Characterization of Au electrode Based Strain Sensor on Magnetic Gripper Structure

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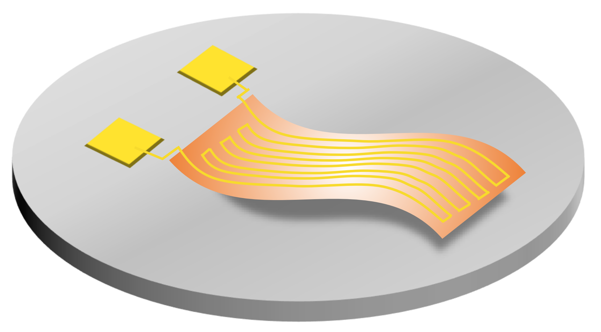
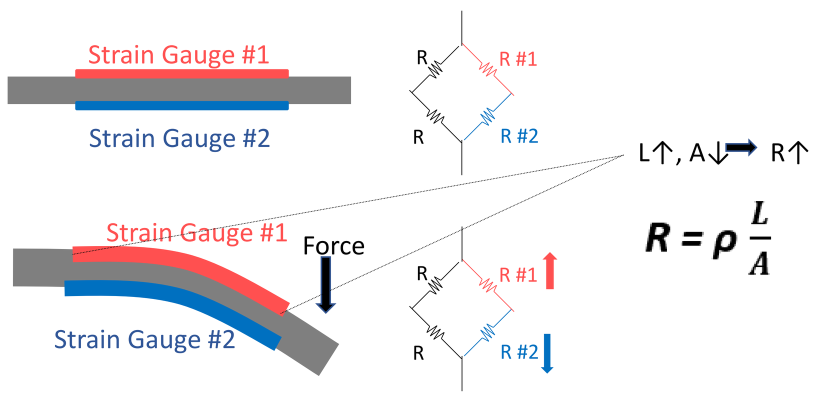
Introduction



Magnetic grippers offer a promising method for manipulating organoids, which are 3D-cultivated miniature organs mimicking human tissue. However, they sometimes show unexpected strain deviations under a magnetic field, resulting in resistance measurements that differ from theoretical predictions.



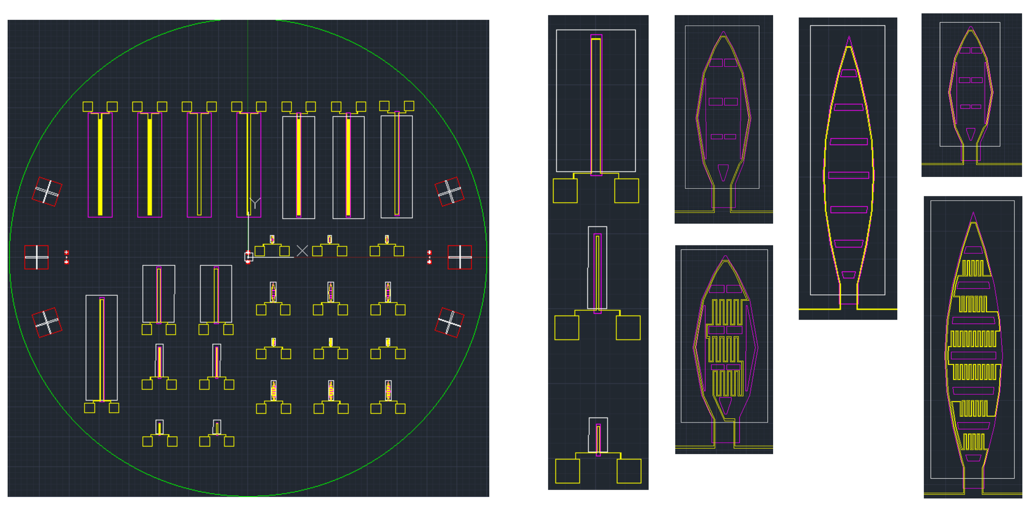
$$R = \rho \frac{L}{A}$$

Strain sensors detect minute mechanical changes and convert them into electrical signals. They measure surface deformation by detecting resistance changes in metals, which alter with stretching or compression. Bending metal can introduce microscopic defects that increase resistance by hindering electron movement.

