High-Quality MBE-grown Aluminum Layers for Experimental Realization of Majorana Bound States

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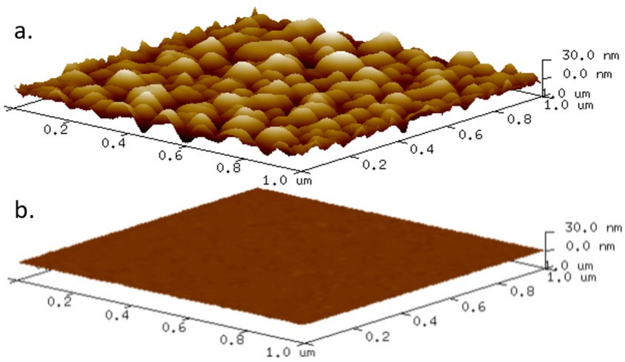
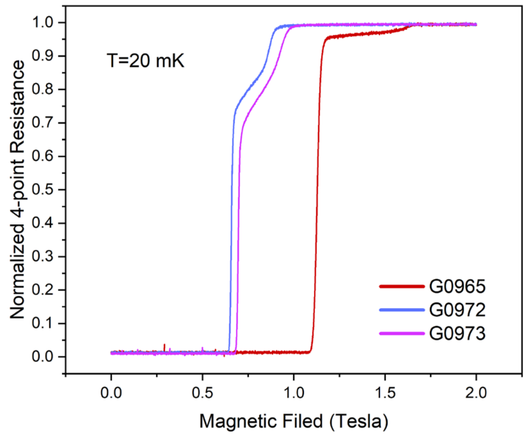
The small effective mass, large Landé g-factor, and strong spin-orbit interactions (SOI) make high-quality InAs, and InSb quantum well (QW) structures particularly appealing for the experimental realization of Majorana bound states (MBS) in the pursuit of topological quantum computing. Besides such near-surface QWs, an essential element of the MBS device is a layer of superconductive material with a very large coherence length at low temperatures and sufficiently high critical value of the in-plane magnetic field. A natural choice for such a material is aluminum. Even though the critical magnetic field of bulk Al is only 0.01 T, this is substantially increased for very thin layers. However, the high surface mobility of Al in a UHV environment, even at room temperature, and its tendency for 3D nucleation make the deposition of thin (~10 nm) continuous layers challenging. Growth of smooth layers has been typically done in dedicated UHV chambers with the substrate actively cooled with liquid nitrogen during Al deposition. Here we report on the growth of high-quality continuous Al layers directly inside the standard Veeco GEN10 MBE reactor at temperatures above 0 °C. We (i) show that at sufficiently high Al flux, the transition from 3D to 2D growth mode takes place, (ii) discuss the possible origin of such transition, and (iii) show results of an extensive in-situ and ex-situ characterization.



AFM scans of two aluminum layers grown on $In_{0.75}Ga_{0.25}As/In_{0.53}Ga_{0.47}As$ (6nm/100nm) on the InP(001) substrate. In both cases, the nominal thickness of the Al layer was 10 nm.

a. The layer was deposited at 0.5 Å/s.
b. The layer was deposited at 3.0 Å/s.



Superconducting to normal phase transition signatures for three Al layers:
G0972 was deposited at 3.0 Å/s (10 nm thick)
G0973 was deposited at 2.0 Å/s (10 nm thick)
G0965 growth rate decreased from 2.0 Å/s to approximately 1.3 Å/s during the deposition and is thinner.

Layers deposited at lower growth rates did not show superconductive behavior.