Aalto University

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"Topological quantum states in designer quantum materials"

Title of the dissertation	Topological quantum matter with designer materials
Contents of the dissertation	Topological quantum matter, where topological concepts are exploited to discover and classify new phases of matter, has emerged as one of the most important topics in condensed-matter physics in recent years. Topological states with exotic properties are robust to local perturbations, which is important for a multitude of applications. In particular, topological superconductors have attracted a lot of interest as they are predicted to host zero-energy Majorana bound states which could make it possible to construct topological qubits. However, the realization of these exotic states is often challenging in naturally occurring materials. This can be overcome using the designer materials approach, where the desired physics emerges from the engineered interactions between different components. This thesis demonstrates the experimental realization and tuneability of topological domain wall modes in one-dimensional artificial lattices constructed using chlorine vacancies in the c(2x2) adsorption layer on Cu(100) crystal with atomic level control using low temperature scanning tunneling microscopy (STM). In addition to topological states, we examine structures with flat bands and demonstrate both gapped and gapless systems with single or multiple flat bands. The designer approach is also be used in two-dimensional van der Waals heterostructures. The combination of ferromagnetic materials and superconductors suggests the possibility of realizing topological superconductivity. We show that a direct synthesis of magnet-superconductor heterostructures with molecular beam epitaxy (MBE) results in the formation of an artificial topological superconductor with one-dimensional Majorana zero modes along the edges of the magnetic islands, which are the key signature of topological superconductivity. The convergence of novel designer materials and future quantum devices is especially apparent in the field of two-dimensional vdW heterostructures. They offer a broad range of materials properties, high flexibility in fabrication pathways, and the ability to form artificial states of quantum matter which can provide crucial advances in technological applications in the field of quantum information science.
Field of the dissertation	Engineering Physics
Doctoral candidate	Md Nurul Huda, M.Sc.(Tech.)
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Opponent	Professor Andrew Wee, National University of Singapore (NUS), Singapore
Custos	Professor Peter Liljeroth, Aalto University School of Science, Department of Applied Physics
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