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A Liquid-Phase Quartz Crystal Microbalance for Photovoltaics Research

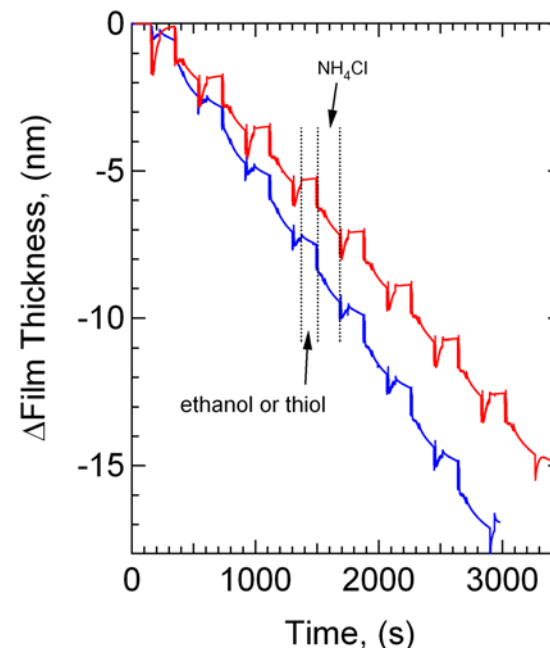
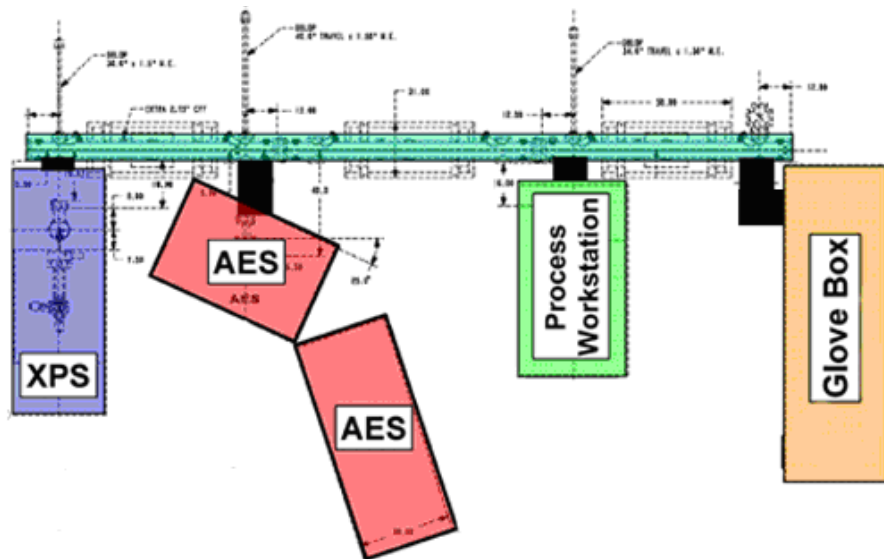
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NREL/PR-520-43324

Presented at the 33rd IEEE Photovoltaic Specialist Conference held May 11-16, 2008 in San Diego, California

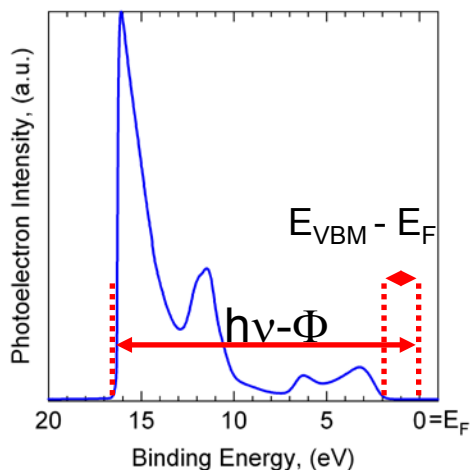


STF 140 cluster tool: PES/AES/MS/LQCM

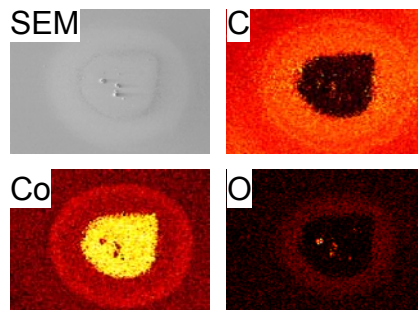


controlled ambient transfer, QCM, chemical growth, etching, & modification

Photoemission



AES mapping & spectroscopy



M. Law et al. "The Structural, Optical and Electrical Properties of PbSe Nanocrystal Solids Treated Thermally and with Simple Amines", *J. Am. Chem. Soc.*, (2008) ASAP article.

