Polymer Matrices for Printing Composites with Acoustic Focusing

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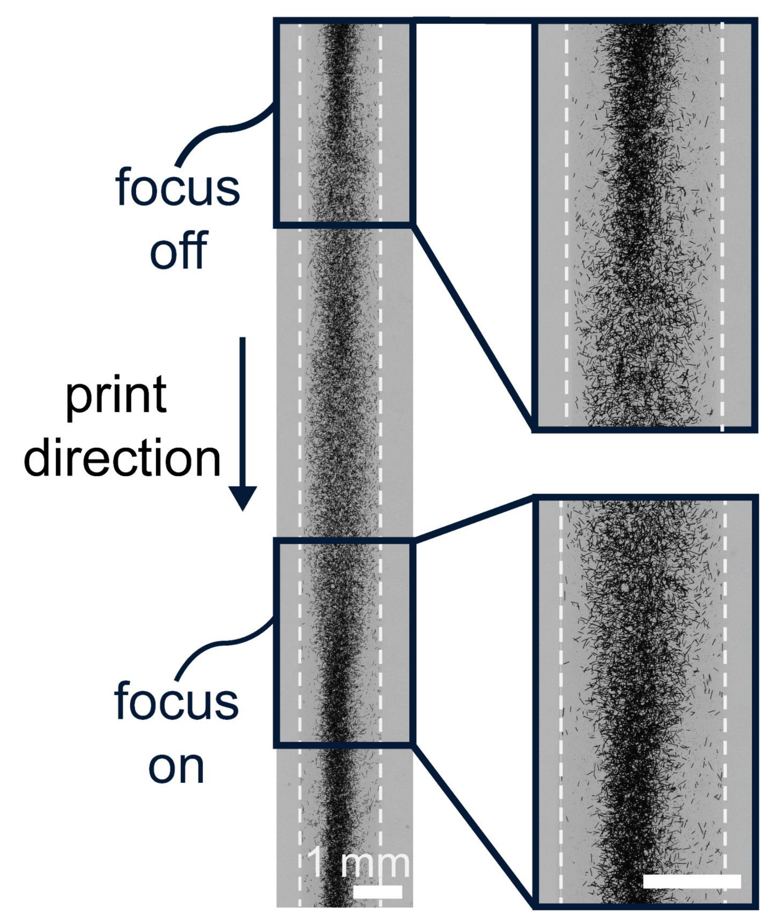
Can we vary material properties mid-print?

Varying strength, stiffness, conductivity, and other properties along the print path can expand the complexity of 3D printed parts.

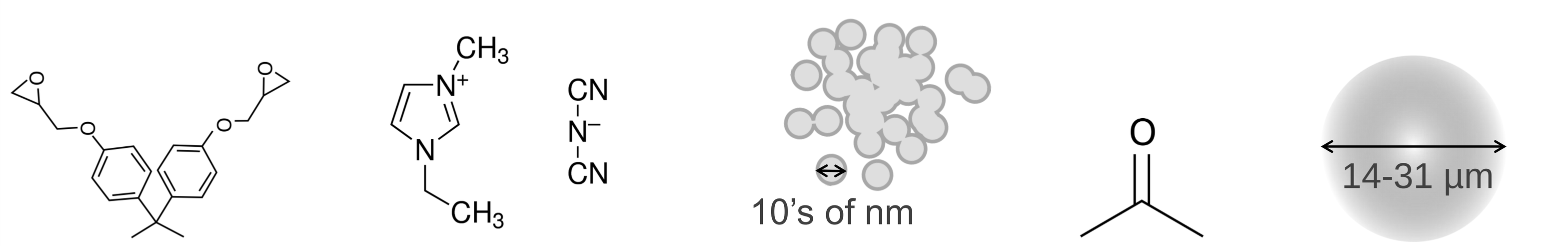
We can print two-phase materials with properties that vary along the print line using **direct ink writing** with **acoustic focusing**.

