THICKNESS DEPENDENT MORPHOLOGY AND RESISTIVITY OF ULTRA-THIN AL FILMS GROWN ON Si (111) BY MOLECULAR BEAM EPITAXY

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Ultra-thin films of Al (thickness <50 nm) are important for nanotechnology applications, such as, counter-electrodes in self-assembled monolayers for molecular electronics, interconnect metallization in ULSI or GSI technology etc. In this work, textured ultra-thin Al films were grown on (111) Si substrates by molecular-beam epitaxy (MBE). Grown films were characterized by in-situ X-ray photoelectron spectroscopy, and ex-situ X-ray diffraction, atomic force microscopy and temperature dependent electrical resisitivity measurements. The results showed that (i) films grow via 3D-island Volmer-Weber growth mechanism, (ii) with increasing film thickness the average grain size increases and the coalescence takes place for thickness >60 nm, and (iii) independent of the thickness, films grow with (111) orientation. The room temperature value of resistivity - contrary to the predictions of existing theoretical models - is found to increase monotonically up to a thickness of 40 nm (see Fig. 1 (a)). This anomalous feature was understood in terms of the film morphology consisting of 2-dimensional networks of Al islands, whereby the charge transport takes place via variable range hopping (VRH). For film thickness ≤ 50nm, the resistivity versus temperature curves exhibited a metal-to-insulator (M-I) transition at ~110 K (see Fig 1(b)), and analysis of insulating region supported a 2D-variable range hopping mechanism of charge transport. However, for thickness ≥60 nm the resistivity decreased sharply and the M-I transition disappeared. The bulk value of resistivity (2.59 μΩcm) was obtained for a thickness of 200nm.

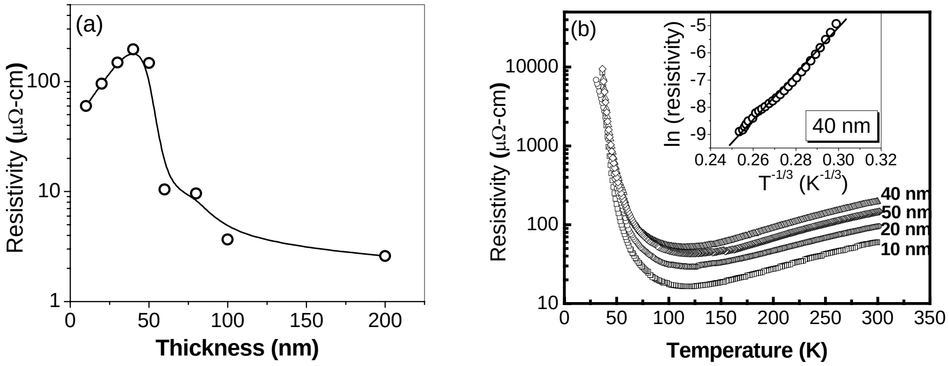

Fig. 1(a) Room temperature ρ of Al thin films as a function of film thickness. (b) Temperature dependence of ρ. The inset shows data of insulating region plotted as ln ρ vs $T^{-1/3}$ for a 40 nm film. A straight line fit of data confirms 2D VRH mechanism.

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