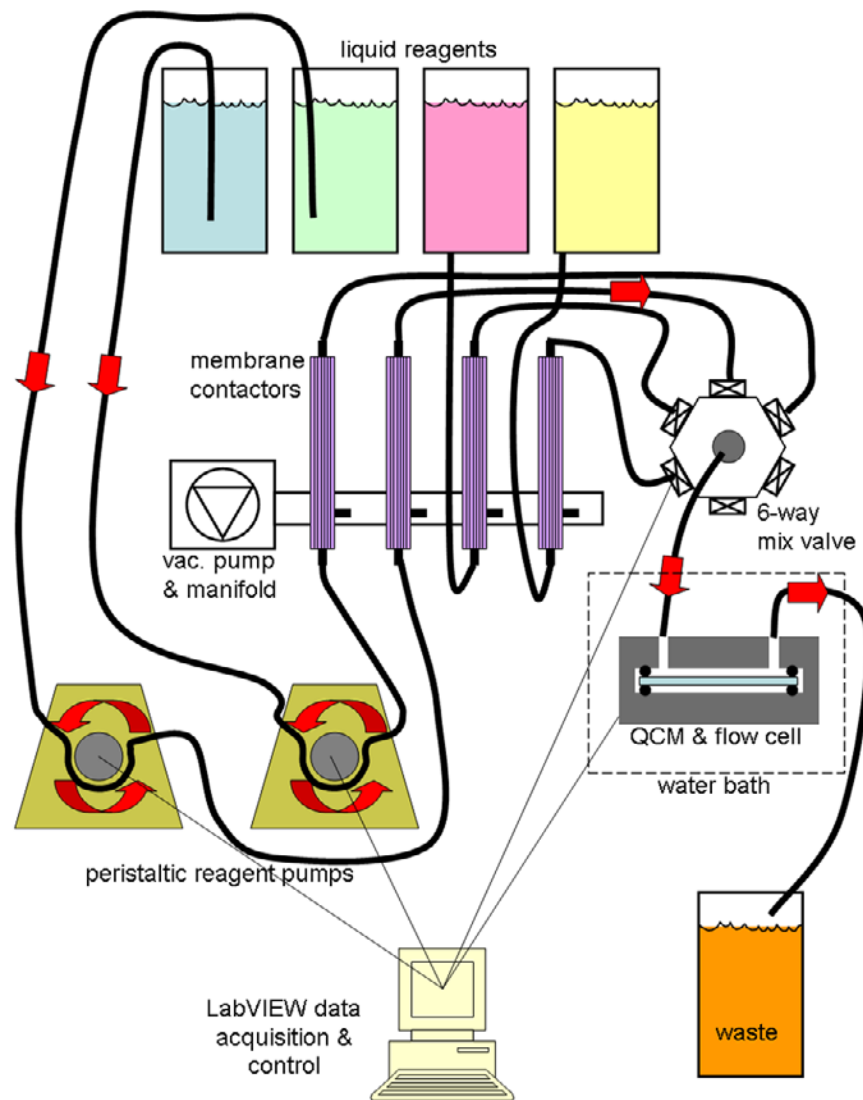
J.M. Luther et al., "The Structural, Optical, and Electrical Properties of Self-Assembled Films of PbSe Nanocrystals Treated with 1,2-ethanedithiol", *ACS Nano*, **2** (2008) 271-280.

G. Teeter, "X-ray and ultraviolet photoelectron spectroscopy measurements of Cu-doped CdTe(111)-B: Observation of temperature-reversible Cu_xTe precipitation and effect on ionization potential", *J. Appl. Phys.*, **102** (2007) 034504.



