Hotwire-assisted Atomic Layer Deposition of Pure Metals and Metal Nitrides

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Atomic Layer Deposition (ALD) has become a major player in field of deposition of thin dielectric, semiconducting and metallic layers (films) of various functionalities. ALD has been successfully utilized for manufacturing of semiconductor devices, such as microprocessors, memories, and sensors. Hot-wire assisted ALD (HWALD) is a novel energy-enhancement technique, enabling the formation of reactive species (radicals) at low substrate temperatures, without the generation of energetic ions and UV-photons as by plasma. The HWALD approach employs a hot wire (filament) that is heated up to a temperature in the range of 1300-2000 ^{o}C to dissociate selected precursor molecules.

In our work, we have successfully employed HWALD technique to grow low-resistivity tungsten (W) films at a substrate temperature of 275 °C, using pulses of WF_6 and atomic hydrogen [1-3]. In-situ spectroscopic ellipsometry (SE) is used to monitor the growth behavior and film properties in real time. The high-resolution transmission electron microscopy (HRTEM) analysis reveals a uniform and conformal coverage of high aspect ratio structures, confirming the effective ALD process. Further, HWALD of W has been compared on various substrates in terms of films growth and crystallinity. The results will be summarized in the presentation.

Further, with the trends in miniaturization of semiconductor components following Moore’s law, industry will soon reach the limits of material capabilities offered by silicon. This demands exploration into other semiconductors which have comparable or even superior properties to Si, and also to integrate them into the existing Si technology. Group III–nitride semiconductors, such as GaN and Al(Ga)N, are potential candidates owing to their unique properties, making them attractive for optical, high speed and high power applications.

The successful deposition of W films by HWALD opens the possibility to explore HWALD of various other materials. In our work, we further applied the HWLAD approach to catalytically crack molecular ammonia (NH_3) into atomic hydrogen and nitrogen-containing radicals, and thereby realize HWALD of aluminum nitride (AlN) [3] and gallium nitride (GaN) films. The role of residual oxidants, present in the deposition chamber, on film properties appeared to be crucial in these processes. Finally, we have attempted to deposit boron nitride (BN) layers in the temperature range 300-400 ^{o}C [3] utilizing the hot-wire tool. The as-generated nitrogen-containing radicals resulted in the appearance of a clear shoulder in the X-ray photoelectron spectroscopy (XPS) sputter profiles, corresponding to the B1s peak position of BN and thereby confirming the nitridation enhancement by the hot wire.

In the presentation, mentioned experimental results will be demonstrated and discussed.

[1] M. Yang, et.al., Phys. Stat. Solidi A, 212, No. 7, 1607 (**2015**).
[2] M. Yang, et.al., Journal of Vacuum Science & Technology A, 34, 01A129 (**2016**).
[3] A.Y. Kovalgin, et.al., Hot-Wire Assisted ALD: A Study Powered by In Situ Spectroscopic Ellipsometry, Advanced Materials Interfaces, 1700058 (**2017**).