Low-Temperature ALD for Electronic Applications

Jun Yang[1,2], Amin Bahrami[1],Samik Mukherjee[1], Shiyang He[1,2], Sebastian Lehmann[1], Kornelius Nielsch[1,2]

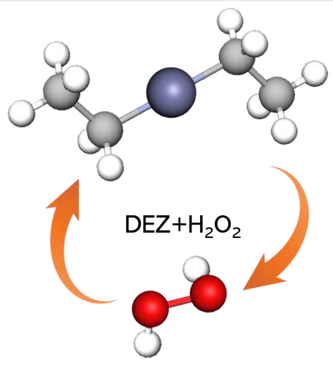
[1] *Institute for Metallic Materials, Leibniz Institute of Solid State and Materials Science, 01069 Dresden, Germany*

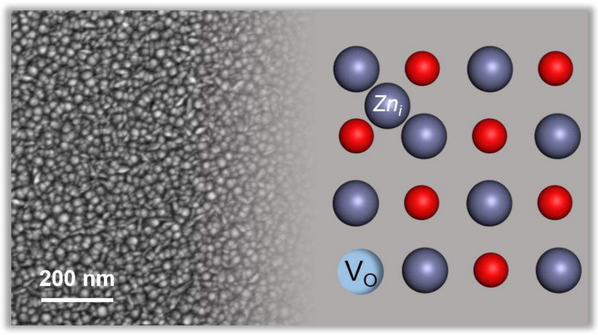
[2] *Institute of Materials Science, Technische Universität Dresden, 01062 Dresden, Germany*

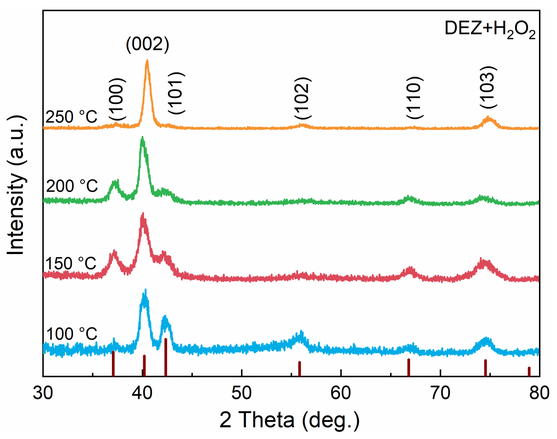
Motivation and Outline

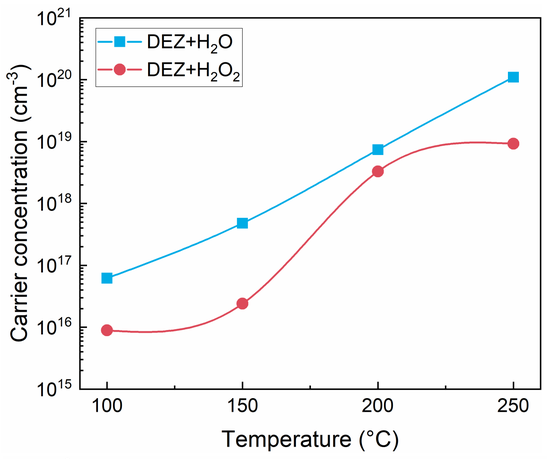
Atomic layer deposition (ALD) is an advanced thin film deposition technique, based on self-limited surface reaction, to dose in the chamber with two or more separated gaseous reactant pulses at a low temperature. The development of semiconductor thin films with good performance may be a true enabler for a variety of applications, such as displays, sensors, photovoltaics, memristors, and electronics. Here, a variety of thin films, including ZnO, SbO_x, and Sb_2Te_3 were developed. The quality of the thin film was evaluated using XRD, XPS, and ERDA. Finally, these thin films were successfully integrated on field-effect transistors (FETs) or photodetectors and the performance of devices was discussed.