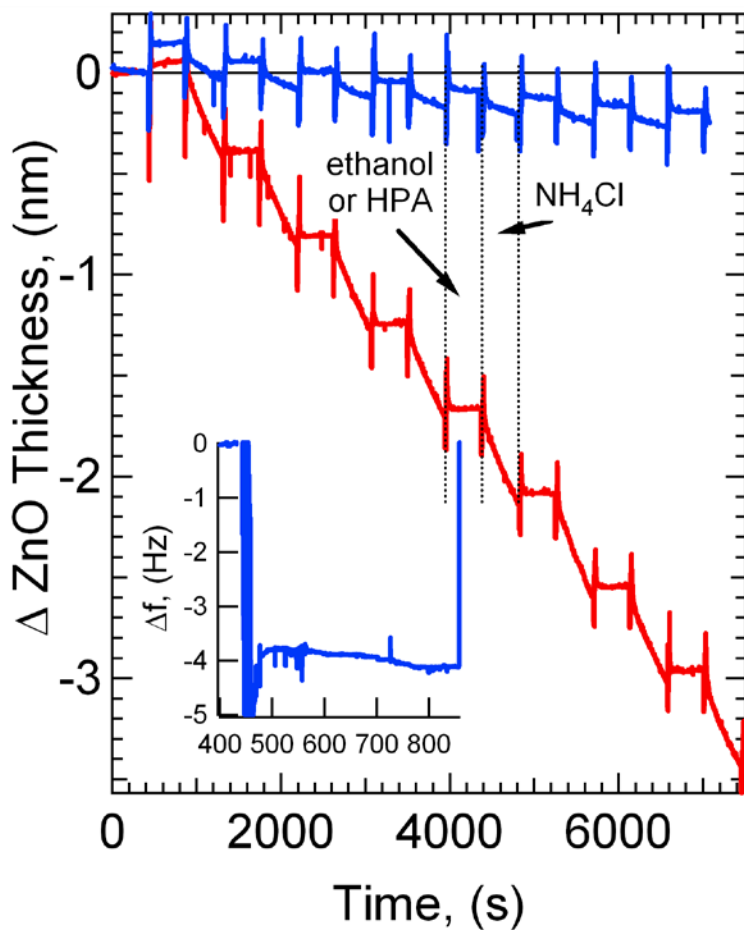
QCM-Based Flow Reactor Schematic

$$\Delta f = -f^{3/2} \sqrt{\frac{\eta_L \cdot \rho_L}{\pi \cdot \mu_q \cdot \rho_q}}$$

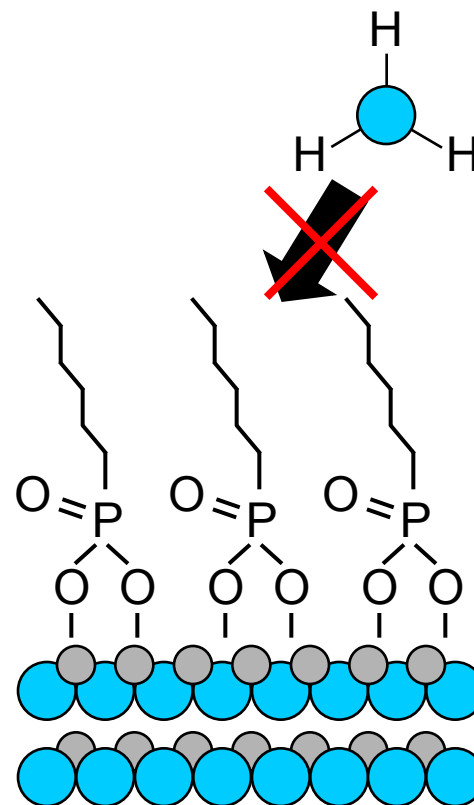




NH₄Cl: Using an Etchant as a Probe of ZnO-molecule Interactions



— rinse - HPA - rinse - NH₄Cl...
— rinse - ethanol - rinse - NH₄Cl...

