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Analysis of the growth behavior of ultrathin Cu films by using in-situ impedance spectroscopy

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We investigated the growth behavior of ultrathin Cu films by using *in-situ* I-V measurements and impedance spectroscopy simultaneously. The Cu films on glass substrates were deposited up to a thickness of 7 nm in an UHV e-beam evaporator system. The analysis of impedance spectrum and I-V measurements gives the information that the growth stage can be classfied into three kinds which are sequentially discontinuous, semicontinuous, and continuous regimes. In addition, the percolation threshold thickness of Cu film, which was determined by the impedance spectrum, coincides with the value by the resistance measurements to be 2.5 nm. For a thickness of less than 2.5 nm, the complex dielectric moduli of films could be presented by a parallel circuit with a resistor and a capacitor, on the other side, those of films thicker than 2.5 nm by an equivalent series circuit of resistor and inductor. The real part changes the sign during the insulator-metal transition. The scattering relaxation time could also be known by the circuit model for the impedance spectrum. Changes in the relaxation time and the inductance of semicontinuous and continuous films are discussed by considering the roughness and grain-boundary scattering effects.