



Beitrag ID: 98

Typ: Poster

MBE thin-film growth of quantum materials

Dienstag, 7. Oktober 2025 17:23 (8 Minuten)

Studying the physics of thin films is the first step towards understanding how ‘quantum’ devices will be controlled as the plethora of phenomena promised by quantum materials can only be fully exploited once they can be fabricated as thin films. Meanwhile, there is a growing focus on scaling up the growth of interesting quantum materials to 200–300 mm wafer size using molecular beam epitaxy (MBE), with the aim of integrating these materials into the semiconductor industry [1]. However, much remains to be discovered about growing quantum materials as thin films rather than in bulk and the effect this has on the quantum or topological properties of the materials and their subsequent control. In this review study, we identify systems in which quantum effects are particularly relevant when grown in thin film form, highlighting the challenges and initial successes and addressing issues such as feasibility and effort-to-impact ratios. These include: topological insulators, Weyl semimetals, and subsequent topological phase transitions; altermagnets (particularly those that exhibit altermagnetism only in thin film form); high-temperature superconductors and the emerging phenomena of oxides and nitrides; magnetic spin textures (particularly skyrmions and hopfions); quantum spin liquids and spin ices; and hexagonal perovskites and other 2D materials [2, 3, 4, 5]. Our goal is to generate interest in growing new thin-film quantum materials at the JCNS facilities and to initiate discussions about implementing these material systems. MBE is clearly at the heart of a materials revolution and will become an increasingly necessary growth process for furthering the fundamental science of quantum materials, as well as their utility in developing the next generation of devices.

- [1] ‘Introducing the latest production MBE systems for III-V and nitride materials!’ DCA, (2025) [Online]. Available: <https://dca.fi/introducing-the-latest-production-mbe-systems-for-iii-v-and-nitride-materials/>
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Sitzung Einordnung: Poster session

Track Klassifizierung: Emergent phenomena in functional and nano-magnets