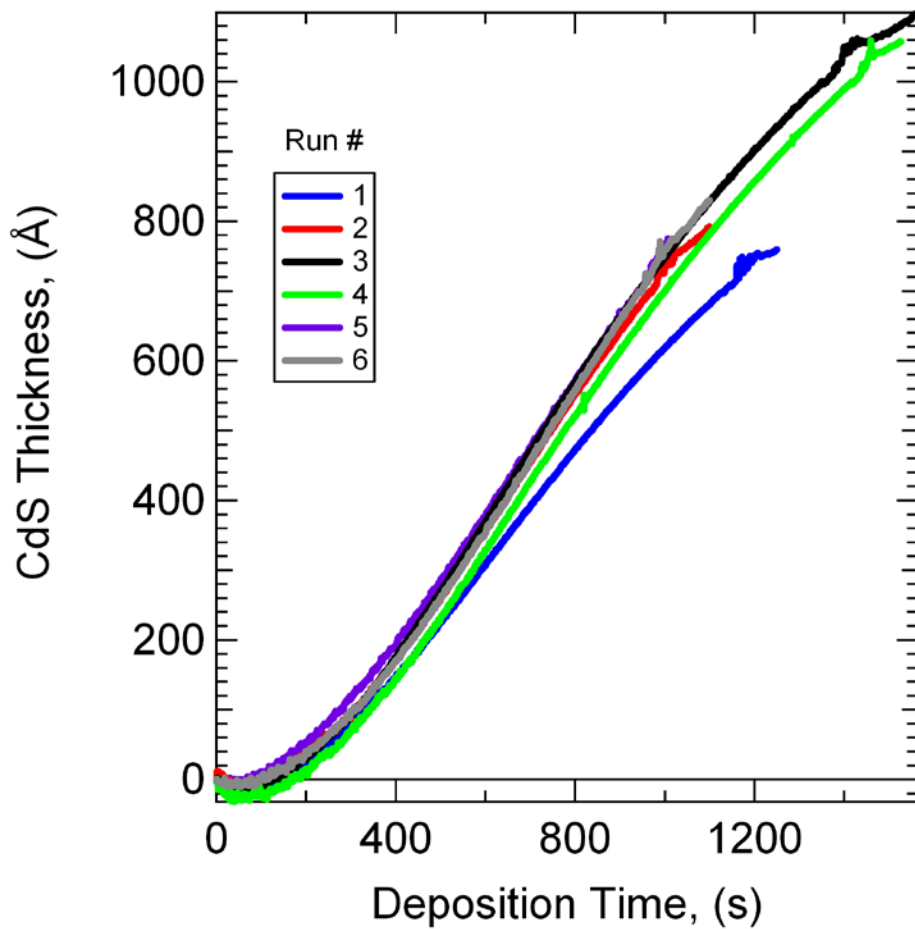


4 Hz \rightarrow 2.6×10^{14} mol \cdot cm⁻²,
or 0.24 monolayer.

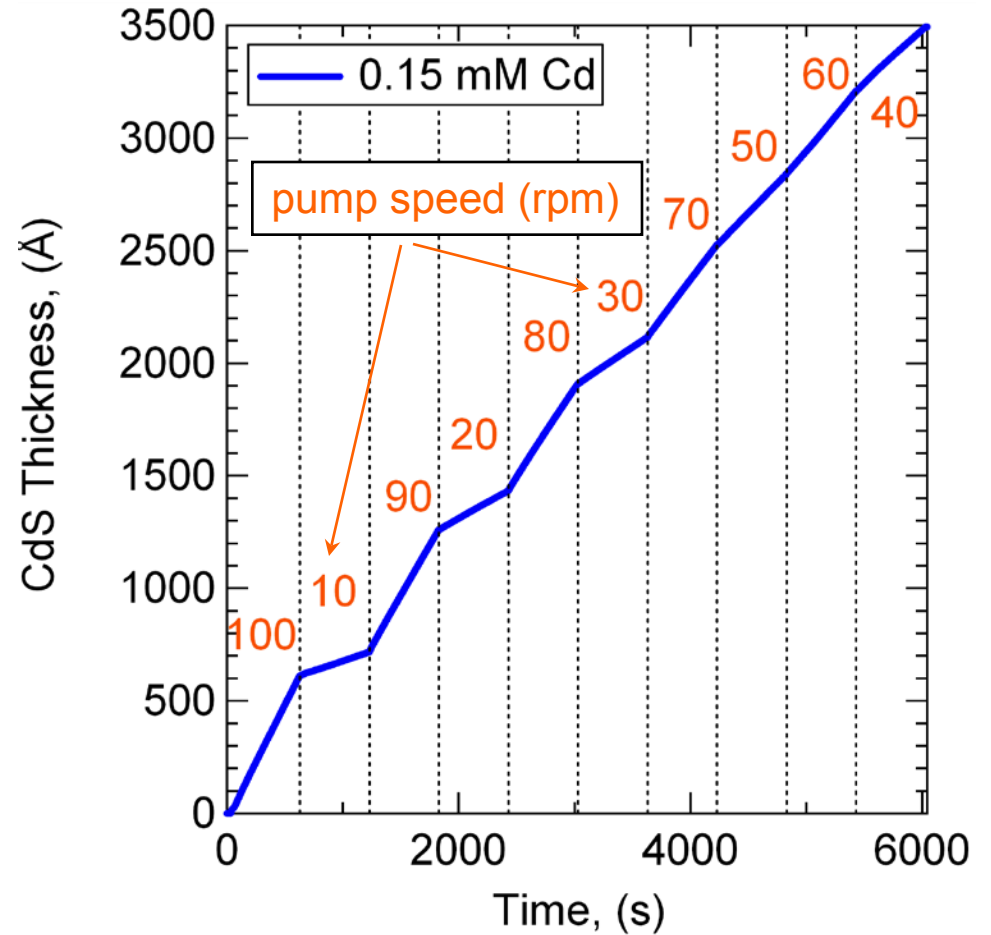