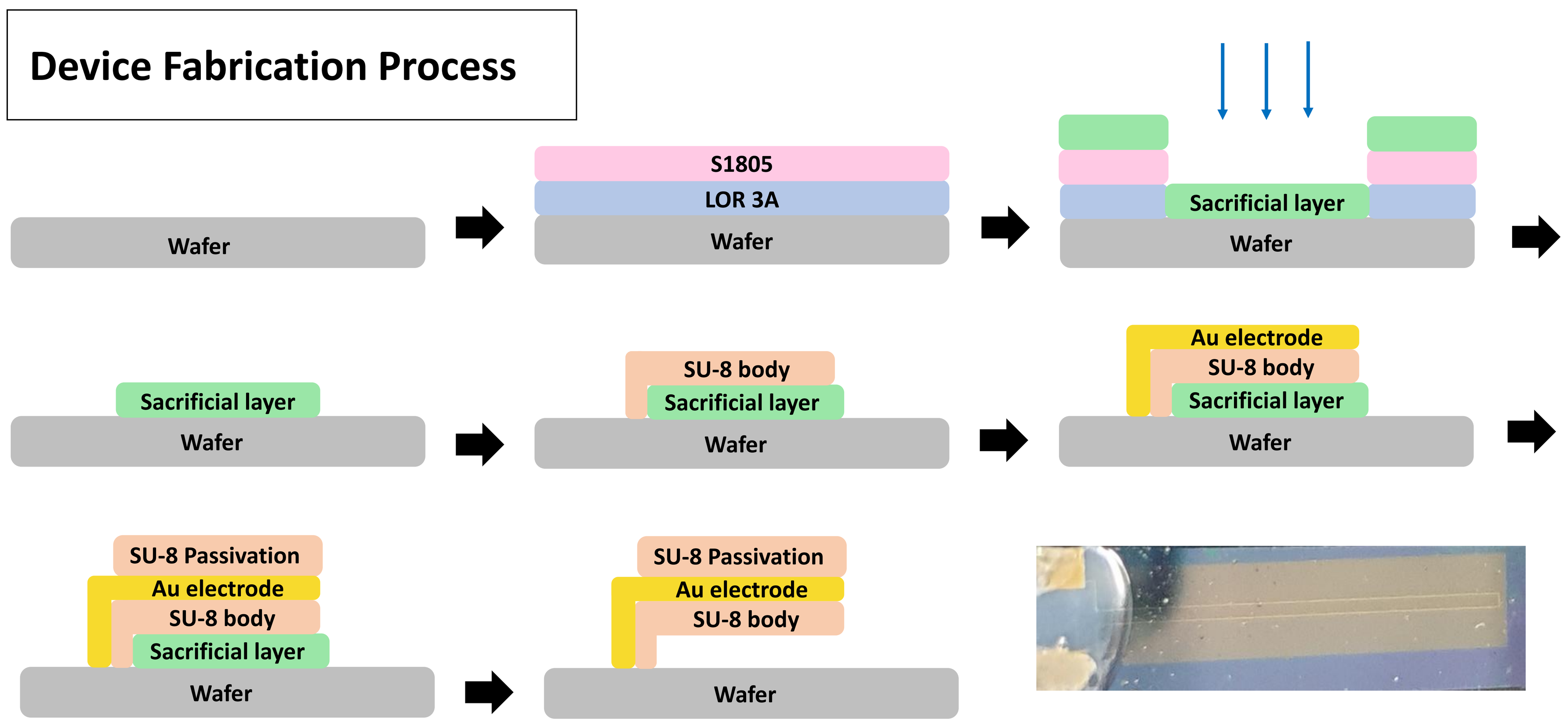
This study aims to enhance the accuracy of strain measurements and the effectiveness of magnetic grippers in organoid manipulation by experimenting with various films, bending forces, and strain sensor designs.

