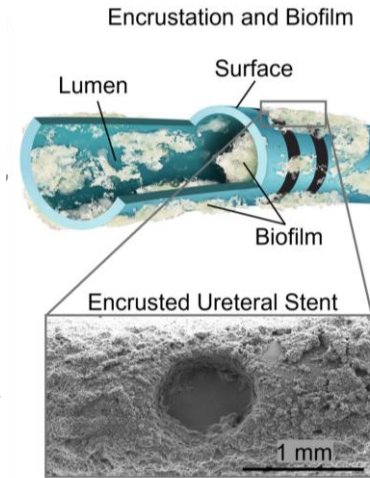
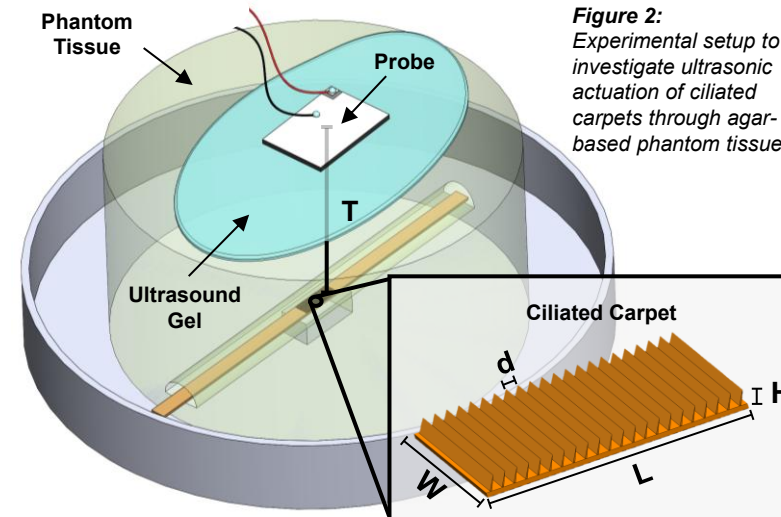


Ureteral stents and urinary catheters are limited during long-term use by biofilm formation and crystalline encrustation, causing dysfunction and repeated interventions (1,2).



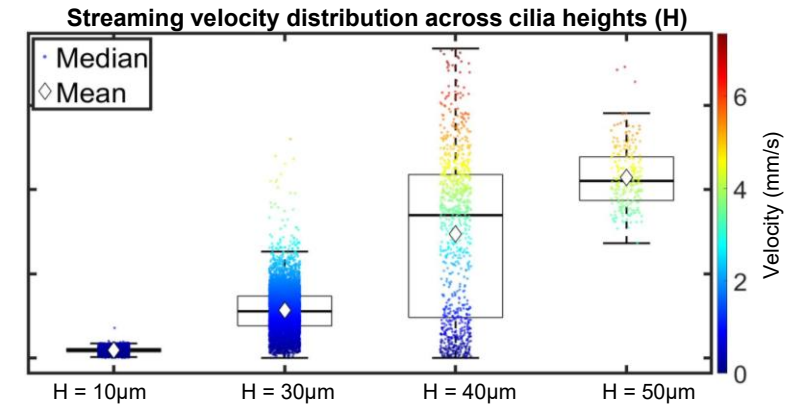
**Figure 1:** Biofilm and encrustation on a ureteral stent.

Inspired by the fluid transport and self-cleaning of biological cilia, we developed "ciliated carpets", i.e., microstructured polymeric surfaces designed to generate localized acoustic streaming (3). When ultrasound is applied through a tissue phantom using a probe, these surfaces can remove encrustation formed from artificial urine.



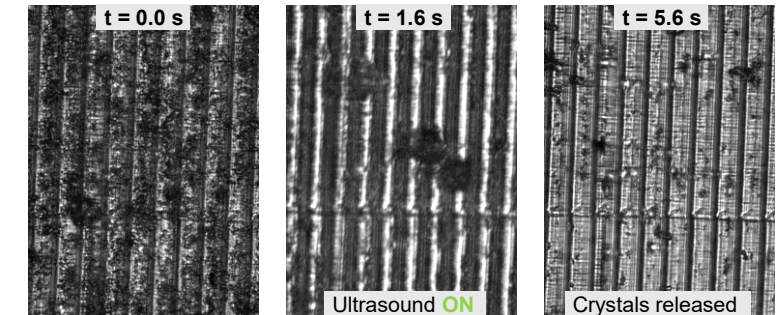
**Figure 2:** Experimental setup to investigate ultrasonic actuation of ciliated carpets through agar-based phantom tissue.

At 4 cm phantom tissue depth, ultrasound-induced streaming increased with microstructure height: 40-50  $\mu\text{m}$  structures generated velocities exceeding 5 mm/s corresponding to high shear forces.



**Figure 3:** Acoustic streaming velocity as a function of cilia height ( $H = 10 - 50 \mu\text{m}$ ), measured by flow-tracer particle tracking under 1 MHz ultrasound.

Using this configuration, effective cleaning (> 90 % clean surface) was achieved at a depth of 2 cm within 5 seconds of continuous ultrasound, demonstrating rapid, non-invasive cleaning through phantom tissue.



**Figure 4:** Image sequence showing ultrasound-induced encrustation removal (from artificial urine). Ciliated carpet ( $H = 50 \mu\text{m}$ ) at depth  $T = 2 \text{ cm}$  within  $\sim 5 \text{ s}$  of actuation. Probe actuation parameters:  $f = 1.0 \text{ MHz}$  and  $80 \text{ Vpp}$ .

**References:**

- (1) Stickler, D. J., & Feneley, R. C. L. (2010). The encrustation and blockage of long-term indwelling bladder catheters: a way forward in prevention and control. *Spinal cord*.
- (2) Lange, D., Bidnur, S., Hoag, N., & Chew, B. H. (2015). Ureteral stent-associated complications—where we are and where we are going. *Nature Reviews Urology*.
- (3) Amado, P., Dillinger, C., Bahou, C., ... & Clavica, F. (2025). Ultrasound-activated cilia for biofilm control in indwelling medical devices. *PNAS*, 122(18), e2418938122.



# ULTRASOUND-DRIVEN DISRUPTION OF ENCRUSTATION ON STENT AND CATHETER SURFACES: AN IN VITRO MODEL

Cornel Dillinger<sup>1,2</sup>, Pedro Amado<sup>1,2</sup>, Dominik Obrist<sup>1</sup>, Fiona Burkhard<sup>3</sup>, Beat Roth<sup>2</sup>, Daniel Ahmed<sup>1</sup>, Francesco Clavica<sup>1,2</sup>

<sup>1</sup>ARTORG Center for Biomedical Engineering Research, University of Bern, Bern, Switzerland

<sup>2</sup>Department of Urology, Inselspital, Bern University Hospital, University of Bern, Bern, Switzerland

<sup>3</sup>Department of Urology, Kantonsspital Aarau, Aarau, Switzerland