Blu-Ray-based micromechanical characterization platform for biopolymer degradation assessment

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Supplementary information:

1. **Astigmatic Detection:**

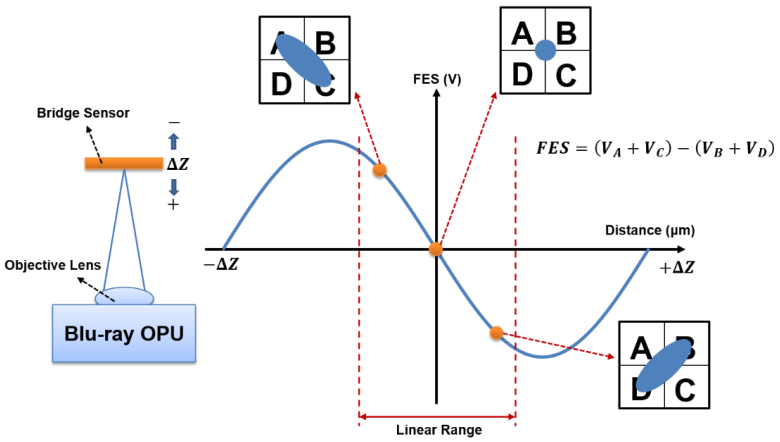


FIG S 1 Focus error signal for a Blu ray-OPU.

Figure S1 shows the signal calculation of the astigmatic detection method. The quadrant photodetector is defined as four independent sensing areas A, B, C and D. The converted output voltage can be defined as V_A, V_B, V_C and V_D. The signal focus error $S_{FE,}$ is defined as $(V_A+V_C)-(V_B+V_D)$. If the beam is perfectly focused in the center the output voltage is zero.

The output signal, also known as the S-curve, depends on the working distance Δz(fig 2) . In a certain range the behavior of the sensor is linear, and we will use such range to make our measurement.

2. Measurement Routine

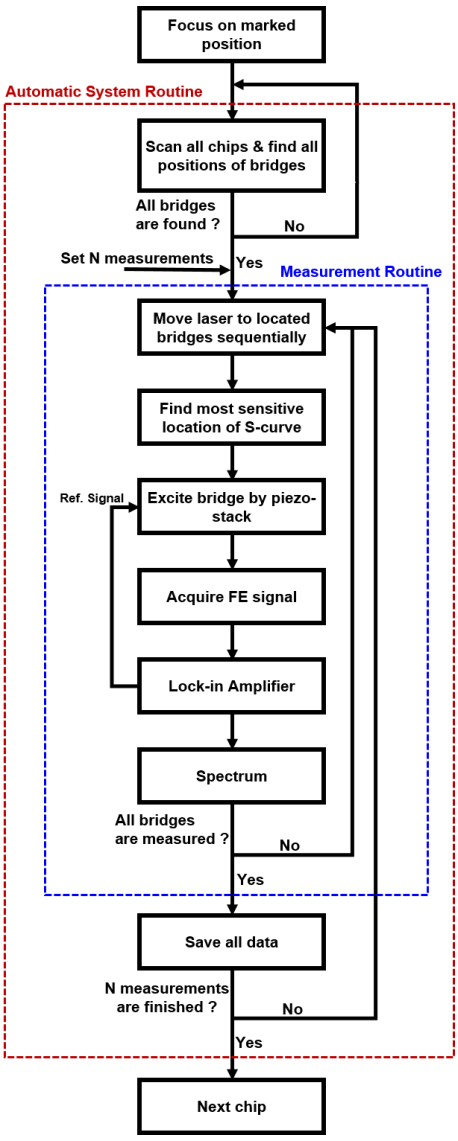


FIG S 2 Measurement routine for automatic positon detection actuation and readout:

As the first step the user has to focus on one bridge, making the distance between the bridges and the lens within a reasonable range such that by the motion of the VCM all the bridges are in the linear range. In the automatic system routine (reds) the sled motor is moving along the chip and the position of the bridges are found and saved. In the measurement routine(blue) the blu-ray pickup head moves on the position of the bridges, the VCM coil motor is actuated and the best position within the linear range in found. Then the piezo element is actuated and recorded. At the end of i^{th} measurment the spectra are recorded into one file.

