Correlations between Structure, Composition and Electrical Properties of Tungsten / Tungsten Oxide Periodic Nanolaminates

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Tungsten/tungsten oxide-based periodic nanolaminates were grown by DC reactive sputtering by means of the reactive gas pulsing process (RGPP). Oxygen gas was periodically injected during the growth in order to produce regular metal-oxide alternations with period thicknesses ranging from a couple to a few tens of nanometers. We systematically implemented high resolution transmission electron microscopy, scanning transmission electron microscopy, X-ray energy dispersive spectroscopy and electron energy loss spectroscopy to analyse the structure, dimensions and reliability of the metal-oxide periodic stacks. Regularity of tungsten-based alternations, oxygen content through the multilayered structure and quality of interfaces were determined and correlated to the growth conditions ; real time measurement of the target potential vs. time was specially studied. Periodic sharp and smooth interfaces pointed out through the film thickness are connected to the abrupt oxygen injection during the deposition stage and to the kinetics required to restore the process in the metallic sputtering mode [Superlattices and Microstructure 101 (2017) 127-137].

The position and the broadening of the bulk plasmon peak mapped from low-loss EELS correlates with the chemical composition in the metallic sub-layers and at interfaces (Figure 1). For the thickest periods, pure metal is only present whereas for the smallest periods (lower than 10 nm), oxygen is significantly and systematically measured in the tungsten-rich metallic layer. Finally, a correlation is established between sputtering conditions (poisoning of the tungsten target surface), structure (period thickness) and chemical parameters (oxygen concentration in the metallic layer) and electrical properties. A relationship connecting total thickness, metal/oxide period, tungsten concentration in the metallic layers and electrical resistivity at room temperature, is successfully proposed. It supports the fundamental role of interfaces for the electronic transport behaviors in these W/WOx periodic multilayers.

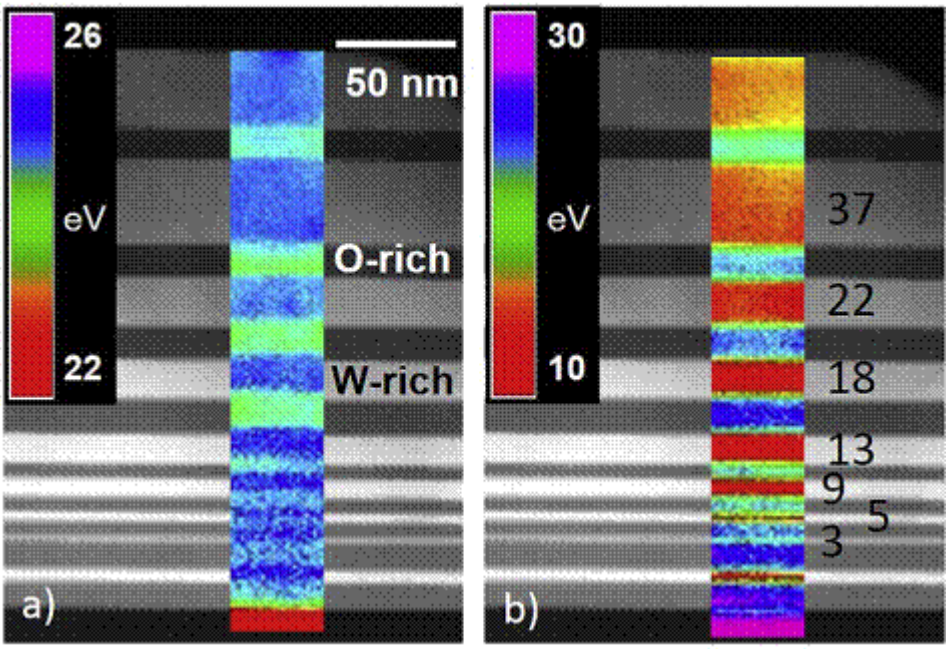

Figure 1: Color-maps of a) center and b) FWMH extracted after NLLS fitting with a Gaussian curve, of the most intense low-loss peak, superposed on the original dark-field STEM image from a sample with various metallic and oxide thicknesses.