Direct ink writing (DIW): Layer-by-layer printing of fluid inks which are solidified after deposition

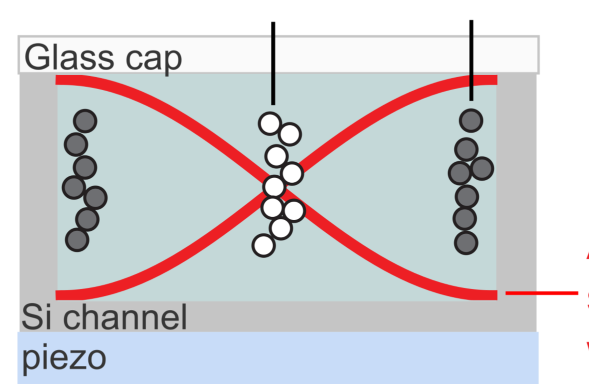
Acoustic focusing: Controlling the movement of particles in microfluidic channels using acoustic waves



1. Mix 2-phase inks



2. Flow inks through the nozzle and establish a standing wave using a piezoelectric actuator, pushing the spheres to the center of the print line.



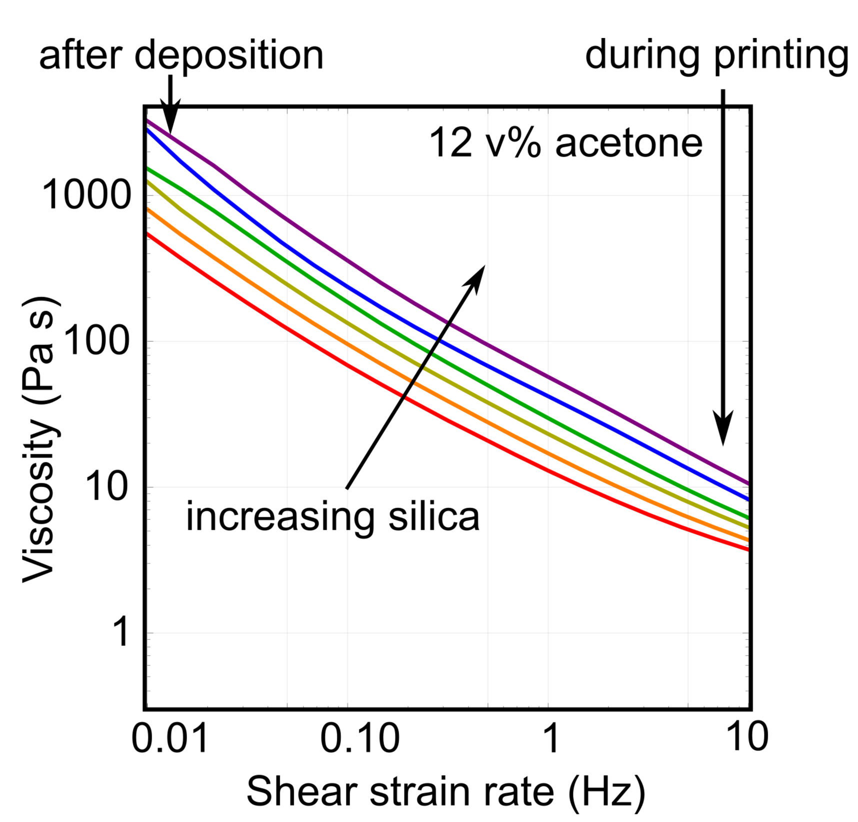
What are the trade-offs?

Holding form with direct ink writing requires **viscous** inks.