3. Theoretical background

The resonance frequencies of the bridges have been recorded both in air and water environment. For multilayer structures the resonance frequency can be approximated as (Bose et al., 2015a; Keller et al., 2011)

$$f_n \approx \frac{1}{2\pi}\frac{\beta_n^2}{L^2}\sqrt{\sum_{i=1}^{N} I_i E_i \Big/ w\sum_{i=1}^{N}\rho_i t_i} \quad (1)$$

where β_n represents the mode number which for a doubly clamped beam is 4.73, 7.85, 10.99, for n =1,2,3, *L* is the length of the beam,I_i and E_i are the beam's moment of inertia and the Young's modulus respectively, $\rho_i t_i$ are the density and the thickness of the i^{th} layer. The degradation process is evaluated in terms of relative frequency shift of the coated microbridges. The mass responsivity can be written as:

$$R = {}^{\partial f}\,/_{\partial m} \approx {}^{f_n}/_{2m_0}\,[Hz/g] \quad (2)$$

f_n is the value of the resonance frequency and m_0 is the mass of the resonator.

In order to obtain the frequency values that are comparable to the degradation experiments, we can consider as a reference value, for the *i* th microbridge its resonance frequency at the end of the degradation when the polymer has been completely removed from the surface. The degradation on the i^{th} coated microbridge at the j^{th} time step is evaluated in terms of relative frequency shift $\Delta_{fi,tj}$:

$$\Delta_{fi,tj}\% = {f_{i,tf} - f_{i,tj}}\Big/{f_{i,tf}}\ 100. (3)$$

This shift is measured *n* times on the same bridges and then averaged:

$$\overline{\Delta_{fi,tj}} = \frac{1}{n}\sum_{k=1}^{n}(\Delta_{fi,tj})_k \ (4)$$

The N frequency shifts measured on the array are then averaged on N microbridges employed to perform the degradation analysis.

$$\overline{\Delta_{f,tj}} = \frac{1}{N}\sum_{k=1}^{N}(\overline{\Delta_{fi,tj}})_k \ (5)$$

The mean degradation rate is evaluated considering the time taken for the degradation process to remove the initial mass deposited.

$$DR = m/(A\Delta_t)\ [\mu g/h] \ (6)$$

Where *m* is the initially mass deposited on the microbridges, *A* is the area of the microbridges (*lw*) and Δ_t is the time needed to reach 0% in the relative frequency shift (the resonance frequency returns to the value for an uncoated microbridge).

The stability of the readout has been monitored thorough a lock-in amplifier. The shift in the resonance frequency has been monitored through a lock-in amplifier for 4 minutes.

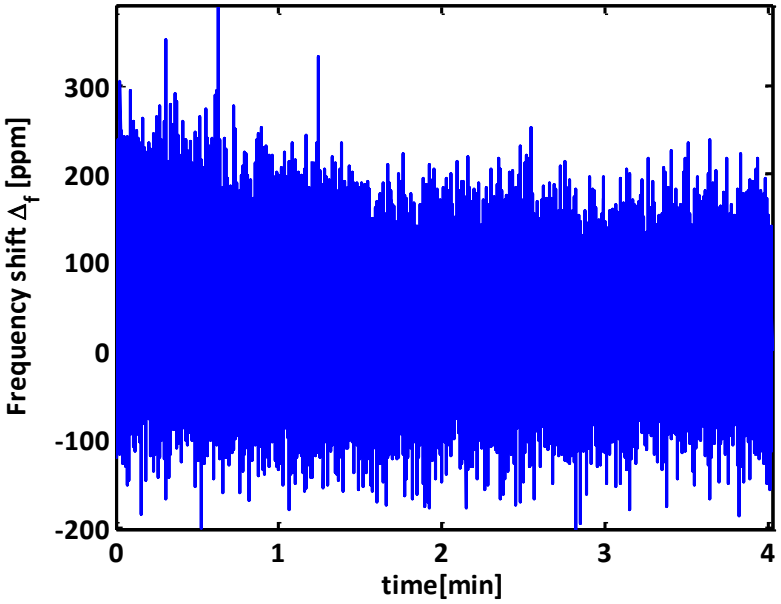


Figure S 3. Fluctuation on the resonance frequency measured through the lock-in amplifier

The root mean square of the noise is of 143 ppm and the max value +/- 200 ppm which is translated with a minimum detectable mass of 2.6 ng.

