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Watching Silica's Dance: Imaging the Structure and Dynamics of the Atomic (Re-) Arrangements in 2D Glass[1]

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Even though glasses are almost ubiquitous—in our windows, on our iPhones, even on our faces—they are also mysterious. Because glasses are notoriously difficult to study, basic questions like: "How are the atoms arranged? Where and how do glasses break?" are still under contention. We use aberration corrected transmission electron microscopy (TEM) to image the atoms in a new two-dimensional phase of silica glass – freestanding it becomes the world's thinnest pane of glass at only 3-atoms thick, and take a unique look into these questions. Using atom-by-atom imaging and spectroscopy, we are able to reconstruct the full structure and bonding of this 2D glass and identify it as a bi-tetrahedral layer of SiO_2 [1]. Our images also strikingly resemble Zachariasen's original cartoon models of glasses, drawn in 1932. As such, our work realizes an 80-year-old vision for easily understandable glassy systems and introduces promising methods to test theoretical predictions against experimental data. We image atoms in the disordered solid [1] and track their motions in response to local strain [2]. We directly obtain ring statistics and pair distribution functions that span short-, medium-, and long-range order, and test these against long-standing theoretical predictions of glass structure and dynamics. We use the electron beam to excite atomic rearrangements, producing surprisingly rich and beautiful videos of how a glass bends and breaks, as well as the exchange of atoms at a solid/liquid interface. Detailed analyses of these videos reveal a complex dance of elastic and plastic deformations, phase transitions, and their interplay. These examples illustrate the wide-ranging and fundamental materials physics that can now be studied at atomic-resolution via transmission electron microscopy of two-dimensional glasses. Work in collaboration with: S. Kurasch, U. Kaiser, R. Hovden, Q. Mao, J. Kotakoski, J. S. Alden, A. Shekhawat, A. A. Alemi, J. P. Sethna, P. L. McEuen, A.V. Krasheninnikov, A. Srivastava, V. Skakalova, J. C. Meyer, and J.H. Smet.

[1] P. Y. Huang, et al., *Nano Lett.*, **12** 1081–1086 (2012).
[2] P. Y. Huang et. al, *Science* **342**, 224-227 (2013)

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