Investigation of Palladium Strains and Actuation in Gaseous Environments

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Primary CNF Tools Used: Heidelberg Mask Writer - DWL2000, ABM Contact Aligner, Oxford 81/82/100 Etchers, AJA Sputter Deposition Tool, AJA Ion Mill, Oxford PECVD, SC4500 Odd-Hour Evaporator, PT770 Etcher (Left Side), OEM Endeavor Aluminum Nitride Sputtering System, Leica CPD300 Critical Point Dryer, DISCO Dicing Saw

Abstract:

We are developing a palladium-based microactuator that is driven by hydrogen as a fuel. After an initial delay upon exposure to hydrogen, these actuators exhibit high strains within a short time period. In this report, we show the fabrication process of these devices, present the characterization of simple hinge structures, and discuss initial results.

Summary of Research:

We are interested in understanding palladium as a material that can be used to drive the actuation of microscopic hinges for use in micro robotics. Palladium is a metal known for its high hydrogen affinity, and the palladium hydride system is well-studied [1]. For this project, we are utilizing palladium's high affinity to hydrogen to obtain actuation on the microscale. By inducing an asymmetric strain across the thickness of a bimorph made with palladium and an inert material (currently using titanium), we have observed curling and bending in these devices.

To fabricate these devices, a sacrificial layer of aluminum nitride is initially sputtered onto a fused silica wafer with the OEM Endeavor tool and patterned. Then a layer of titanium sputtered, and a layer of palladium is evaporated onto the sample to create a Ti-Pd bimorph of various thicknesses. This bimorph is patterned and etched with the Ion Mill. To selectively control where the bimorph bends, silicon dioxide panels that are around 500nm thick are deposited with plasma enhanced chemical vapor deposition on the Oxford PECVD and etched with a mixture of trifluoromethane and oxygen plasma on the Oxford 100. We then soak the chips in 726 MIF developer to release the devices and use the Leica critical point dryer to dry the chips.

After the devices are made, we bring them into the lab to test inside a gas chamber.

Conclusions and Future Steps:

Figure 1 shows some example devices that we are currently testing. After an initial delay upon exposure to hydrogen, these devices respond rapidly and show high strain (Figure 2). We also observed that this process is reversible (Figure 3).

To understand palladium's interaction with hydrogen in our microactuators, we are planning various experiments in which critical dimensions of the palladium microactuators will be varied. We will also perform imaging of the deposited palladium before, during and after exposure to gaseous environments.

References:

[1] Dekura, S., Kobayashi, H., Kusada, K., and Kitagawa, H. (2019). Hydrogen in Palladium and Storage Properties of Related Nanomaterials: Size, Shape, Alloying, and Metal-Organic Framework Coating Effects. ChemPhysChem, 20(10), 1158-1176.

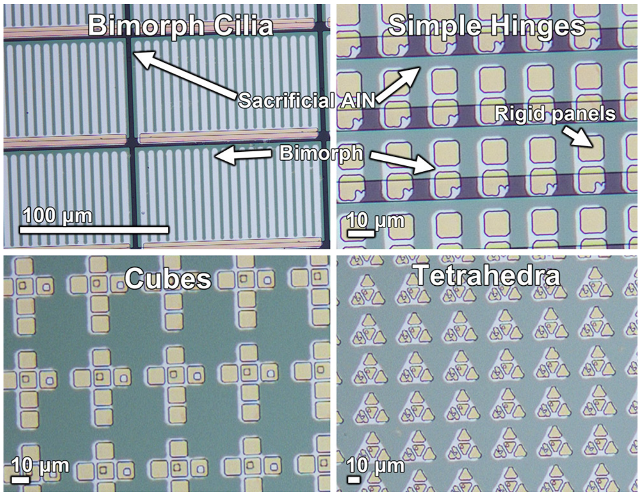

Figure 1: Example collection of devices pre-release.

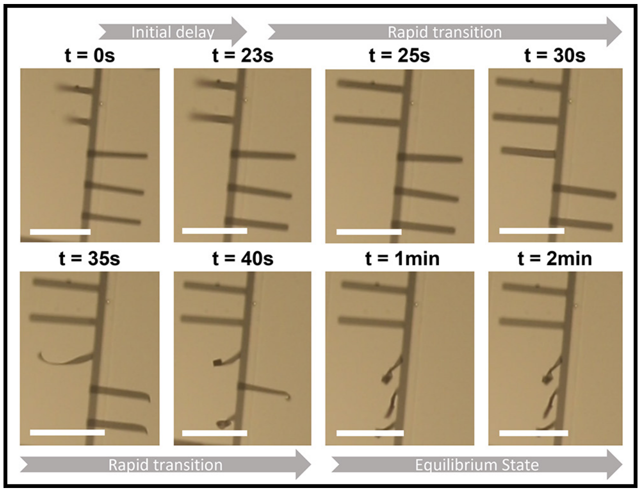

Figure 2: Time-lapse photos showing palladium's response to hydrogen using simple cilia-like microactuator devices. The microactuators consist of 3.5 nm of sputtered titanium and 7.6 nm of evaporated palladium, both deposited as a bilayer. Scale bars are 50 µm.

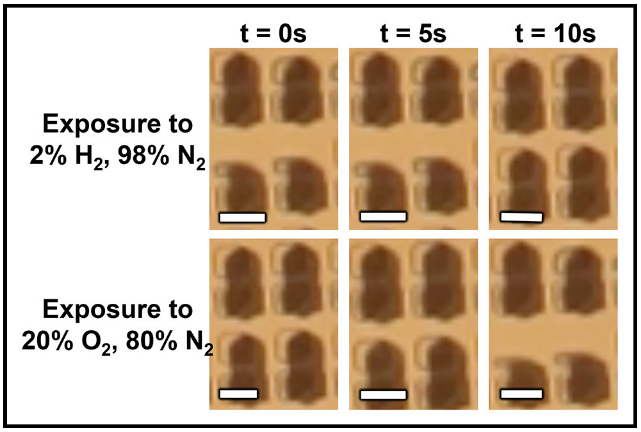

Figure 3: Time-lapse photos showing bilayer hinges exposed to a hydrogen environment and then air. Scale bars are 10 µm. The bilayer hinge consists of 10 nm of sputtered titanium and 20 nm of evaporated palladium. The panels are fabricated from 420 nm of SiO_2. A 20 nm layer of titanium is used to adhere the palladium and SiO_2 layers.