Low-temperature PEALD of Ga_2O_3 using TMGa and O_2 plasma

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Gallium oxide (Ga_2O_3), a transparent semiconducting oxide, is promising for a wide range of applications in the fields of electronics, optoelectronics, and sensors [1]. For specific applications, low deposition temperatures are required to maintain the individual material properties of subjacent layers realized in prior process steps. The use of plasma-enhanced atomic layer deposition (PEALD) on the one hand and of a gallium precursor exhibiting a high vapor pressure on the other hand facilitates the deposition at lower substrate temperatures.

Hence, in this work thin Ga_2O_3 layers were deposited by PEALD with alternating pulses of trimethylgallium (TMGa) as gallium precursor and oxygen (O_2) plasma at substrate temperatures in the range of 80 to 200 °C. The layers were prepared on silicon wafers in the SENTECH SI PEALD system [2] and subsequently characterized by spectroscopic ellipsometry (SE), X-ray photoelectron spectroscopy (XPS), and electrical measurements.

In the SE measurements a linear thickness evolution with a growth rate of ~0.66 Å per cycle and an inhomogeneity of ≤ 2% across 4” wafers were found for all samples. While the refractive index of the Ga_2O_3 thin films is independent of temperature (1.86 ± 0.01 at 632.8 nm), the bandgap slightly decreases from 80°C to 200 °C (4.68 eV to 4.57 eV). Correspondingly, the permittivity of the layers determined from capacitance-voltage (C-V) measurements is constant with temperature (9.7 ± 0.2 at 10 kHz). Moreover, fixed and mobile oxide charge densities in the order of 1 to 4×10^{12} were deduced from C-V data. In addition, the films show electrical breakdown fields in the range of 2.2 to 2.7 MV/cm. The analysis of the chemical composition of the films by XPS revealed ideal stoichiometric gallium to oxygen ratios of 2:3 accompanied by a lowest carbon contribution of ~10% for the sample prepared at 150 °C. [3]

Furthermore, these results will be complemented by a depth profiling analysis of the layer composition based on cyclic Ar^+ ion sputtering using XPS.

The excellent materials properties are maintained even at low substrate temperatures as low as 80 °C confirming that the TMGa/O_2 PEALD process is indeed suitable for low-temperature growth.

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