QCM Thickness Data for CdS Chemical Depositions

Typical Bath Process

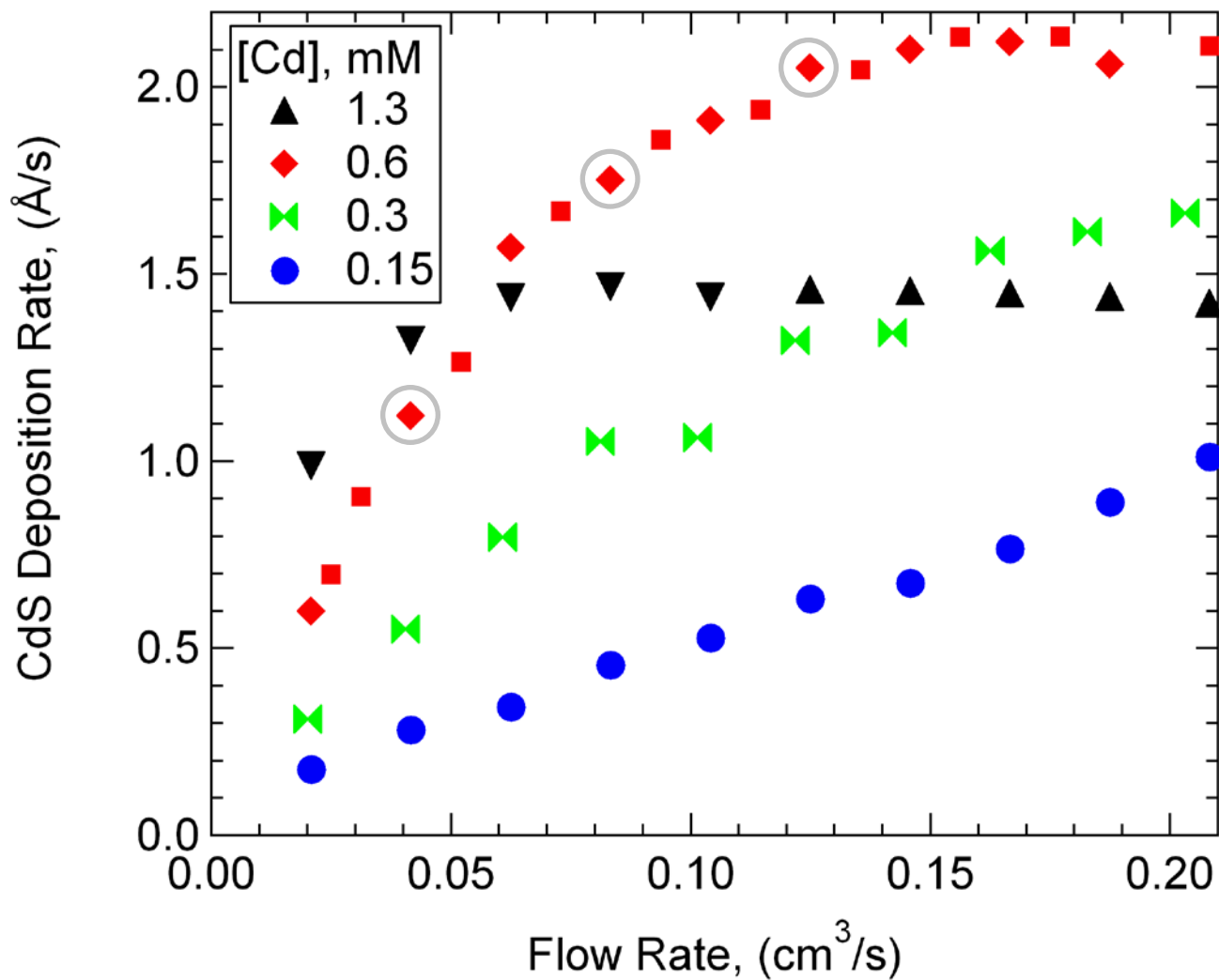


Flow-Growth





Deposition Rates as f(flow, [reactants])