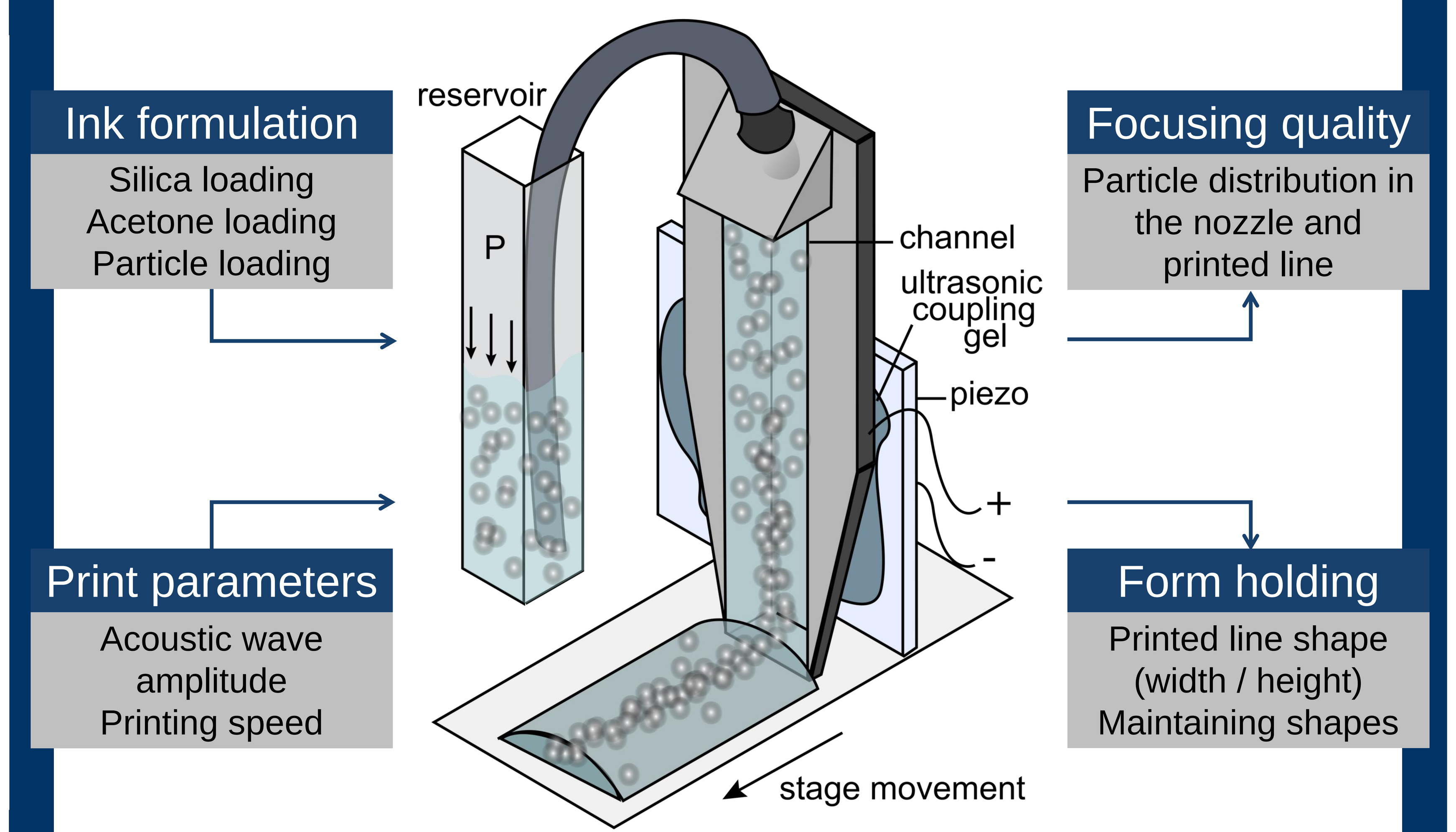
Moving particles with acoustic focusing requires **inviscid** inks.

We can compromise using **shear thinning** inks (viscosity changes with shear strain rate).

