Nano crystalline cellulose-protein composites: Super performing biomaterials for tissue engineering and regenerative medicine

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A platform technology that brings together the toughness of cellulose nano-fibers from the plant kingdom, the remarkable elasticity and resilience of resilin that enables flees to jump as high as 400 times their height from the insect kingdom, and the adhesion power of DOPA, the functional molecule of mussels that enable it to bind tightly under water to organic and inorganic matter from the marine kingdom and all that combined with Human Recombinant Type I collagen produced in tobacco plants; SUPERPERFORMING BIOMATERIALS.

Resilin is a polymeric rubber-like protein secreted by insects to specialized cuticle regions, in areas where high resilience and low stiffness are required. Resilin binds to the cuticle polysaccharide chitin via a chitin binding domain and is further polymerized through oxidation of the tyrosine residues resulting in the formation of dityrosine bridges and assembly of a high-performance protein-carbohydrate composite material. Plant cell walls also present durable composite structures made of cellulose, other polysaccharides, and structural proteins. Plant cell wall composite exhibit extraordinary strength exemplified by their ability to carry the huge mass of some forest trees. Inspired by the remarkable mechanical properties of insect cuticle and plant cell walls we have developed novel composite materials of resilin and Nano-Crystalline Cellulose (resiline-NCC) that display remarkable mechanical properties combining strength and elasticity. We produced a novel resilin protein with affinity to cellulose by genetically engineering a cellulose binding domain into the resilin. This CBD-Resilin enable, interfacing at the nano-level between the resilin; the elastic component of the composite, to the cellulose, the stiff component. Furthermore, chemical and enzymatic modifications of the composite are developed to produce DOPA- Resiline-NCC which confers adhesive and sealant properties to the composite.

As a central element of the extracellular matrix, collagen is intimately involved in tissue development, remodeling, and repair and confers high tensile strength to tissues. Numerous medical applications, particularly, wound healing, cell therapy, and bone reconstruction, rely on its supportive and healing qualities. Its synthesis and assembly require a multitude of genes and post-translational modifications. Historically, collagen was always extracted from animal and human cadaver sources, but bare risk of contamination and allergenicity and was subjected to harsh purification conditions resulting in irreversible modifications impeding its biofunctionality. In parallel, the highly complex and stringent post-translational processing of collagen, prerequisite of its viability and proper functioning, sets significant limitations on recombinant expression systems. A tobacco plant expression platform has been recruited to effectively express human collagen, along with three modifying enzymes, critical to collagen maturation. The plant extracted recombinant human collagen type I forms thermally stable helical structures, fibrillates, and demonstrates bioactivity resembling that of native collagen. Combining collagen at the nano-scale with resilin to produce fibers resulted in super-performing fibers with mechanical properties which exceed that of natural fibers.