

Autonomously propelled microscavengers for precious metal recovery

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(Supplementary Information)

Materials and Method

Materials

Dracanea Marginata plant, Plant protoplast isolation kit (Sigma), HAuCl_4 (Sigma), H_2O_2 solution, DI water

Extraction and Purification of calcified microstructures (biotubes)

Plant derived biotubes were extracted as described previously by Srivastava et al. (Srivastava et al. *Adv. Mater.* 2016, 28, 832.)

The resulting biotubes were then covered by an iron layer (flat deposition; 30 nm with 5 nm Ti to avoid oxidation) and Pt layer (10 nm) using e-beam deposition (angle deposition 70°) at a deposition rate of $1\text{\AA}/\text{sec}$. The sample was kept in a moisture free dry place till further use. For more details regarding surface metal coating, please refer to Srivastava et al. *Adv. Mater.* 2016, 28, 832.

Macroscopic gold particles formation over micromotor surface (seeding site):

An aqueous solution of 10% H_2O_2 solution with 1% SDS at room temperature to analyse the biogenic micromotor motion. With this reaction solution, 100 mM HAuCl_4 was also prepared to make our reaction solution (1:1 v/v). To this reaction solution, we introduced our Fe-Pt coated micromotors resulting in rapid bubbling due to dissociation of H_2O_2 via a gas evolution reaction (O_2 in this case). The reaction was continued for a period of 30 minutes with the formation of a visible macroscopic metallic gold (gold nugget yellow in color). Videos were recorded at 20 frames per second, with 20X and 50X magnification. It should be noted that the reduction of gold can be initiated in the presence of H_2O_2 solution alone but we no macroscopic metallic particle cluster was observed in the absence of our micromotors under the provided reaction parameters.

Material characterization and media analysis

Scanning electron microscopic pictures were taken with a Zeiss SEM/FIB scanning electron microscope. Also, surface analysis was carried out before and after the reaction from a PHI-5600 photoelectron using $(\text{Al})\text{K}\alpha$ radiation with pass energy as 29 eV. A Zeiss axioScope A1 optical microscope with Phantom Miro eX2 high-speed camera from VisionResearch was used to record videos of homogeneous activation and movement of our micromotors at the rate of 20 frames per second. The free software Fiji was used to track particle speed and edit videos and pictures.

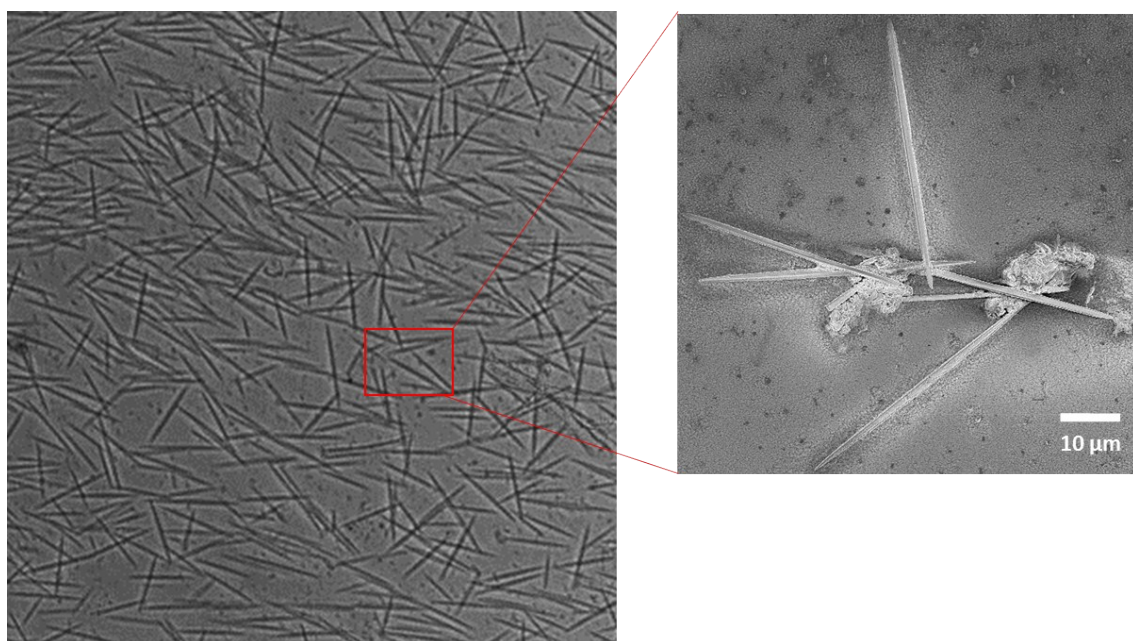


Figure S1. Optical microscopy images and representative SEM image of the extracted biotubes.