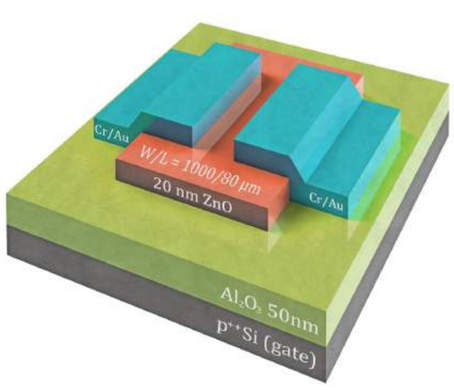
ZnO FETs using H_2O_2 as oxidizer

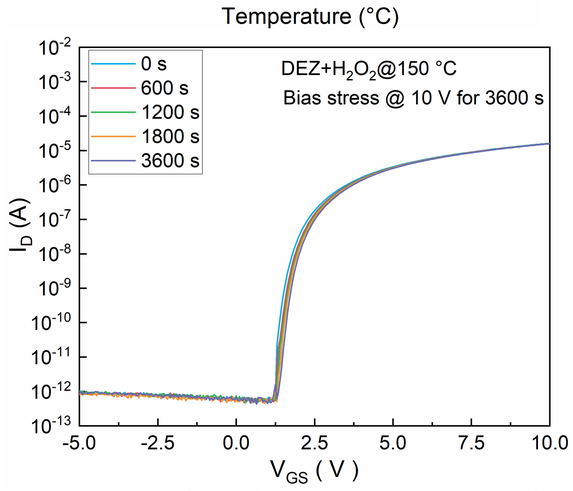






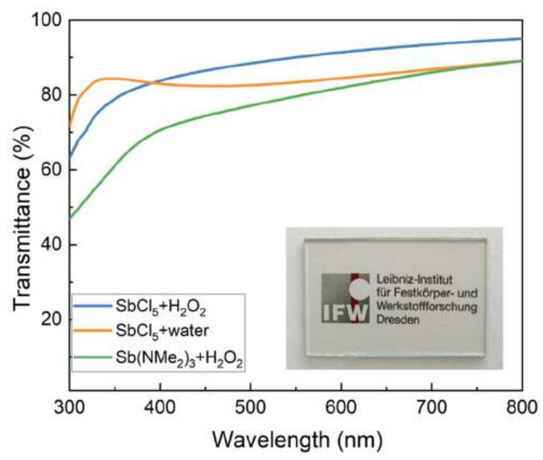


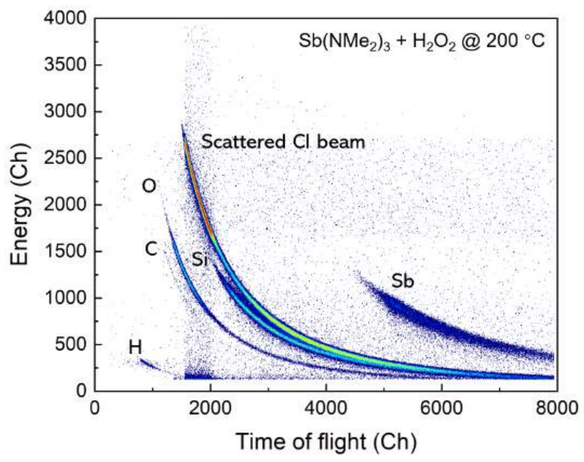


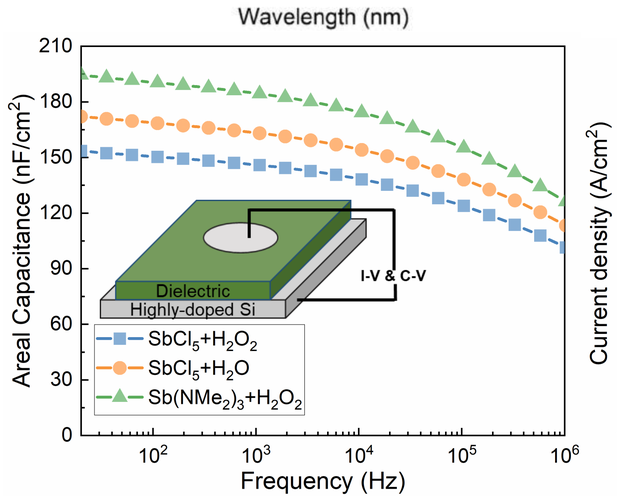


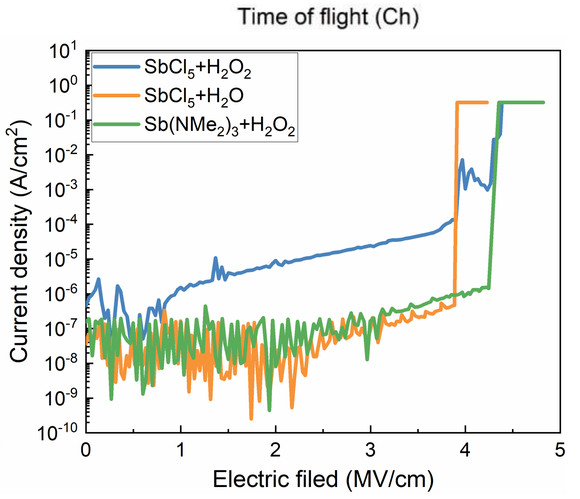
- H_2O_2 provides an oxygen-rich environment so that the oxygen vacancies (O_v) are suppressed, implying a lower carrier concentration.
- The lower growth rate makes it possible for the H_2O_2-ZnO thin films to grow along the lower surface energy direction of <002>.
- The TFT with H_2O_2-ZnO grown at 150 °C shows a high field-effect mobility of 10.7 cm^2 V^{-1} s^{-1}, a high ratio Ion/Ioff of 2×10^7, and a sharp subthreshold swing (SS) of 0.25 V $dec.^{-1}$.

