Fabrication of a Nanofluidic Fabry-Perot Cavity

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Primary CNF Tools Used: Mask Aligner, Substrate Bonder

Abstract:

Nanofluidic Fabry-Pérot cavities allow well understood experimental techniques from condensed matter physics to be applied to photoactive proteins under biological conditions [1]. Previous attempts to probe photoactive proteins with these techniques required the encapsulation of the system into a polymer [2] or the creation of a dehydrated thin film [3], significantly altering the proteins from their natural form. Recently, a method for measuring the reorganization energy via strong coupling to a Fabry-Pérot cavity has been proposed [4]. Due to the wavelengths involved in photo excitation, the height of these cavities must be on the order of 100 nm. These cavities can only be loaded nanofluidicly. Bahsoun and collaborators have recently fabricated a nanofluidic Fabry-Pérot cavity suitable for this experiment [1]. Our fabrication strategy borrows heavily from their approach. We are using the resources provided by the Cornell NanoScale Science and Technology Facility (CNF) to fabricate a nanofluidic Fabry-Perot Cavity.

Summary of Research:

Our lab is engaged in the design and engineering of new photosynthetic proteins [4]. Electron transfer in biological systems is well described by Marcus Theory [5]. The reorganization energy (λ) is crucial to predicting the rate of electron transfer for a given process. The parameter is most easily measured by measuring the rate of transfer as a function of the driving force of the reaction. Within a Fabry-Perot cavity, the energy of the donor state, and by extension the free energy of electron transfer, can be controlled by the number of molecules in the cavity. This observation suggests measuring the transfer rate as a function of concentration is equivalent to measuring a Marcus curve, from which λ can be extracted. The electron transfer rate can be measured by fabricating two cavities with an equal number of coupled molecules. In one cavity, the electron acceptor is absent. The reduction in transmission intensity in the presence of an electron acceptor is due to electron transfer.

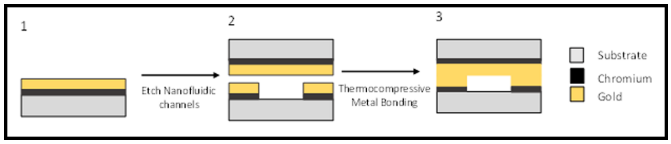

Figure 1: The nanofluidic cavity fabrication strategy. First metal is deposited on a substrate, then channels are etched into the metal via a lithographic process and two chips are bonded together by thermocompressive gold bonding.

An outline of our fabrication strategy is shown in Figure 1. A 100 mm glass wafer is coated with a 5 nm layer of chromium and between 250-500 nm of gold. A roughly 2 μm layer of AZ1512 photoresist is deposited via spin coating and baked at 110°C for 1 minute. The channels are patterned into the photoresist by exposing the resist to 150 mJ of UV light and baked for an additional minute. Development takes place by submerging the wafer in AZ 300 MIF developer for ~ 35 seconds. The exposed gold and chromium are etched away by submersion in Transene gold TFA etchant and chromium 1020 etchant for an amount of time dictated by the thickness of each metal layer. The remaining photoresist is stripped by soaking the wafer in acetone for two minutes with constant agitation. The wafers are then washed twice with methanol, isopropanol and deionized water before being blown dry with nitrogen. The wafer is then diced

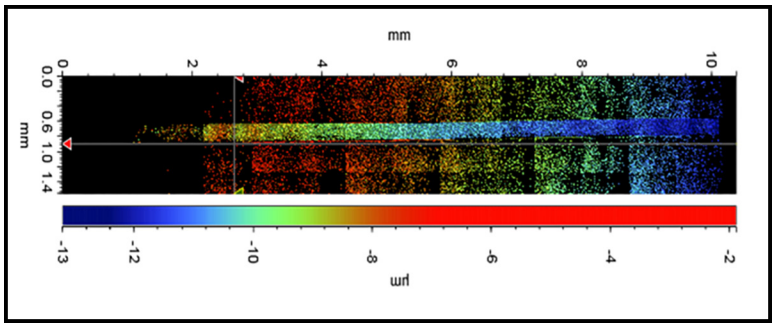

Figure 2: The depth of the cavity across the length of the channel, showing significant depth changes from one end of the channel to the other.

into 10 mm × 10 mm chips. Immediately before bonding, the washing step is repeated followed by a 2-minute 200-watt oxygen plasma ashing. One patterned chip and an unpatterned chip are aligned in a custom machined stainless-steel plate and another plate is hand screwed on top to apply pressure. The entire set-up is heated to 350°C for 30 minutes under a vacuum. Once the apparatus is cooled, the finished chip is removed.

So far, none of the finished chips have been wettable. This is due to the uneven application of pressure applied by the two steel plates. A depth profile of the resulting cavity can be seen in Figure 2. The cavity is of non-unform depth, a quality that is known for impeding nanofluidic flow.

Conclusion and Future Steps:

Currently, thermocompressive gold bonding is carried out using a custom, home built apparatus. We have been unable to produce a smooth enough surface to apply uniform pressure and thus create cavities of uniform depth. The thermocompressive gold bonding will no longer be performed using a hand screwed apparatus. Instead, a SUSS SB8e substrate bonder will be used to carry out the bonding. The tool allows for controlled, uniform application of pressure as well as temperature and pressure ramping. Once the bonding process is optimized, the cavities will be loaded with the photoactive substrate of interest and the reorganization energy will be measured.

References:

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