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Ion beam engineering of topological insulating surfaces drives electronic transitions via radiation-induced disorder

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The discovery of the topological phases of matter sparked a renaissance in solid-state physics; however, broader applications to materials engineering are still in their infancy. Three-dimensional topological insulators offer a particularly simple new paradigm for developing unique functionality, which relies on the custom design of edges, surfaces, and interfaces.

The interplay between classical crystal and magnetic order parameters is critical in these materials, and glass transitions have important consequences for their electronic properties. For example, delicate van der Waals crystals are highly sensitive to electron and ion beam irradiation [1,2,5], which can be used to deliberately drive glass transitions and spatially control the topological invariant, toggling between $\mathbb{Z}_2 = 1 \longrightarrow \mathbb{Z}_2 = 0$ at a threshold disorder strength [1]. Controlled glass transitions are also important in the search for elusive higher-order amorphous topological insulators predicted by theory.

To enable accurate, non-destructive characterisation of electron density and spin density with atomic resolution, neutron and X-ray scattering have some intrinsic advantages. I will discuss how surface-sensitive neutron and X-ray techniques, including polarised neutron reflectometry, can provide unique insights into classical crystal and magnetic order-disorder transitions, and their concomitant electronic quantum transitions.

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