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Importance of Trimethylaluminum Diffusion in Three-Step ABC Molecular Layer Deposition Using Trimethylaluminum, Ethanolamine, and Maleic Anhydride

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Abstract: Hybrid organic-inorganic films were grown by molecular layer deposition (MLD) with a three-step ABC reaction sequence using (A) **trimethylaluminum** (TMA), (B) ethanolamine (EA), and (C) maleic anhydride (MA) at 90 oC. Very large steady state mass gains of 1854-4220 ng/(cm2 cycle) were measured depending on reaction conditions. These mass gains are much larger than typical mass gains for surface reactions. The quartz crystal microbalance (QCM) mass profiles during the TMA reaction were consistent with TMA diffusion into and out of the ABC films. The ABC mass gains per cycle also displayed a strong dependence on the TMA dose and purge times that was consistent with the effects of TMA diffusion. Multiple dose experiments conducted at 130 oC revealed that the ABC reactions were self-limiting for thin ABC films. For thicker ABC films, increased TMA diffusion into the ABC film led to non-self-limiting behavior. Numerical modeling assuming Fickian diffusion for TMA diffusing into and out of the ABC film could fit the QCM mass profiles. The results all indicate that TMA diffusion into the ABC MLD film plays a key role in the thin film growth. In addition, X-ray reflectivity (XRR) measurements revealed that the ABC films were exceptionally smooth.

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