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Validating Surface Energy Measured by Three Liquid Contact Angle Analysis with Computed Gibbs Energy for $LiNbO_3$/α-Quartz SiO_2 for Direct Wafer Bonding ABBIE ELISON, MOHAMMED SAHAL, SHEFALI PRAKASH, SRIVATSAN SWAMINATHAN, RILEY RANE, BRIAN BAKER, JACOB KINTZ, ALIYA YANO, SAAKETH NARAYAN, ALEX BRIMHALL, LAUREN PUGLISI, DR. ROBERT CULBERTSON, DR. NICOLE HERBOTS, Arizona State University, Dept. of Physics, PROF HERBOTS' NANO-BONDING RESEARCH TEAM — $LiNbO_3$ is a ferro-electric with the most significant electro-optical, piezo-electric properties, and a near perfect linear response. Hence, $LiNbO_3$ is an ideal material to integrate piezoelectrics monolithically to Si. But lattice and thermal expansion mismatches between $LiNbO_3$ and Si/SiO_2 are incompatible with hetero-epitaxy and Direct Wafer Bonding (DWB). This work investigates DWB at RT via Nano-Bonding$^{TM,\,1}$ (NB). NB nucleates bonding inter-phases via complementary 2D- Precursor Phases (2D- PP) instead of thermal activation. 2D-PP relies on Surface Energy Engineering (SEE), which characterizes and then modifies hydro-affinity and surface energy into far-from-equilibrium states. SEE finds that ΔGs for interaction between $LiNbO_3$ and Si/SiO_2 are both positive and do not favor NB. Hence, SEE on $LiNbO_3$ and Si/SiO_2 needs to change ΔG to negative at RT. Experimental results show that SEE of ?-quartz SiO_2 and $LiNbO_3$ yield NB at RT. [1] Herbots et al. US Pat. 6613677 (2003), 7,851,365 (2010), 9,018,077 (2015), 9,589,801 (2017), and pending (2020)

Abbie Elison
Arizona State University, Dept. of Physics

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