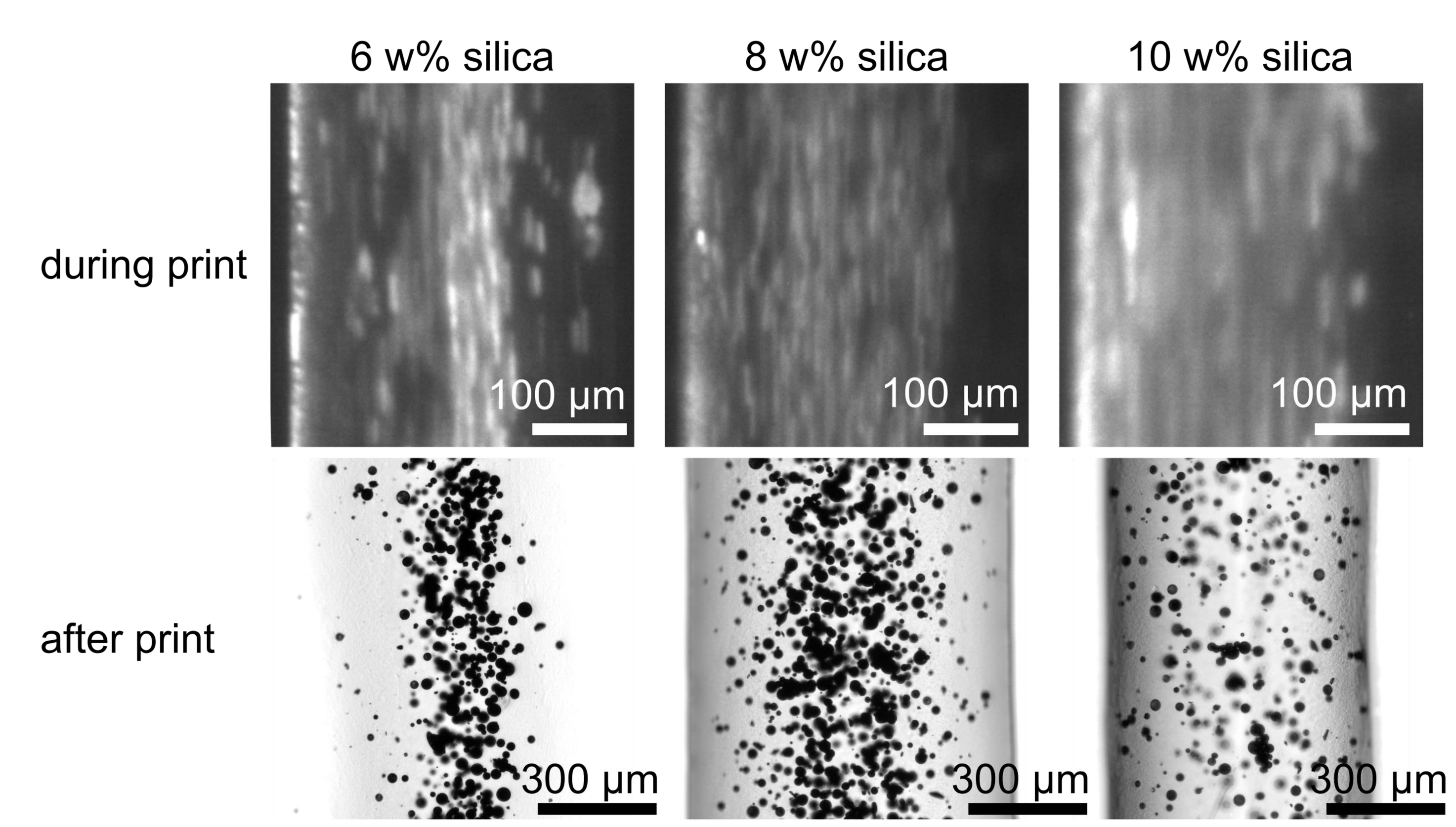
Silica and acetone induce shear thinning. Silica increases the ink viscosity, and acetone lowers the viscosity during printing.