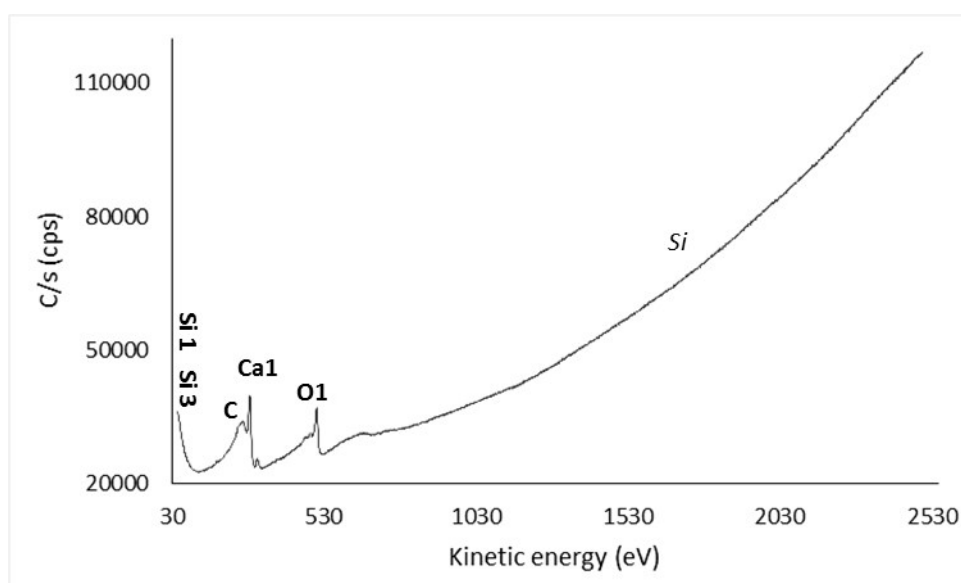


Figure S2. XPS spectra of the purified biotube

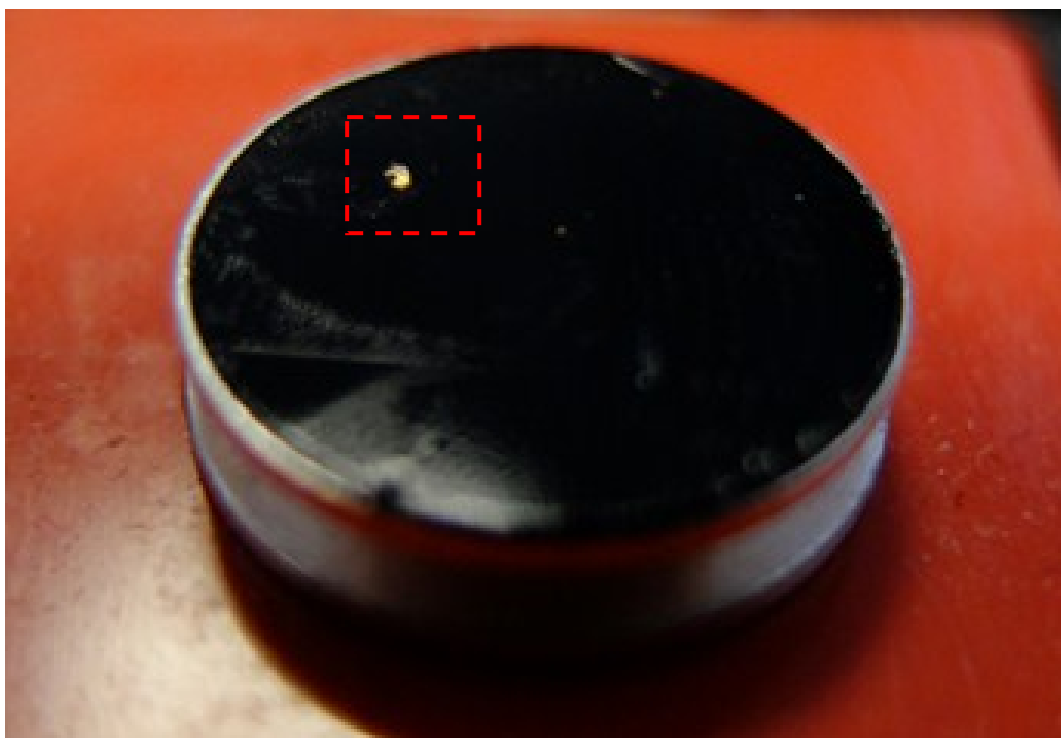


Figure S3. Recovered macroscopic gold particle after the completion of Au scavenging micromotors

