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Pure-metal and metal-nitride films by hotwire-assisted atomic layer deposition

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Manufacturing of semiconductor devices, such as microprocessors, DRAM memories, flash memories, and image sensors, relies on deposition of thin dielectric, semiconducting and metallic layers (films) of various functionalities. Atomic Layer Deposition (ALD), either in a thermal mode or enhanced by plasma (PEALD), is becoming a major player in the field of deposition. Thermal ALD processes for deposition of titanium nitride (TiN) and aluminum oxide (Al_2O_3) are commonly used nowadays. With a few exceptions, single-element films of metals and semiconductors are however rather difficult to deposit using thermal-only ALD processes. A solution in this case is PEALD. Hydrogen- or nitrogen-based plasmas are used to deposit Ta(N), Ti(N), Ru, Si, Ge and Al as well as AlN and GaN. Several limitations however make PEALD less attractive. Plasma can cause damage to the wafer under treatment. Further, a plasma involves a lot (tens, hundreds) of chemical reactions. As a result, the wafer surface is exposed to many ions, radicals and atoms, as well as UV photons. This makes the composition and structure of the growing film hard to predict and control.

Hot-wire ALD is a novel technique that has the potential to overcome the mentioned limitations of PEALD, still being an energy-enhancement technique to enable formation of reactive species, such as radicals, at low substrate temperatures. This alternative-to-plasma and a technically-easier approach employs a filament that is heated up to a temperature in the range 1300-2000 ^{o}C to dissociate precursor molecules.

In this work, a heated tungsten filament is employed to enable the so-called hot-wire (HW) assisted ALD (HWALD) by catalytically cracking molecular hydrogen (H_2) or ammonia (NH_3) into atomic hydrogen (at-H) and nitrogen-containing radicals (N-radicals). The generation of at-H and N-radicals and their successful delivery to the wafer (substrate) surface has been experimentally confirmed by tellurium-etching and silicon-nitridation experiments, respectively. In the presentation, it will be reported on deposition of low-resistivity oxygen-free tungsten (W) films with HWALD, as well as on the effect of HW-generated N-radicals and at-H in deposition of aluminum nitride (AlN) and boron nitride (BN) films. The important illustrative examples of real-time monitoring of deposition processes using in-situ spectroscopic ellipsometry will be given.

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