Doping hafnium oxide by in-situ precursor mixing

C. Mart[1] K. Kühnel[1] T. Kämpfe[1], M. Czernohorsky[1], M. Wiatr[2], S. Kolodinski[2], W. Weinreich[1]

[1]*Fraunhofer Institute for Photonic Microsystems IPMS, Königsbrücker Str. 178, 01099 Dresden, Germany*

[2]*GLOBALFOUNDRIES Management Services LLC & Co.KG, Wilschdorfer Landstraße 101, 01109 Dresden, Germany*

wenke.weinreich@ipms.fraunhofer.de

Since the discovery of ferroelectricity in doped hafnium oxide thin films in 2011, an increasing number of publications have assessed the formation of the polar orthorhombic phase as the premise for spontaneous polarization. Many factors impact the electrical performance of these films, such as thickness, mechanical stress, and defect chemistry. However, adding dopants such as Si, Y, La, Al or Gd remains the most direct and robust way to achieve ferroelectricity in hafnium oxide.

We employ a modified atomic layer deposition process utilizing in-situ mixing of precursors to obtain doped hafnium oxide thin films with improved ferroelectric properties on 300 mm silicon wafers. The method is demonstrated with aluminum, silicon and lanthanum doping, where film composition and crystal structure are analyzed. With the modified process, low dopant concentrations are shown to be accessible while simultaneously improving film uniformity. Characterization of the ferroelectric hysteresis confirms increased remanent polarization values with the modified process variant for all examined dopants. The switching density of the films is analyzed using first-order reversal curve measurements, where confined peaks are observed, which are an indication of low defect density and reduced internal bias fields.

The prescribed in-situ precursor mixing process may be adapted to future large-scale manufacturing processes by mixing the precursors beforehand, which requires knowledge on possible chemical interactions. Emerging applications of doped hafnium oxide thin films such as non-volatile memory, infrared sensors, or neuromorphic devices may benefit from the enhanced stoichiometry control and film properties by using the proposed deposition method.