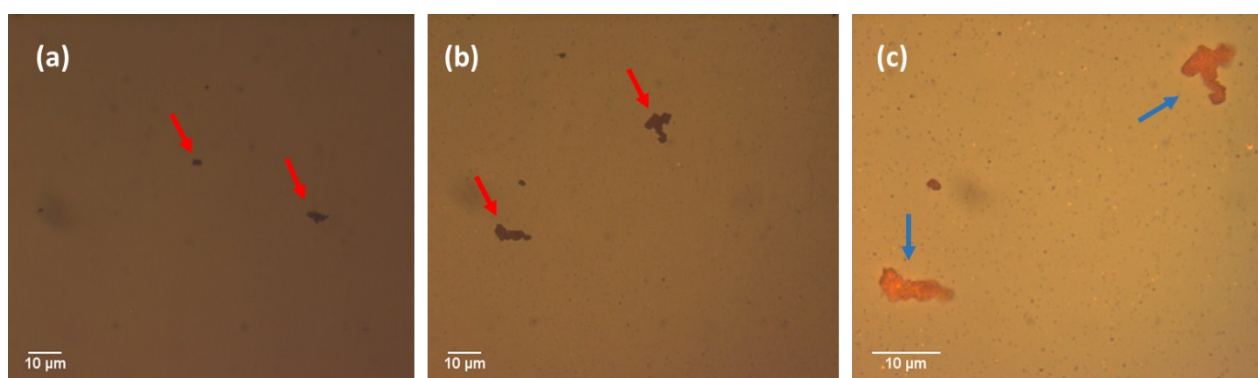


Figure S4. Control reaction showing Pt alone: (a) Pt pieces in H₂O over a glass slide (indicated by an arrow); Pt metal under HAuCl₄ reduction reaction (50mM HAuCl₄, 10% H₂O₂, 1% SDS); (c) Distinct gold particle formation (yellow-orange in color) observed after drying upon completion of the reaction (indicated by arrow)

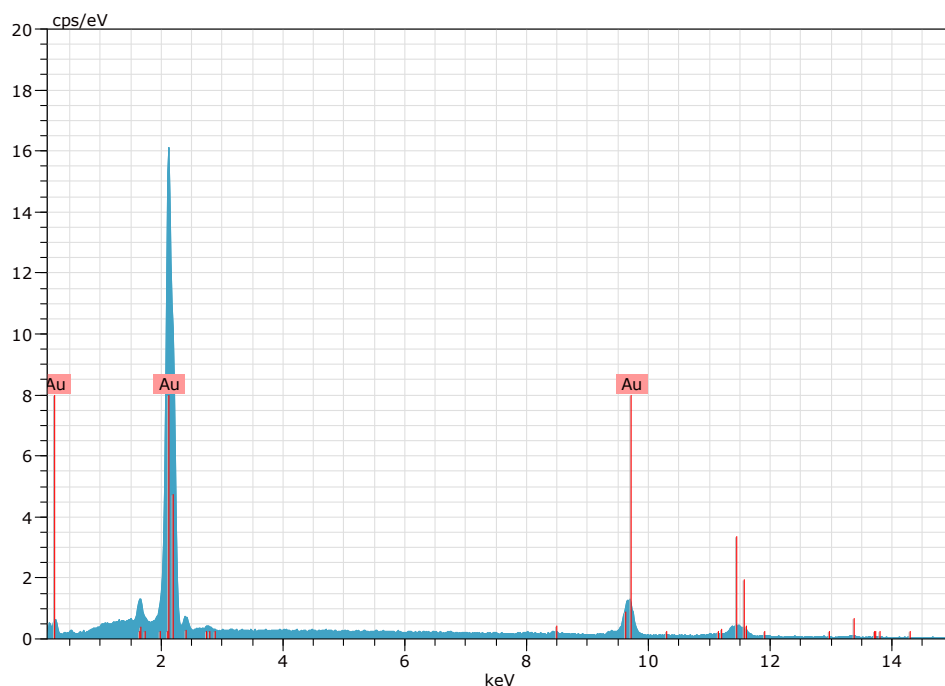


Figure S5. Detailed EDX spectra of gold nuggets obtained after completion of the reaction.

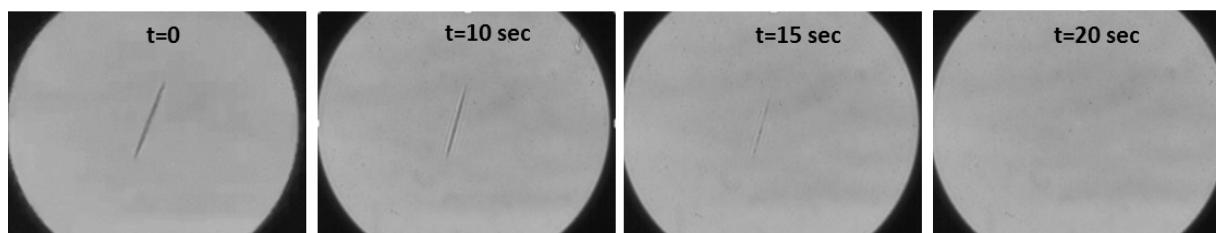


Figure S6. Time-lapse imaging of biotube dissolution in the presence of acidic solution.

Supporting Videos:

Video S1: Biogenic micromotor motion in a straight path in the reaction medium.

Video S2: Biogenic micromotor motion in a screw-cork motion in the reaction medium.

Video S3: Biogenic micromotor motion in a magnetically-guided zig-zag motion in the reaction medium.

Video S4: Gold scavenging of autonomously propelled biogenic microbot.

Video S5. Rapid dissolution of calcified biotubes in the presence of pH 2 HCl solution