**Title**: Tough meets Stretchy - Double Polyrotaxane Networks hydrogels

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**Description:**

Polyrotaxanes are a class of materials in which linear polymer chains (typically PEG) thread through cyclic molecules (typically cyclodextrines) which are then crosslinked to create a sliding crosslinks [1]. These slide-ring gels display a unique “pulley effect” which allows the material to equalise and re-distribute the tension across the polymer chains avoiding the creation of weak points or breakage due to accumulated stress. Thanks to this, polyrotaxane hydrogels are particularly soft (low Young’s modulus < 1 MPa) and highly stretchable (500-1000% strain) and can be made in water [2].

Polyrotaxanes are more tunable than other classical chemically crosslinked polymer hydrogels because it has additional parameters that can be varied, e.g. the number of slide-rings per polymer and the number of crosslinked slide-rings VS uncrosslinked ones. One of the downsides of these materials is that they are not particularly tough (breakage occur around 0.1MPa) [2].

One strategy to endow them with higher toughness is to create a double network [3] with a sacrificial network that works as energy-dissipating structure. Using non-covalent, reversible cross-links (e.g. hydrogen bonds) in the sacrificial network allows the restoration of the sacrificial bonds when the strain is reduced. Double networks are known to be particularly tough (range ~10 MPa tensile stress at breakage, fracture energies ~9’000 J/m^2, see [3-5] and similar papers).

To the best of our knowledge, there are no prior attempts to design a double network in which one of the two (or both) is a polyrotaxane network. This is thus a novel technology for super stretchable but also tough hydrogels. As a first step, we will explore this by synthesising and characterising the materials properties of PEG/cyclodextrins polyrotaxane gels embedded within a polyacrylamide network. These materials will be characterised using rheometers and universal testing machines.

There will be the opportunity for the student to explore these materials using coarse grained molecular dynamics simulations.

[1] K Ito, Polymer Journal, **39** 2007 (<https://www.nature.com/articles/pj200766>)

[2] Imran et al Nature Comm **5**2014 (<https://www.nature.com/articles/ncomms6124>)

[3] Sun et al, Nature **489** 2012 (<https://www.nature.com/articles/nature11409>)

[4] Na <https://link.springer.com/article/10.1007/s13367-013-0020-y>

[5] Haque et al, Polymer **53** 2012 (<https://www.sciencedirect.com/science/article/pii/S0032386112002212?via%3Dihub>)