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Finite Element Analyss of U-Shaped Biodegradable Polyvinyl Alcohol Thin Film for Sustainable MEMS Applications

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Introduction

- MEMS devices benefit from thin films.
- Conventional MEMS materials (Silicon, Gold, Copper) are rigid and non-biodegradable.
- PVA is biodegradable, flexible, and promising for sustainable MEMS.
- Gap: Limited FEA-based mechanical comparison of PVA to standard MEMS materials.

Objectives

i. To simulate U-shaped PVA thin film under microscale forces using SolidWorks.
ii. To compare stress-displacement responses with Silicon, Copper, and Gold.
iii. To assess PVA's suitability in flexible MEMS applications.

Methodology

- Simulation software: SolidWorks Simulation
- Materials: PVA, Si, Cu, Au
- Load: 0.002–0.010 N
- Boundary: Fixed at base, vertical load on free end

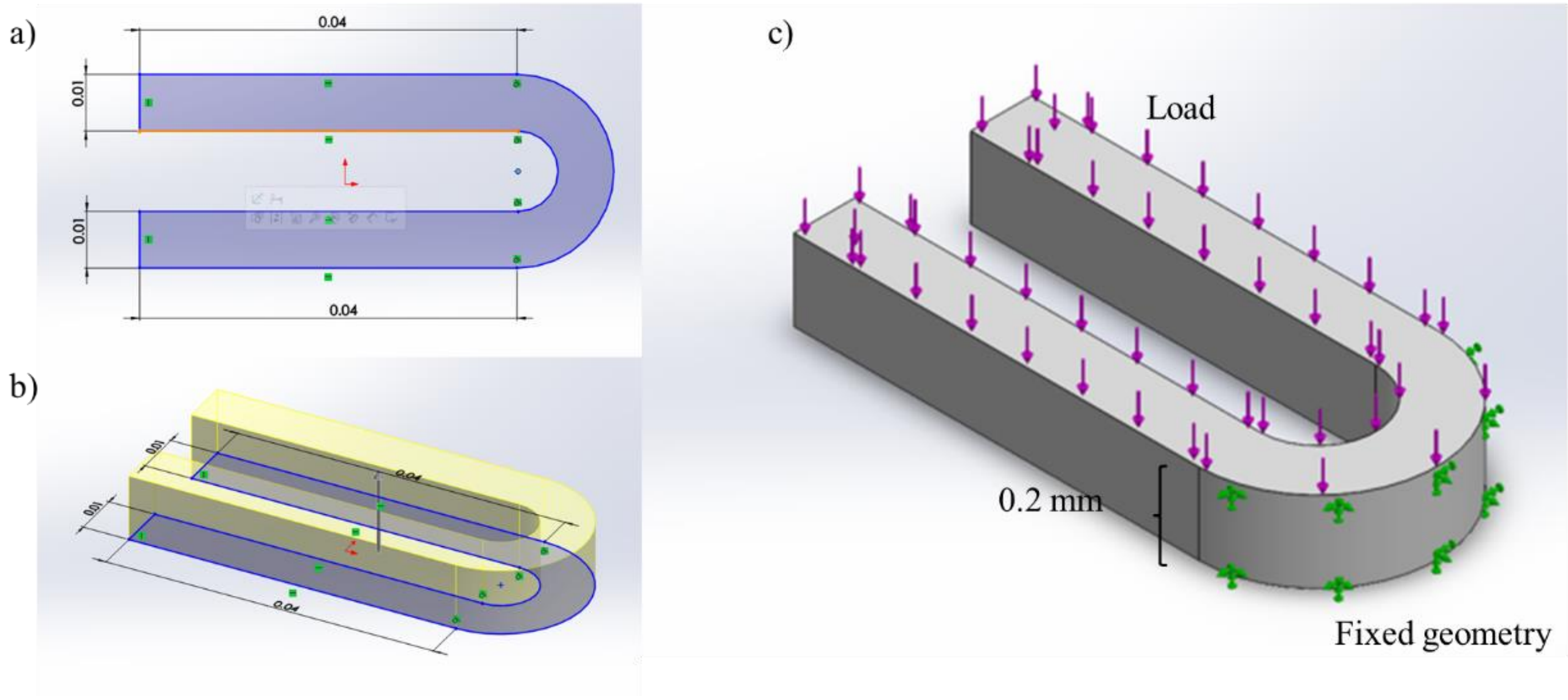

Fig. 1. Design specifications of the U-shaped thin film used in all simulations. a) and b) are the U-shaped design geometry, while c) is the location of the applied load and fixed geometry

