

Smart cellulose-hydrogel composites for 4D Printing

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ABSTRACT

Synthetic smart systems often lack the simplicity of material construction and the complexity in functionality when compared to biological systems. In nature, versatility and functionality is a consequence of controlled placement of 'building blocks' at nano and micro-scale and the resulting multifunctional hierarchical structures. The design and arrangement of these building blocks are programmed into the organisms through billions of years of evolution. In the current scientific drive to towards 4D materials, more-often-than-not the simple building blocks are being overlooked in favour of complex strategies and expensive systems to realise synthetic morphing. In comparison, this project is focussed on developing sustainable and cost-effective smart material systems following the design rules that we observe in nature.

The potential of paper as a cost-effective, sustainable and programmable smart material is the focus of this investigation. A paper inspired cellulose-hydrogel smart composite actuator (previously reported by the authors [1]) adhering to a set of biological design rules (figure 1) has been realised. When adapted to the domain of 3D printing materials, this smart composite system offers unparalleled control over the design configuration to enable programmed transformations. Unlike other reported hydrogel systems [2] the role of the hydrogel in our cellulose-hydrogel composite is to act and behave as the host matrix for the pulp fibre network. In our approach, any actuator realised from this composite construction would benefit from the higher actuation forces arising from the swelling potential as a result of hydrogel entrapment by the pulp network. The pulp fibre network also controls the water diffusion concentration gradient within the paper composite thereby facilitating programmable response of the material system in the 4th dimension (4D - time domain). The swelling potential, storage stability and aqueous stability of these hydrogel composites have all been characterised. Furthermore, the rheological properties, mechanical properties and force–time response of these cellulose hydrogel composite systems will also be presented and discussed to show its potential as a sustainable and cost-effective actuator.



Figure 1: Actuation in Pine cones

REFERENCES

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- [2] Ionov L 2013 Biomimetic Hydrogel-Based Actuating Systems *Adv. Funct. Mater.* **23** 4555–70