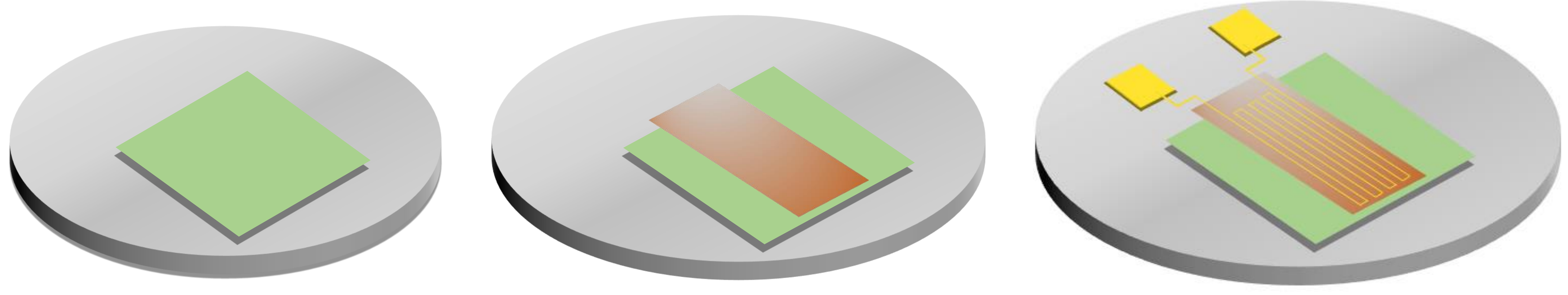
Experimental Methods

Various shapes designed with CAD

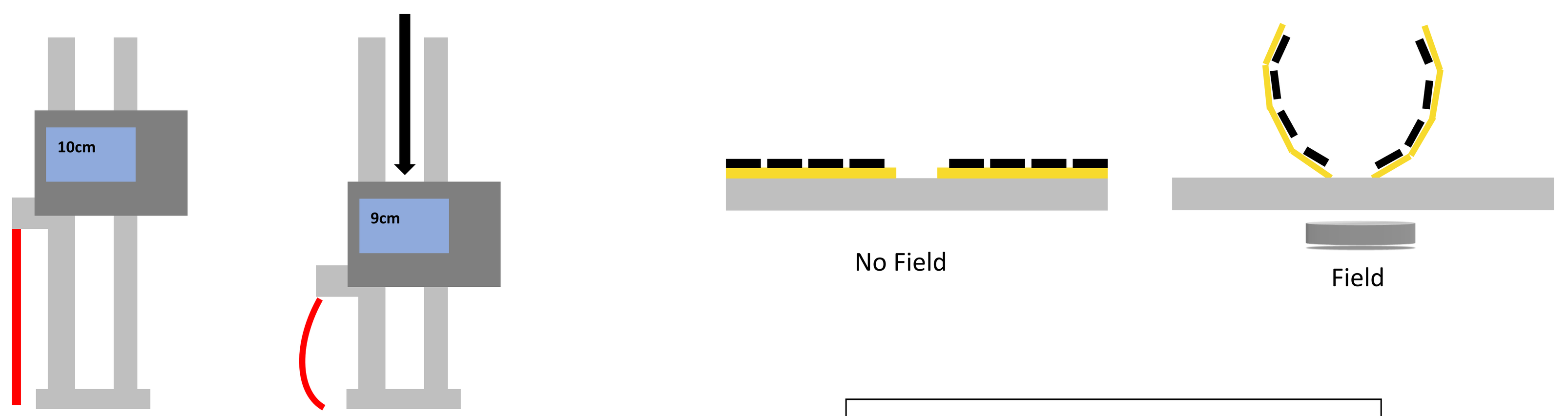


Device Fabrication Process





Motion Mechanism



$$\epsilon = \frac{\Delta L}{L}$$

$$\Delta R = GF \cdot R \cdot \epsilon$$

$$DL = \frac{3\sigma}{S}$$

ϵ : strain
ΔR : change in resistance
R : original resistance
GF : gauge factor
ΔL : change in length
L : original length
DL : detection limit
σ : noise's standard deviation
S : sensitivity

Strain Sensing Strategy

Ⅰ. Polyimide film, Manual bending, Quantitative relationship
Ⅱ. Polyimide film, Manual bending, Qualitative relationship
Ⅲ. Si Wafer, Magnetic bending

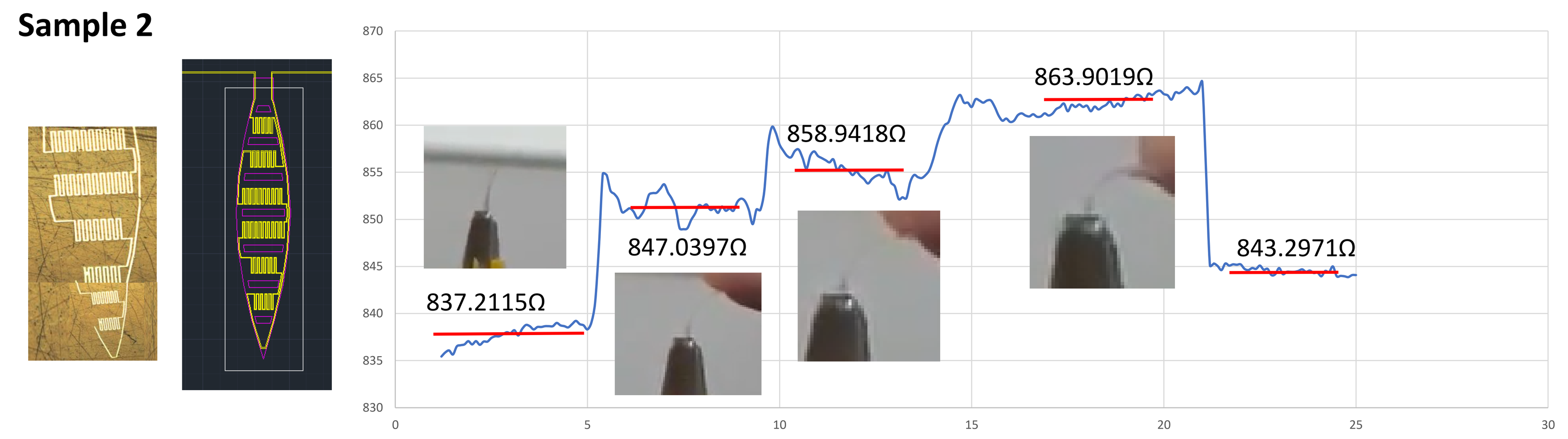
Using this equation, we will recalculate the Gauge Factor, which is approximately known to be 2, to determine the **sensitivity** and **detection limit** that describe the quantitative relationship between strain and resistance change.

