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# Thermally Actuated Colloidal Tip SU-8 Scanning Probes

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**Summary:**

This study presents significant advancements in microfabrication techniques for developing probes with diverse tip geometries and microspheres attached to probe tips for various applications. We introduce a novel method for transfer of spherical microparticles onto probe tips. First, the microparticles were assembled within cavities bulk-etched into (100) oriented single crystal silicon and subsequently the scanning probes were patterned using SU-8 as the structural material. Upon sacrificial layer etching, SU-8 scanning probes were released with spherical microparticle tips at the distal end of the cantilever. Additionally, we explored the integration of bimorph electrothermal actuators for precise probe actuation. Notably, our bimorph thermal actuator demonstrates superior displacement at lower voltages compared to the existing literature. The use of SU-8 as the probe material simplifies the fabrication process and enhances the device's biocompatibility. This property makes it particularly suitable for biomedical applications, extending the potential impact of this research beyond the scope of the current study.

**Keywords:** Actuator, Bimorph, Colloidal probe, Colloidal assembly, SU-8

## Introduction

Cantilevers, especially those with colloidal tips are essential components in precision instruments, utilized across fields like biomedical diagnostics [1] and to quantify surface interfacial forces [2]. Particularly crucial in atomic force microscopy (AFM), they facilitate nanoscale imaging and manipulation [3]. Traditional AFM probes employ piezoelectric or electromagnetic actuation methods to control interactions with sample surfaces [4,5]. However, current cantilever technologies encounter challenges in sensitivity, integration, scalability, reproducibility, and long-term stability [6].

Recent advancements in the design and fabrication of cantilevers have aimed to address these issues. Thermally actuated cantilevers offering a potentially more controlled and adaptable approach compared to traditional piezoelectric actuation [7]. The use of thermally actuated mechanisms in colloidal probes can potentially enhance the sensitivity and adaptability of measurements, allowing for dynamic adjustments of probe properties in response to environmental changes or specific experimental needs. However, integrating these thermal mechanisms with colloidal probes presents a unique set of challenges and opportunities.

This study is motivated by the need to optimize thermally actuated systems, particularly when integrated with colloidal probes. It aims to develop a novel manufacturing protocol for fabricating customized tip geometries and configurations, including integration with complementary technologies like microfluidics, and addressing the associated design, fabrication, and optimization challenges.

## Materials and Methods

The fabrication of cantilevers with various tip shapes or microspheres begins with cavity fabrication. First, $SiO_2/Si_3N_4/SiO_2$ layers are deposited on both sides of a Si wafer via PECVD. These layers are then patterned by lithography and etched using DRIE. For cantilevers with pyramidal tips or microspheres, the wafer is etched in KOH, and remaining $SiO_2$ is removed with BOE.

For cubic-tip cantilevers, we used DRIE instead of KOH etching. To fabricate cantilevers with both pyramidal and cubic tips, a 200 nm $SiO_2$ sacrificial layer was deposited, followed by spin-coating SU-8. After lithography patterning and

BOE immersion, the cantilevers were released. SEM images of the two tip shapes are shown in Fig. 1. Next, we attempted to attach microspheres to the cantilever tips using pyramidal cavities.

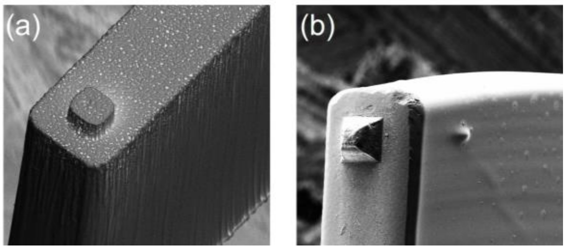


*Fig. 1. SEM images showing (a) a cantilever with a cubic tip, and (b) a cantilever with a pyramidal tip*

To transfer microspheres to the cantilever tips, we used an assembly process within the cavities, aided by capillary flow for precise positioning. However, coating with SU-8 initially displaced the particles, so we switched to the drop-casting technique for SU-8 coating, which serves as the cantilever material.

To drop-cast a 200 µm thick SU-8 film, we calculated the required SU-8 volume for each sample and applied it centrally using a micropipette. After soft-baking on a flat hot plate for even distribution, the SU-8 was UV-exposed through a mask, followed by post-exposure baking and development in PGMEA. The process finished with the release of the samples by etching away the sacrificial layer.

Fig. 2a, 2b illustrate the microsphere assembly on the cantilever tip. Fig. 2c shows an assembled microparticle inside the cavity. Side and top views of the cantilever confirm the microsphere attachment to the tip (Fig. 2d, 2e).

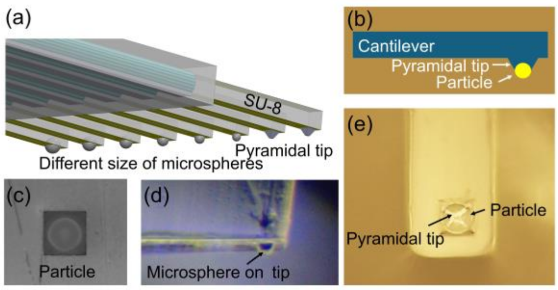


*Fig. 2. (a),(b) Schematics of Microsphere Assembly on Cantilever Tip, (c) Assembled Microparticle within Cavity, (d) Cantilever with Microsphere Attached, (e) Top View of Microsphere on Cantilever Tip.*

The final goal of this study was to fabricate cantilevers with various tip geometries or microspheres attached to the tip that could be actuated. Fig. 3a illustrates a schematic of an actuated cantilever. To achieve this, we employed a bimorph electrothermal actuator. Initially, a 250 nm thick layer of Cu was coated onto the sacrificial layer using a thermal evaporator, leaving the cavity area empty. To enhance adhesion, a 5 nm layer of Cr was deposited on both the top and bottom surfaces of the Cu. To apply the input voltage to the pads of the thermal actuator, a probe station was utilized (Fig. 3b). Fig. 3c depicts the Cu layer, which served as the active layer of the thermal actuator aligned with the cavities. Notably, there is no residual copper in the cavity area, and the cantilever can successfully actuate (Fig. 3d).

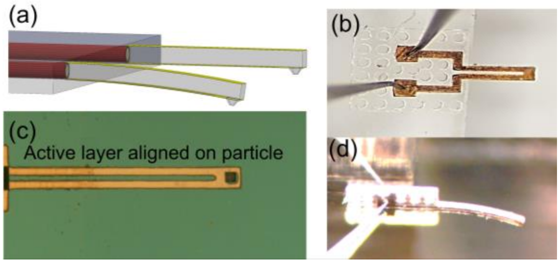


*Fig. 3. (a) Schematic of an actuated cantilever, (b) Utilization of a probe station to drive the cantilever (c) image of the active Cu layer, (d) Actuated cantilever.*

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