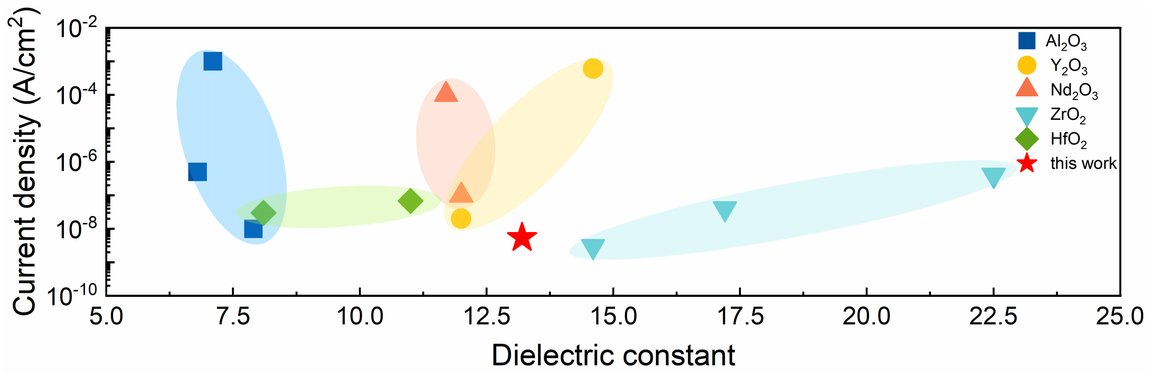
SbO_x high-*k* insulator





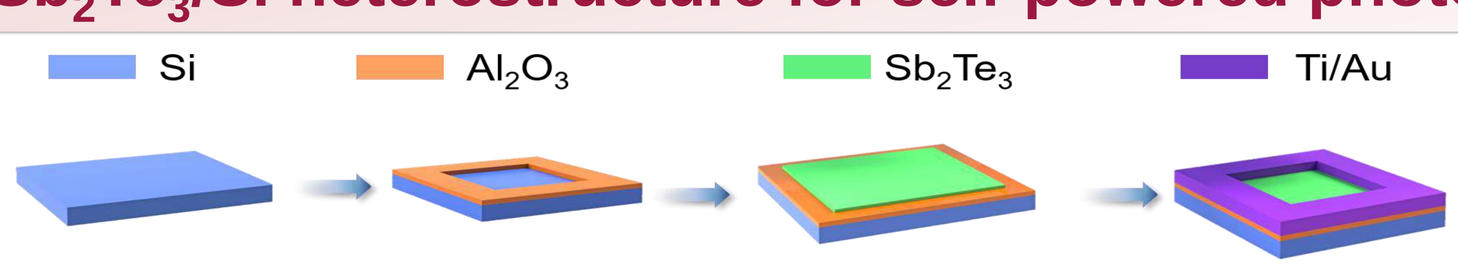


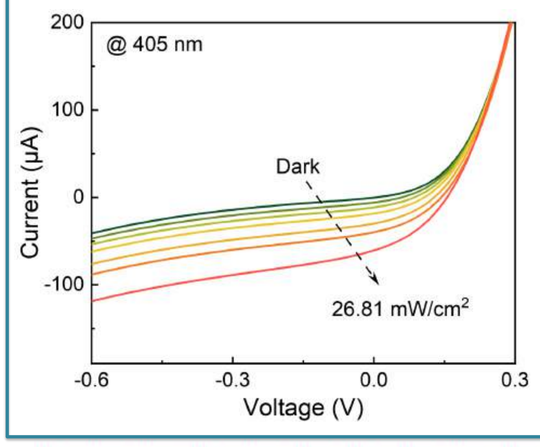


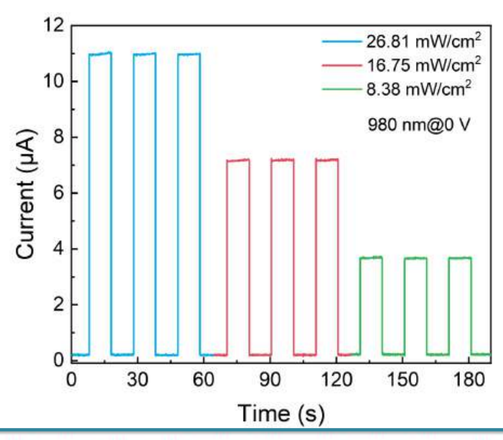


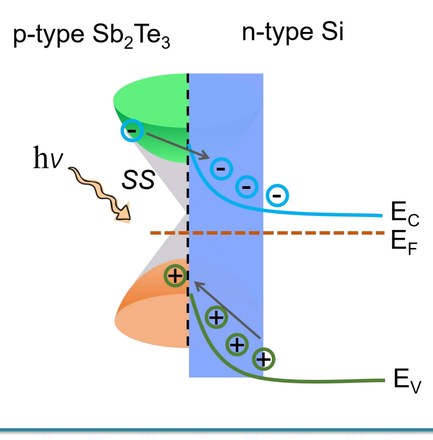
- In the visible range, the thin films are highly transparent at 80%.
- Tof-ERDA result shows the hydrogen content is only ~0.6% at the deposition temperature of 200 °C.
- ALD-SbO_x thin films exhibits a very low current density of approximately 10^{-8} A/cm^2 and a dielectric constant of about 13, which is a prospective candidates to replace the conventional dielectrics.

Sb_2Te_3/Si heterostructure for self-powered photodetector









- P-type Sb_2Te_3 thin film was deposited by ALD at the temperature of 80 °C using $(Et_3Si)_2Te$ and $SbCl_3$ as precursors.
- The photodetector showed a high responsivity of 4287 mA/W at 405 nm, and a fast response speed of 98 μs (t_{rise}) was obtained under 0 bias voltage.
- Because of the band alignment, the energy band of Si bends downward at the junction interface, forming a strong built-in electric field directing from Si to Sb_2Te_3 side.
- The superior quality of ALD processed Sb_2Te_3 keep a topological surface state, and the internal surface of Sb_2Te_3 is a “smooth road” for electron transportation, while the top surface can promote the hole transportation to the top electrode.

Leibniz Association
Alexander von Humboldt Stiftung/Foundation
TECHNISCHE UNIVERSITÄT DRESDEN
IFW Leibniz Institute for Solid State and Materials Research Dresden