Discussion

- PVA thin film exhibited the **highest** flexibility, with a peak displacement of **18.4 µm** at **0.010 N**, over 30 times greater than Gold.
- Von Mises stress in PVA **reached 4.88 MPa**, slightly lower than Gold (4.89 MPa), indicating comparable stress tolerance.
- Stress concentration occurred at the inner curvature of the U-shaped design, **consistent** with typical failure zones in MEMS structures.
- PVA showed a **linear elastic response** across all applied forces, validating its predictable mechanical behavior for MEMS design.
- Compared to Silicon, Copper, and Gold, **PVA offers a favorable trade-off between flexibility** and **mechanical strength**, making it suitable for flexible, bio-integrated, or wearable MEMS.
- Deformation scale factor decreased proportionally with increasing force in PVA, indicating controlled and predictable deformation.
- Despite lower stiffness, PVA's biodegradability and compliance **align** with sustainable **MEMS development goals**.

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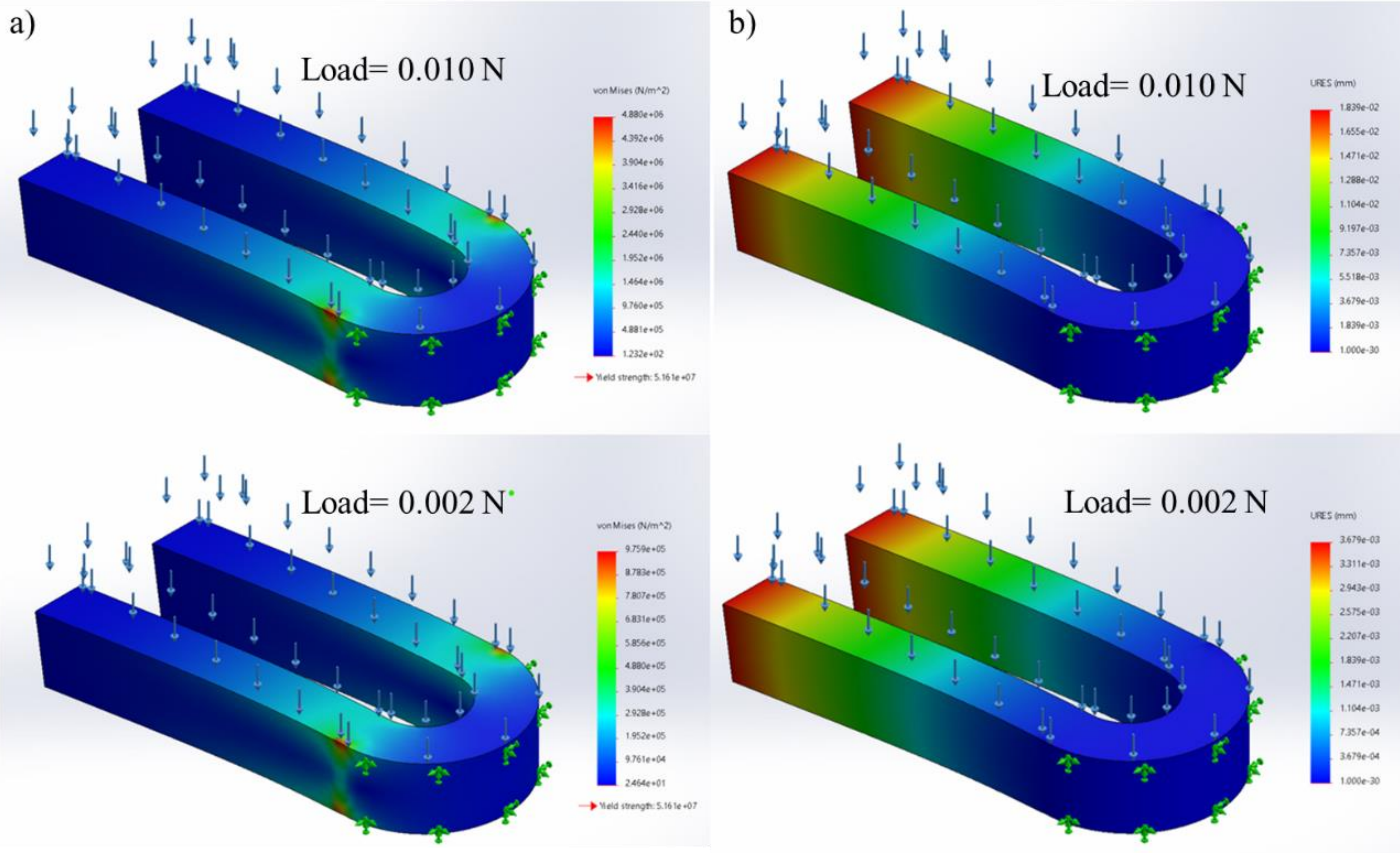