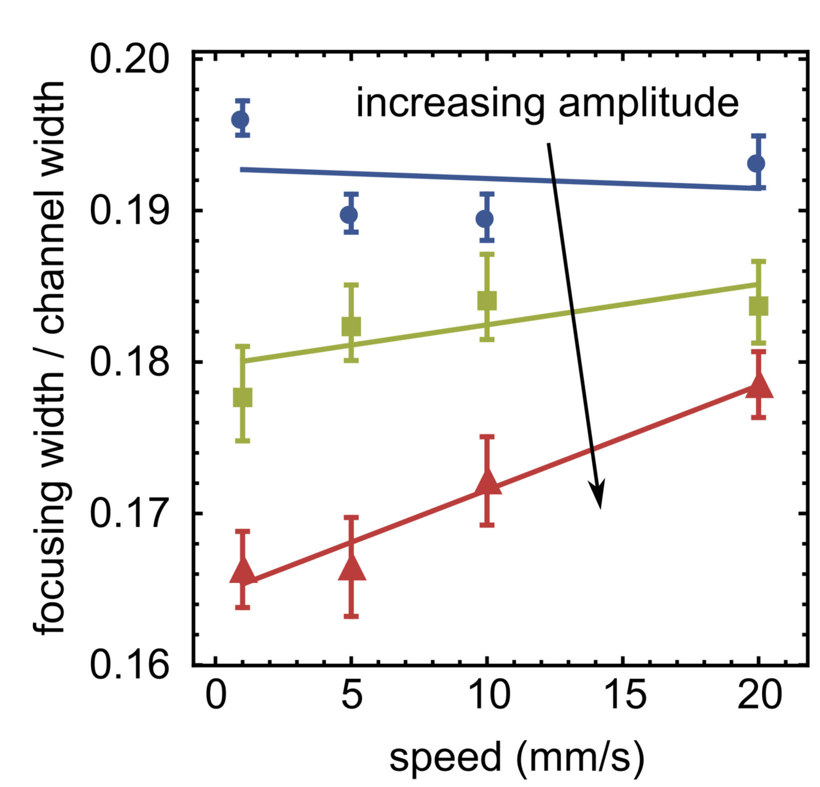


A systematic study of acoustic focusing DIW



How can we optimize focusing quality?





Particle distributions widen with additional silica but are largely unaffected by acetone loading.

Decreasing the print speed and increasing the acoustic wave amplitude improve focusing.

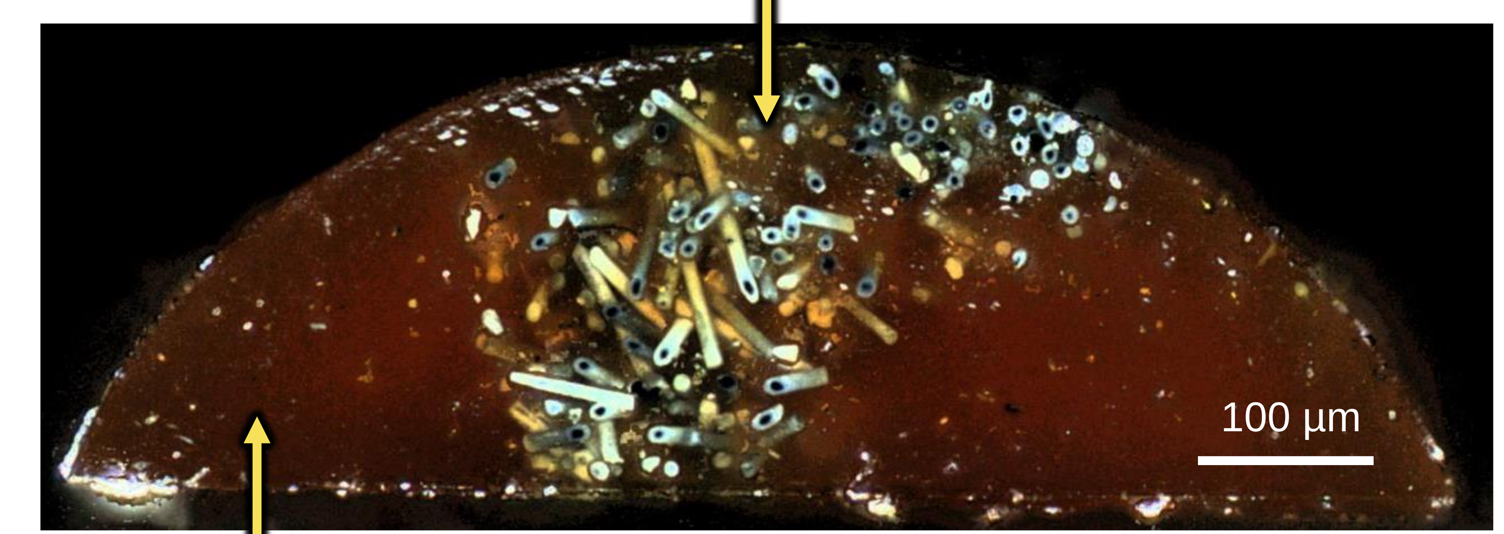
Higher particle loadings do not focus as tightly.

How can we optimize form holding?

