foams. These foams are comprised by bubbles having bi-modal bubble size distribution, mediated by the interplay between rigid rod length and bubble curvature. Due to their very high mechanical stability, rod-stabilized bubbles can be treated as solid particles and could be ordered and dried into packed 2D arrays on solid substrates, showing pronounced effects of bubble bi-modality, where big bubbles attach first, while small bubbles are filing the crevices in between. These 2D arrays of dried packed bubbles represent a hierarchy of self–assembled surfaces at different levels and types: at rod, at bubble and at solid substrate. This self assembly hierarchy spans more then 6 orders of magnitude: where a small changes in the degree of saturation at the Å level, has an effect on the self assembly of the fatty acids chains at rigid rods surface at nm level, which combined with rod topology then influences the interaction between the rods and their self assembly at the bubble surface at the micron level, thus determining the bubble size distribution at mm level, which in turn governs the bubble ordering and self assembly on solid substrates at the cm level. In the last example we will use learn how nature creates some of the most beautiful colours, by using light diffraction from colloidal structures and will use this approach to create colourful bubbles stabilised by mixture of modified $CaCO_3$ rods and modified pearlescent pigments. This in turn allows us to create multi-layered collared aerated products, where the colours do not mix and the continuous phase is still liquid.