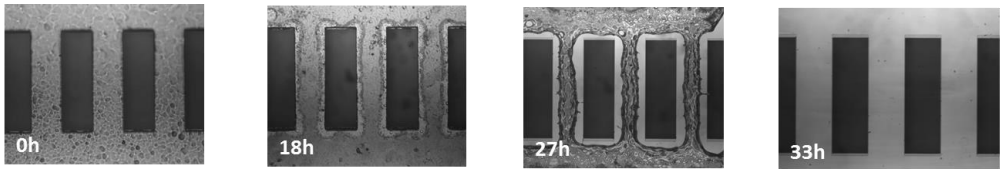
This value is greater in the actual configuration used during the degradation experiments. The shift in the resonance frequency was not followed during the degradation experiments through the lock-in amplifier but by repeating the measurement at different time step; the minimum detectable mass is thus higher, since independent measurement they are seen to have a larger variation than the fluctuation of the resonance frequency recorded with the lock-in amplifier.

4. Degradation experiments

We report here the complete degradation profile under the action of the only Tris-Hcl at 20 µl/min.

PLGA showed to be degraded within 33 hours of experimental time frame.

Within the experimental time frame that led to the complete biopolymer removal under the action of the enzyme we have not measured any degradation phenomena.



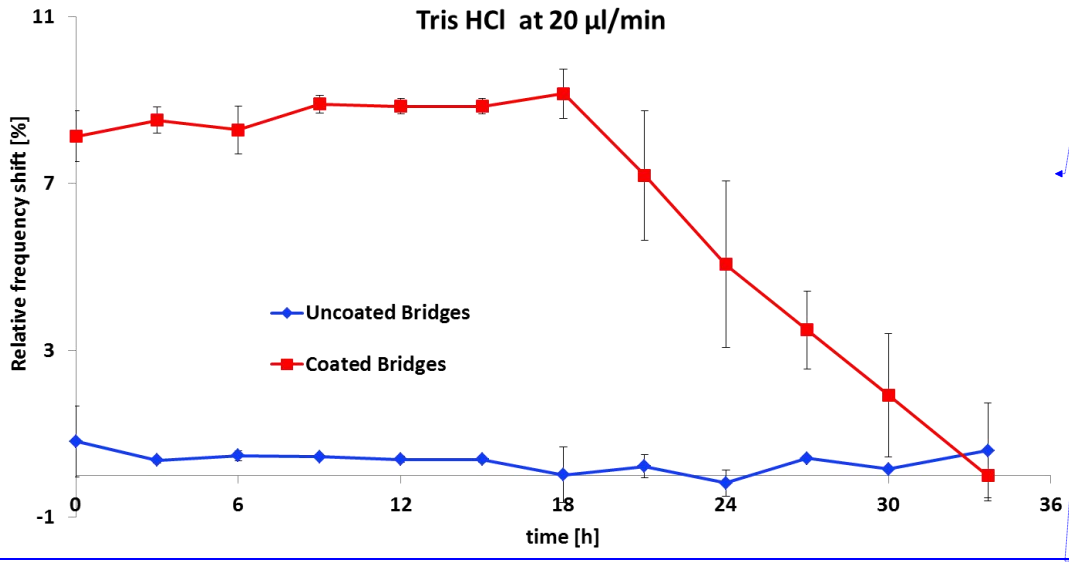


Figure S4 Degradation profile of PLGA under the action of Tris-HCl at 20 µl/min

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