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2014 Beller Lectureship: Quantum Size Effects: surface morphology and the stability of low dimensional structures

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Quantum Size Effects (QSE) play an important role in determining the surface morphology of certain epitaxial metal films on metal and semiconductor substrates. These give rise to distinct preferred film heights, imposed by a favourable relationship between the film's Fermi wave length and its interlayer spacing. QSE in thin films are usually observed on substrates with a surface projected band gap. We obtained evidence for QSE in Pb and Bi films deposited on Ni(111) [1]. For Pb on Ni(111) a classic QSE induced stabilization of specific Pb film thicknesses is obtained in a way very similar to Pb/Si(111). Slow heating of large QSE-stabilized Pb mesas leads to their ultrafast collapse and evidences collective motion of giant numbers of Pb atoms, resulting in mass transport rates much higher than expected form the activation energies derived from STM observations and DFT calculations for individual processes. For ultrathin Bi fims on Ni(111), the QSE lead to the evolution of distinctly different crystalline structures. No longer, a sequence of preferred heights with one unique crystal structure is observed, but rather the emergence of different crystalline structures with increasing thickness. This remarkable observation is attributed to the establishment of specific favourable relationships between the Fermi wave length and the interlayer spacing. The film's crystal structure is imposed by QSE, facilitated by the inclination of Bi towards allotropism. QSE not only lead to preferred thicknesses of thin layers (2D), as reported for various systems in the recent past, but can also lead to quantized nanowire lengths (1D), as we reported for Ir/Ge(001). The preferred Ir-nanowire lengths correspond to multiples of six unit cells and SPS measurements support the QSE induced nature of the length quantization.

[1] T. R. J. Bollmann, R. van Gastel, H. J. W. Zandvliet, and B. Poelsema, Phys. Rev. Let. 107, 136103 (2011); PRL 107, 176102 (2011).
[2] T. F. Mocking, P. Bampoulis, N. Oncel, B. Poelsema, Nature Commun. 4, 2387 (2013).