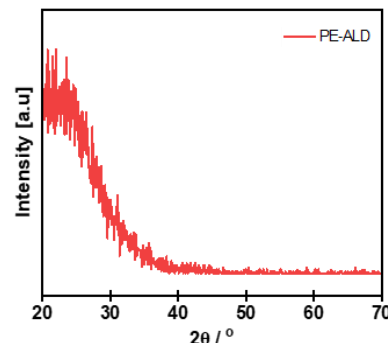


Atomic Layer Deposition of Cr₂O₃: Comparing Ozone and Plasma Routes for TFTs

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Chromium(III) oxide (Cr₂O₃), a wide-bandgap p-type semiconductor with antiferromagnetic ordering, is promising for thin-film transistors (TFTs) and spintronic heterostructures [1]. Complementary p-type oxides are essential for CMOS, as n-type ZnO and IGZO already show excellent performance [2]. Atomic layer deposition (ALD) offers conformality, thickness precision, and scalability for integration. Here, we investigate Cr₂O₃ films from Cr(acac)₃ using two oxidation pathways: ozone and oxygen plasma. Drawing on studies of structurally related oxides [3, 4], we hypothesize that plasma-enhanced (PE) oxidation reduces trap density and improves TFT stability, while ozone post-annealing tunes oxygen vacancy concentrations to balance conductivity and on/off ratios [5]. In ALD of Cr₂O₃, growth proceeds via ligand exchange of surface –OH with Cr(acac)₃, releasing H-acac [6]. O₃ promotes combustion-like oxidation, inserting oxygen into the Cr–O lattice and removing ligands [2], whereas O₂ plasma supplies O*, O₂⁺, and OH radicals that efficiently eliminate ligands at lower temperatures, yielding denser films with reduced hydroxyl and carbon [3]. While such differences are well documented for NiO and Al₂O₃ [3, 5], they remain unexplored for Cr₂O₃. Oxygen vacancies, donor-like defects that degrade mobility—are central to this gap. We thus compare O₃ - and PE-based ALD of Cr₂O₃, linking oxidant chemistry to stoichiometry, defect density, and electronic properties. For PE-ALD, Cr(acac)₃ was pulsed onto heated substrates under Ar, followed by plasma and purge. Growth-per-cycle (GPC) was <0.1 Å/cycle, limited by precursor volatility and etching, with XRD confirming amorphous films [6]. Ongoing optimization seeks to mitigate plasma induced etching while improving GPC. This work establishes scalable ALD of Cr₂O₃ for TFTs; devices fabricated with both oxidants will clarify growth–etching mechanisms and evaluate Cr₂O₃ as a p-type channel for logic and spintronics.



- [1] M. Salari Mehr, L. Aarik, T. Jõgiaas, A. Kasikov, E. Damerchi, H. Mändar, *Nanomaterials*, **13**, 19 (2023).
- [2] T. S. Tripathi, J. P. Niemelä, M. Karppinen, *J Mater Chem C Mater*, **3**, 32 (2015).
- [3] M. A. Hidrogo-Rico, N. Nedev, P. Horley, I. Mendivil, J. Castillo-Saenz, E. Martínez-Guerra, E. J. Juarez-Perez, F. Servando Aguirre-Tostado, A. Susarrey-Arce, E. Martínez-Guerra, *ACS Omega*, **10**, 438 (2024).
- [4] C. R. Allemang, T. H. Cho, O. Trejo, S. Ravan, R. E. Rodríguez, N. P. Dasgupta, R. L. Peterson, *Adv Electron Mater*, **6**, 7 (2020).
- [5] V. R. Rai, V. Vandalon, S. Agarwal, *Langmuir*, **26**, 17 (2010).
- [6] B. Mandol, N. Mahuli, K. Ohno, L. Scudder, S. K. Sarkar, *Journal of Vacuum Science & Technology A*, **39**, 3 (2021).

Supplementary Information:

Ozone-based ALD of Cr_2O_3 is currently under optimization. Using $\text{Cr}(\text{acac})_3$ at the same precursor delivery conditions as plasma ALD, growth requires higher substrate temperatures to proceed. Ongoing work is mapping the saturation behavior across different precursor pulse times and identifying the optimal temperature window for obtaining stoichiometric, crystalline Cr_2O_3 films.

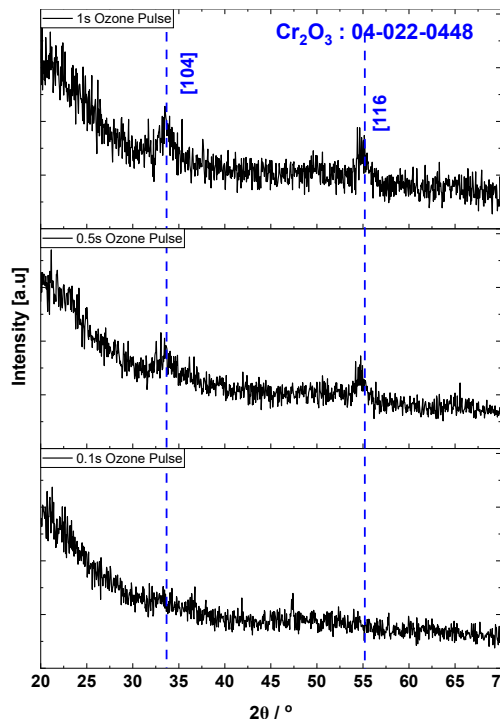


Figure 3: GIXRD spectra of Ozone-ALD chromium (III) oxide indicates crystalline films.

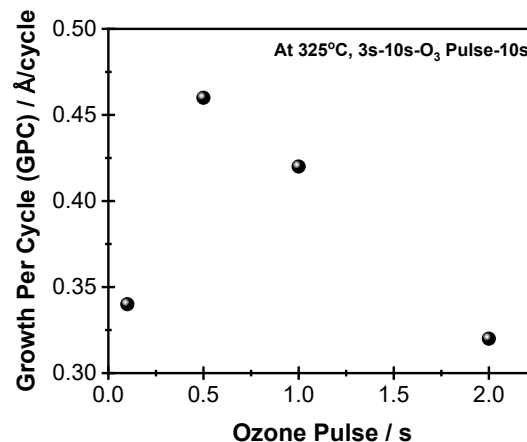


Figure 4: Ozone-ALD chromium (III) oxide deposition at 325°C, but with varied O_3 pulse.