Wool That Breathes: Integrating Porous Micro-Crystals and Structural Modelling on NZ Wool to Develop the Foundation for Passive CO2 Capturing Textiles

Rumball-Smith, Jesse (School: Wellington College)

Mitigating climate change requires carbon dioxide removal, but conventional Direct Air Capture is prohibitively expensive. A scalable alternative is distributed, passive capture: embedding CO_2-absorbing capabilities into everyday materials. Recently, Metal-Organic Frameworks (MOFs) have gained research attention for ambient CO_2 sorption, making them ideal for textile integration. Simultaneously, New Zealand's strong wool sector faces economic depression. Using wool as a substrate for MOF functionalisation creates a dual-impact solution: forming distributed carbon sinks while revitalising a struggling commodity. Developing this material is a multi-scale engineering challenge requiring micro-scale chemical bonding and macro-scale structural coordination. First, laboratory synthesis established a repeatable pathway for functionalising complex biological keratin. Through 17 iterations, ambient in-situ growth of Zeolitic Imidazolate Frameworks (ZIF-8 and ZIF-67) was achieved on merino fibres. SEM, EDS, and XRD confirmed robust crystal nucleation, proving MOFs preferentially anchor to rough cuticle edges. Second, because physical weaves dictate airflow and CO_2 access, a computational pipeline was developed to generatively design fabric architecture. Focused on 3D weft knitting and trained on real-world topological data, the model uses a physics simulation module to estimate theoretical CO_2 sorption. This acts as an optimisation feedback loop, iteratively tweaking parameters to maximise capture capacity. Outputs are mathematically validated to ensure designs are structurally realistic and "machine-knittable". Integrating chemical feasibility with digital textile generation provides a blueprint for climate-positive fabrics.

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