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## Improved Method for 3D Nano/Microfabrication of Shell-Stabilized Liquid Metal Pipe Networks

Stretchable conductors have a variety of applications in flexible electronics, soft robotics, and biomedical devices. Room-temperature liquid metals can be used to create circuits that are intrinsically soft and remain functional even when stretched to several times their initial length. Traditional methods of manufacturing liquid metal structures are labor intensive, non-scalable, and dimensionally limited. Furthermore, rapid surface oxidation causes these metals to adhere to a variety of materials, making it more difficult to shape the metal into a specific form. By using the oxidation layer as a functional shell, new 3D printing techniques have been able to freely shape the metal. However, when the extrusion rate exceeds 200  $\mu\text{m/s}$  the forming liquid metal structure breaks from the printing nozzle, limiting the printing speed to a rate that is too slow for commercial fabrication (around 2-3 cm/s).

Researchers at ASU have developed a method for rapid 3D nano/microfabrication of multifunctional shell-stabilized liquid metal pipe networks using a coaxial nozzle that jointly disperses reactive gases or fluids with liquid metals for modifying their surfaces. These reactive gases or fluids can be used to increase the rate of the oxide shell formation, tailor various properties of the oxide shell, and adjust the liquid metal flow down to the nanoscale level. The liquid metal and secondary fluid can also be interchanged to make annular liquid metal pipes with an internal and external shell, and/or a third fluid can be added to create a multi-layered shell around the liquid metal. This method induces rapid formation of a mechanically robust stabilizing shell, permitting liquid metal extrusion rates suitable for 3D commercial printing.

### Potential Applications

- 3D Printed Liquid Metal Pipe Networks
- Biointegrated Devices
- Elastomer Sensors
- Microfluidics
- Stretchable Electronics
  - Liquid Metal Capacitors
  - Liquid Metal Electromechanical Switches

### Benefits and Advantages

- Innovative – Coaxial nozzle yields a much higher liquid metal extrusion rate that enables commercial 3D printing.
- Precise – Can print liquid metal pipes at the nanoscale level.
- Versatile – Reactive outer fluids can be tailored for specific functionality of the oxide shells with different mechanical, chemical, electrical, and thermal

## Inventors

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For more information about the inventor(s) and their research, please see

[Dr. Konrad Rykaczewski's directory webpage](#)

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