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A multiscale approach to 3D printed facades with bespoke thermo-optical properties

Daylighting and solar control are fundamental aspects of building design, especially for modern architecture marked by large glazed building envelopes. Visual and thermal comfort, heat gains, and, ultimately, energy consumption can be controlled with the correct management of solar penetration, which has become an essential element of facade design aimed at decarbonizing the construction sector. Solar control strategies need to account for the interactions of indoor and outdoor environments, which are specific to the building's location and use. The seasonal variation of solar irradiation, the dependence on the latitude and orientation of the site, and the different functional requirements of indoor spaces make solar control a challenging yet exciting task for designers and engineers.

This high level of control and customization required to tune the thermo-optical properties of building facades is not easy to achieve with traditional manufacturing techniques based on mass production and standardization. While the facade industry has been refining glazing and shading products toward increased performances and complexity of the components, the stringent need to consider embodied emissions of facades and their end-of-life has brought attention to radically new ways of designing and manufacturing facades. Among these, 3D printing holds promise for fabricating customized geometries with tailored thermo-optical properties. In particular, large-scale 3D printing of thermoplastic enables the fabrication of large-scale elements and control over finer geometrical features.

We investigate the potential of 3D-printed polymer facades with bespoke properties for thermo-optical control in buildings. Using a combination of numerical and experimental approaches, we observe that the tuning of facades'thermo-optical properties, such as visual transmission, reflection, haze, and solar heat gain coefficient, can be achieved by controlling geometrical features on multiple dimensional scales. At the material scale (nm), the choice of thermoplastic determines the base optical properties and can be altered during the printing process, where the material is melted, deposited, and cooled. On a larger scale (μm - mm), the characteristic layer resolution resulting from 3D printing also plays an important role in light transmission through 3D-printed components, resulting in variations of quantity (amount) and quality (directionality, diffraction) of transmitted light. At the component scale (cm - m), the facade geometry can be designed to respond to the specific site daylighting conditions (irradiation, orientation) and can be varied locally to reflect the requirement of the indoor spaces it encloses.

By combining geometrical and material control over multiple scales, we propose novel 3D-printed polymer facade components which exhibit locally tuned optical properties. Moreover, we propose characterization methods that can be used to assess the performance of such non-standard elements. These design and fabrication strategies hold promise for novel building components with reduced embodied and operational emissions.

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Keyword 2

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Keyword 3

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Keyword 5

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