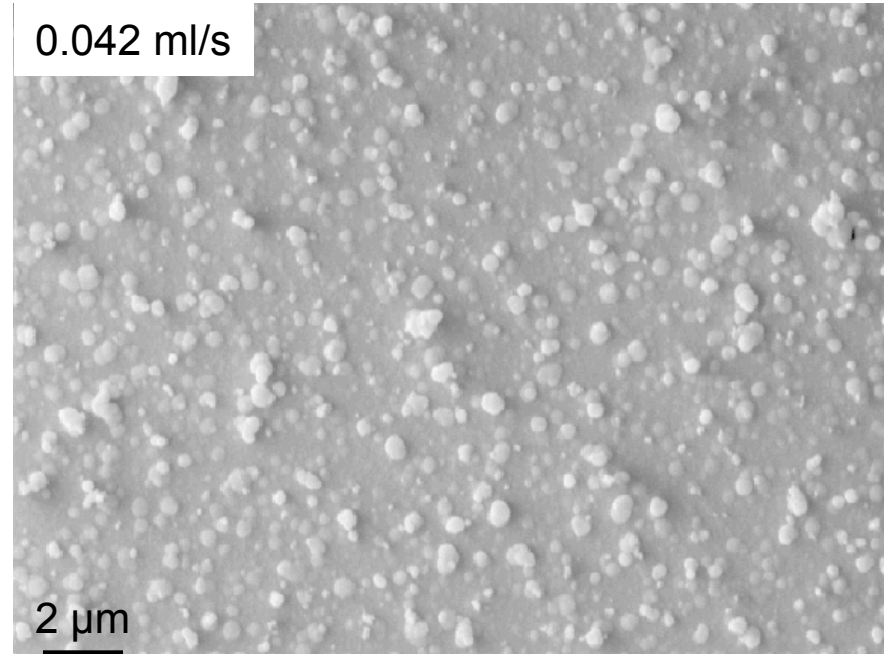


Flow-Rate Dependent Morphology of Chemically Grown CdS Films

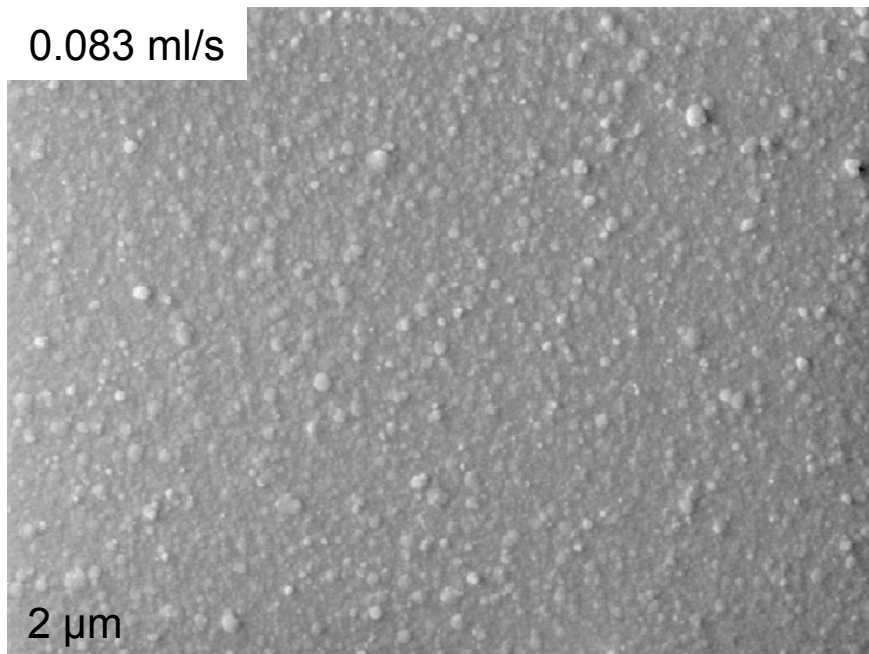
Film thickness = $0.4 \mu\text{m}$

$T_{\text{growth}} = 63 \text{ }^\circ\text{C}$

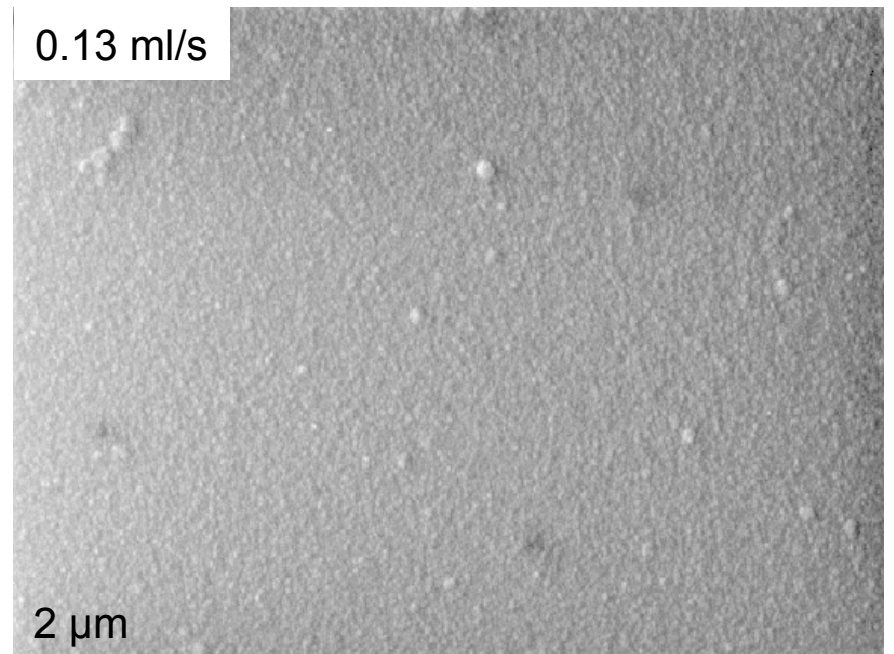
0.042 ml/s



0.083 ml/s



0.13 ml/s





Summary

- Construction of a new QCM-based flow reactor has been completed
- Initial results include:
 - Stable oscillation achieved with crystals sputter coated at 200 °C with 500 nm ZnO
 - Sub-Hz noise level means \ll monolayer sensitivity
 - Operation at elevated temperature possible after installation of membrane contactors
 - Determination of ZnO etch rates using dilute ethanolic NH_4Cl
 - Demonstration of use of an etchant as a probe of oxide-molecule interactions.
 - Use in flow rate-dependent CdS chemical deposition

Acknowledgments:

Xiaonan Li, Sally Asher, Glenn Teeter, Pete Sheldon

This work was supported by the U.S. Department of Energy under Contract No. DE-AC36-99GO10337 with the National Renewable Energy Laboratory.



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