Fig. 2. a) FEA-generated von Mises stress distribution and b) Simulated total displacement field in the U-shaped PVA thin film under an applied force of 0.010 N and 0.002 N

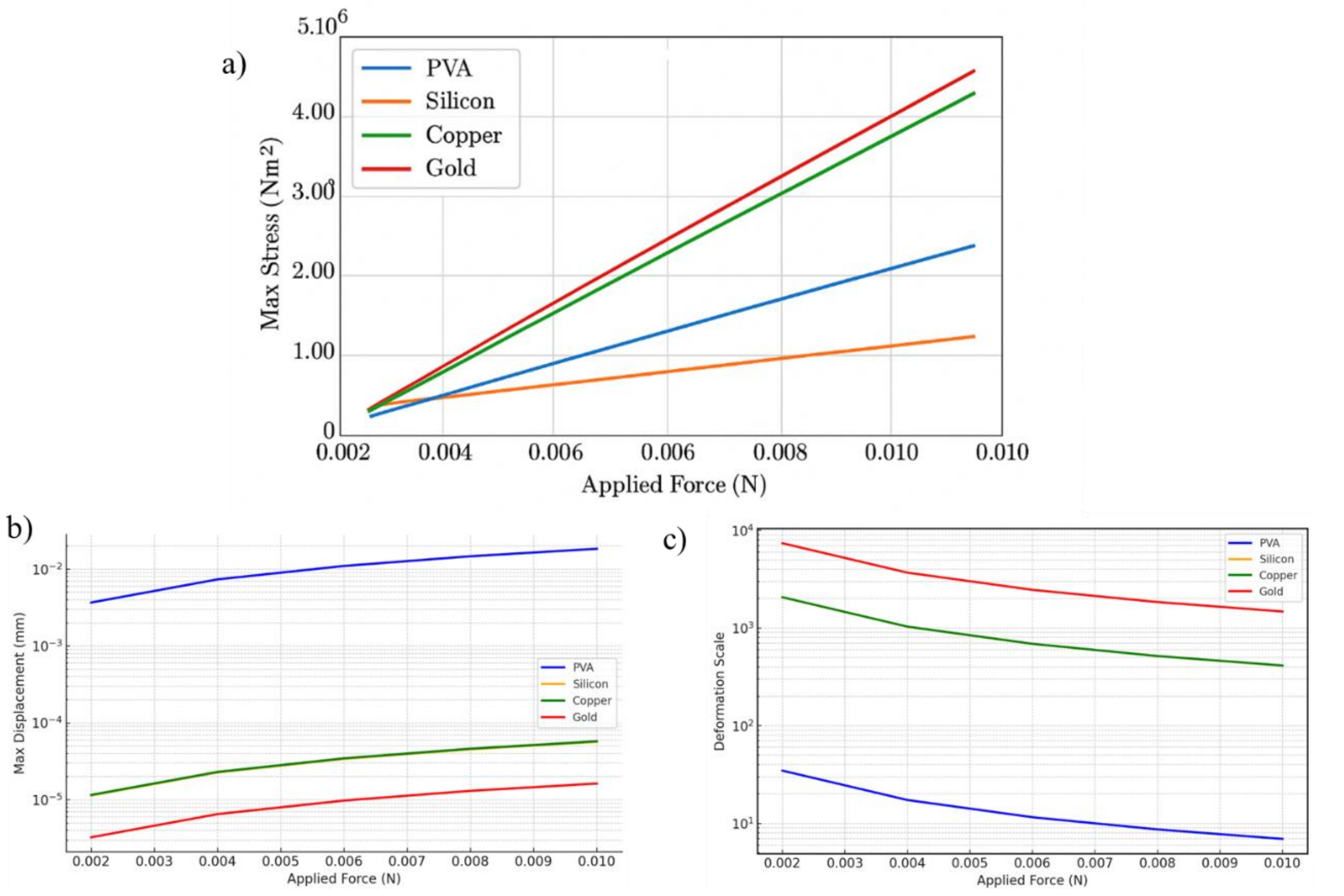

Fig.3. a) Maximum von Mises stress as a function of applied force for PVA, Silicon, Copper and Gold. Linear trends confirm elastic response across the tested load range. b) Comparison of total displacement across materials as force increases.

Conclusion & Future work

This study confirms that PVA thin films offer high flexibility and adequate stress tolerance, outperforming conventional MEMS materials in displacement under micro-scale loading. With predictable elastic behavior and biodegradable properties, PVA is a strong candidate for sustainable, flexible MEMS applications. These findings support its potential use in soft electronics, biomedical sensors, and eco-friendly micro-device fabrication.

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