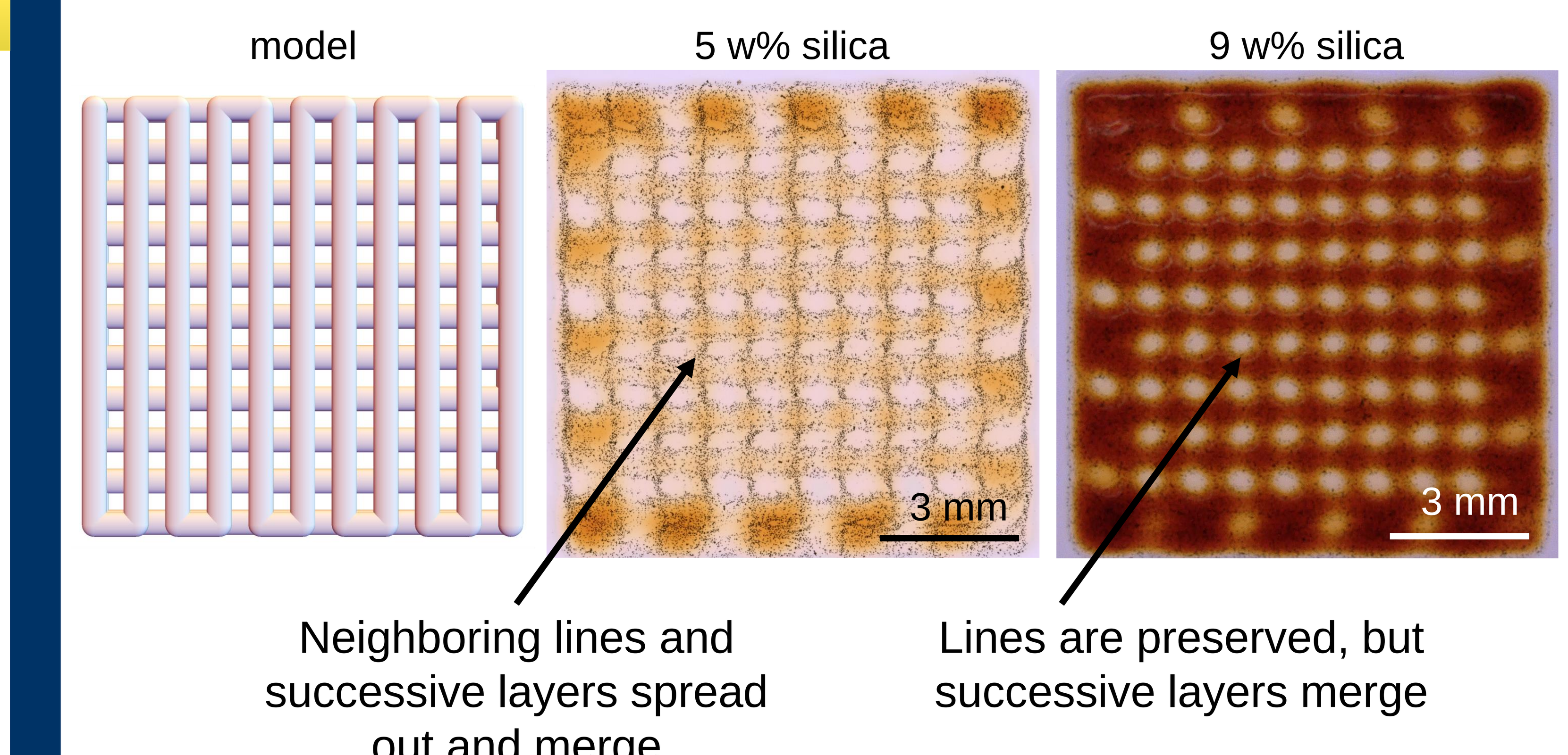
Lines spread out more when inviscid matrices (less silica, more acetone) are used, but post-deposition particle movement is unaffected by matrix selection.

No matrices that enable focusing can produce spanning structures. Support material is necessary for many applications.

Particles stay focused in the line center



Inviscid matrices spread out on line edges



Which matrix should we use?

For single-layer structures with very good focusing, use low filler, low diluent, slow print speeds, and large acoustic wave amplitudes.

For multi-layer structures with moderate focusing, use high filler, low diluent, slow print speeds, large acoustic wave amplitudes, and long focusing zones.

R. R. Collino, T. R. Ray, R. C. Fleming, J. D. Cornell, B. G. Compton, M. R. Begley, *Extreme Mechanics Letters* **2016**, DOI 10.1016/j.eml.2016.04.003.

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