Results

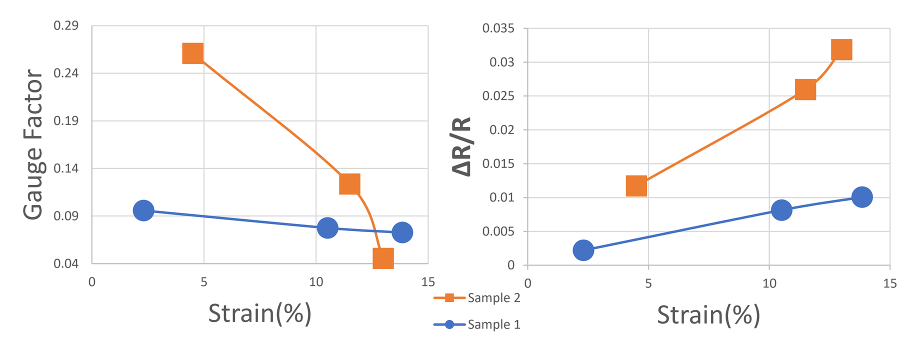
Ⅰ. Polyimide film, Manual bending, Quantitative relationship

Sample 1

Sample 2

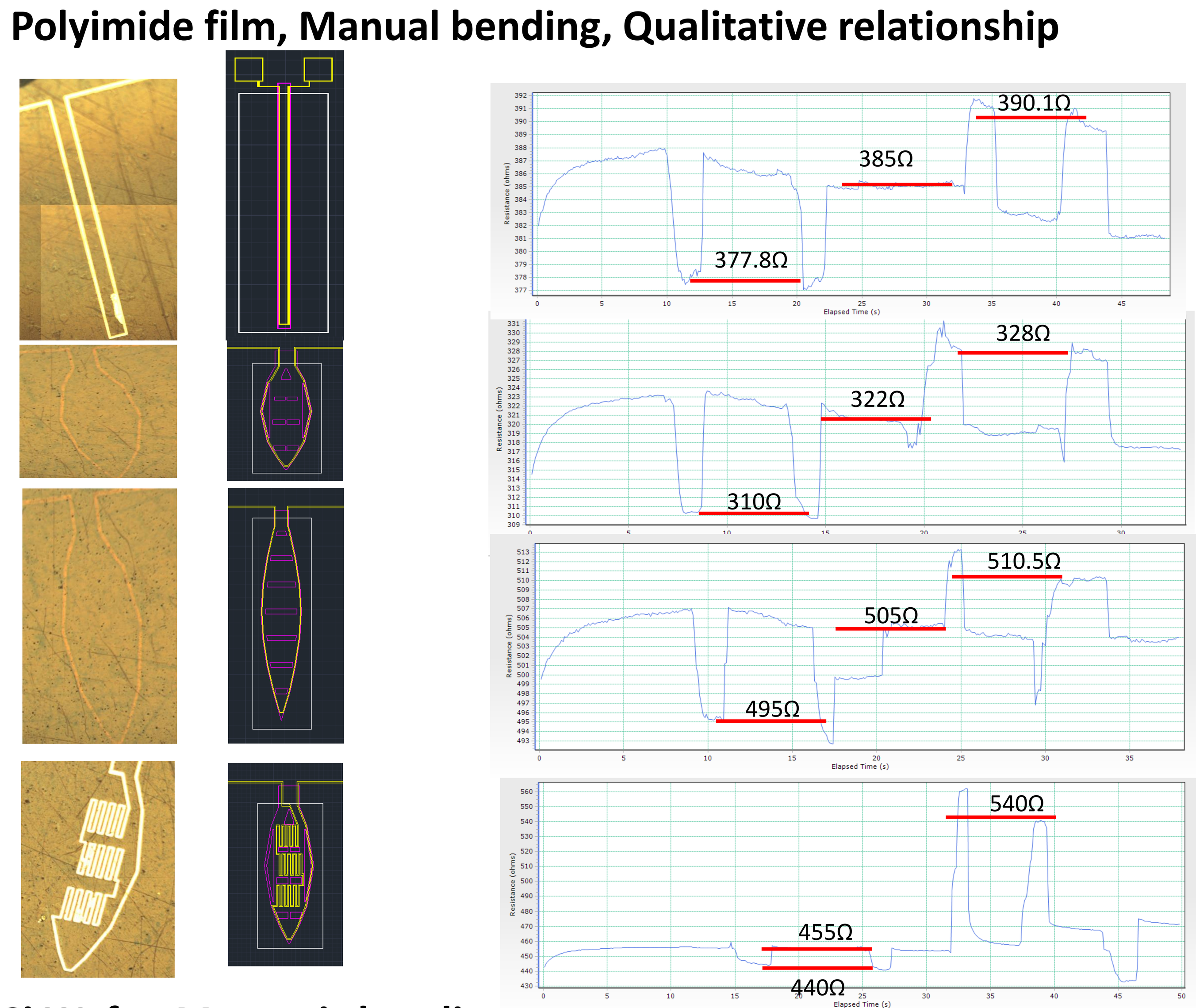


	sensitivity	detection limit(ε)
sample1	0.082055	7.894786
sample2	0.24393	20.9823

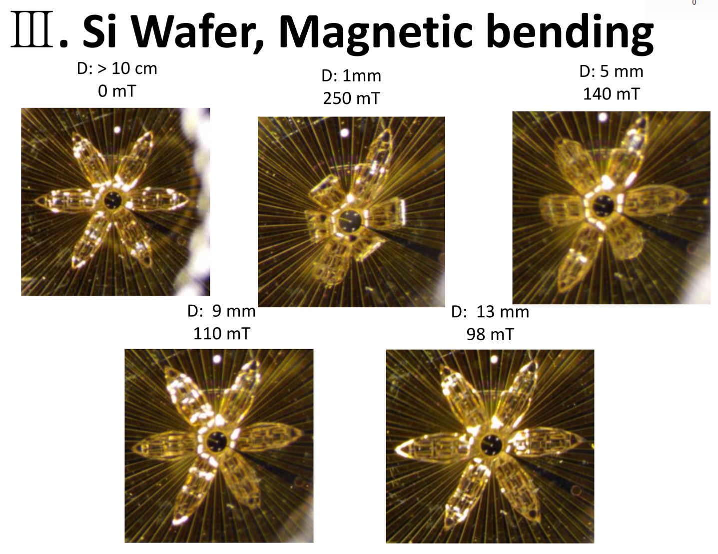


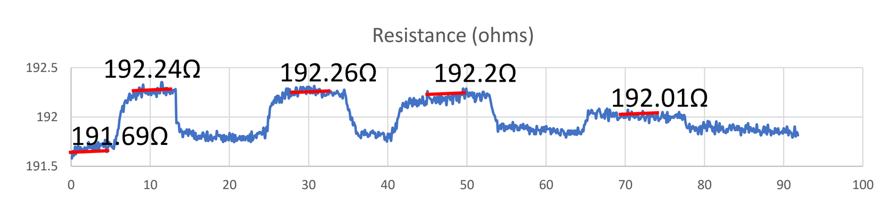
High contact resistance between the gold and electrode, The **aggregation** of Au during the deposition process

Ⅱ. Polyimide film, Manual bending, Qualitative relationship



Ⅲ. Si Wafer, Magnetic bending





SU8 body and SU8 passivation layer are deposited with similar thicknesses, the internal resistance can significantly decrease.

Conclusion & Further Study

The experiments showed accurate trends in resistance changes, but there were significant discrepancies in quantitative values. The primary issues identified were aggregation and high contact resistance.
When fabricating strain sensors on silicon wafers, designing them large enough to avoid wafer breakage while ensuring effective strain detection is advisable. Additionally, aggregation of the gold thin film in certain areas led to discarded samples. If aggregation occurs, strain may become concentrated in specific regions, resulting in minimal resistance changes. Future studies should consider adjustments to SU-8 layer thickness and recipe, explore methods for quantitatively analyzing the mechanical stress-strain relationship of metals, and address contact resistance issues between electrodes and gold thin films.

Reference

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[3] Cheong, Jiyong, et al. "Engineered nanoparticles for clinical assays." *Nature Reviews Bioengineering* (2024): 1-19.