Design And Optimization Of Mobile Microrobots With Piezoelectric Actuation For High-precision Manipulation

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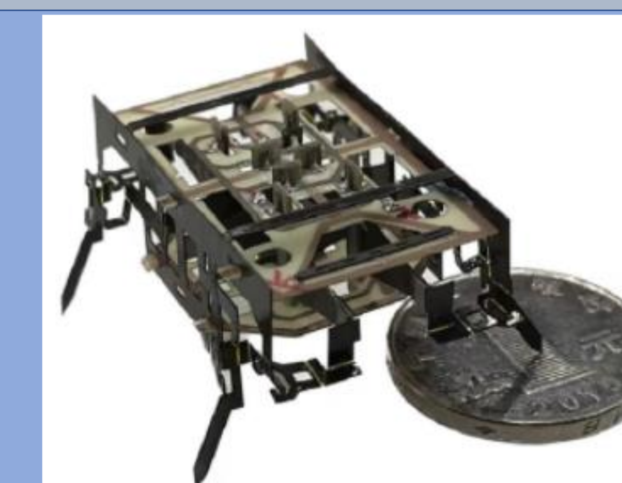
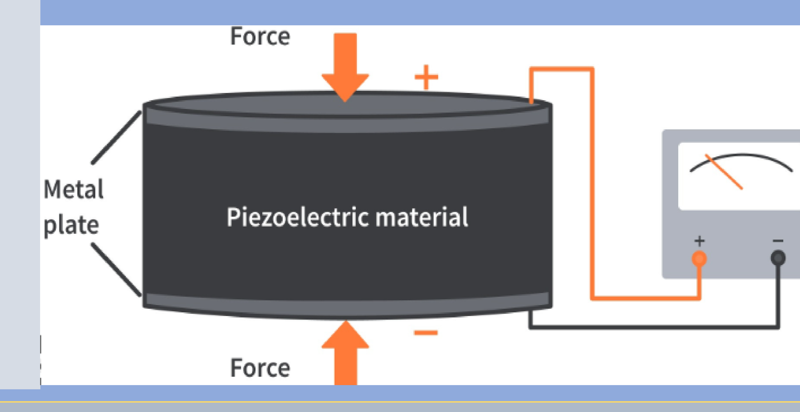
Introduction

- **Microrobots** - Tiny robots, often smaller than a millimeter, that perform tasks in highly constrained environments.
- ✓ Promising for medical procedures, precision manufacturing, and targeted environmental interventions.
- **Piezoelectric Effect:** These materials generate an electric charge when subjected to mechanical stress, and conversely, they can deform when an electric field is applied.
- **Actuation**- Actuation refers to the process by which energy is converted into motion, allowing robots or devices to perform controlled mechanical movements. Piezoelectric materials expand or contract when subjected to an electric field, generating movement.





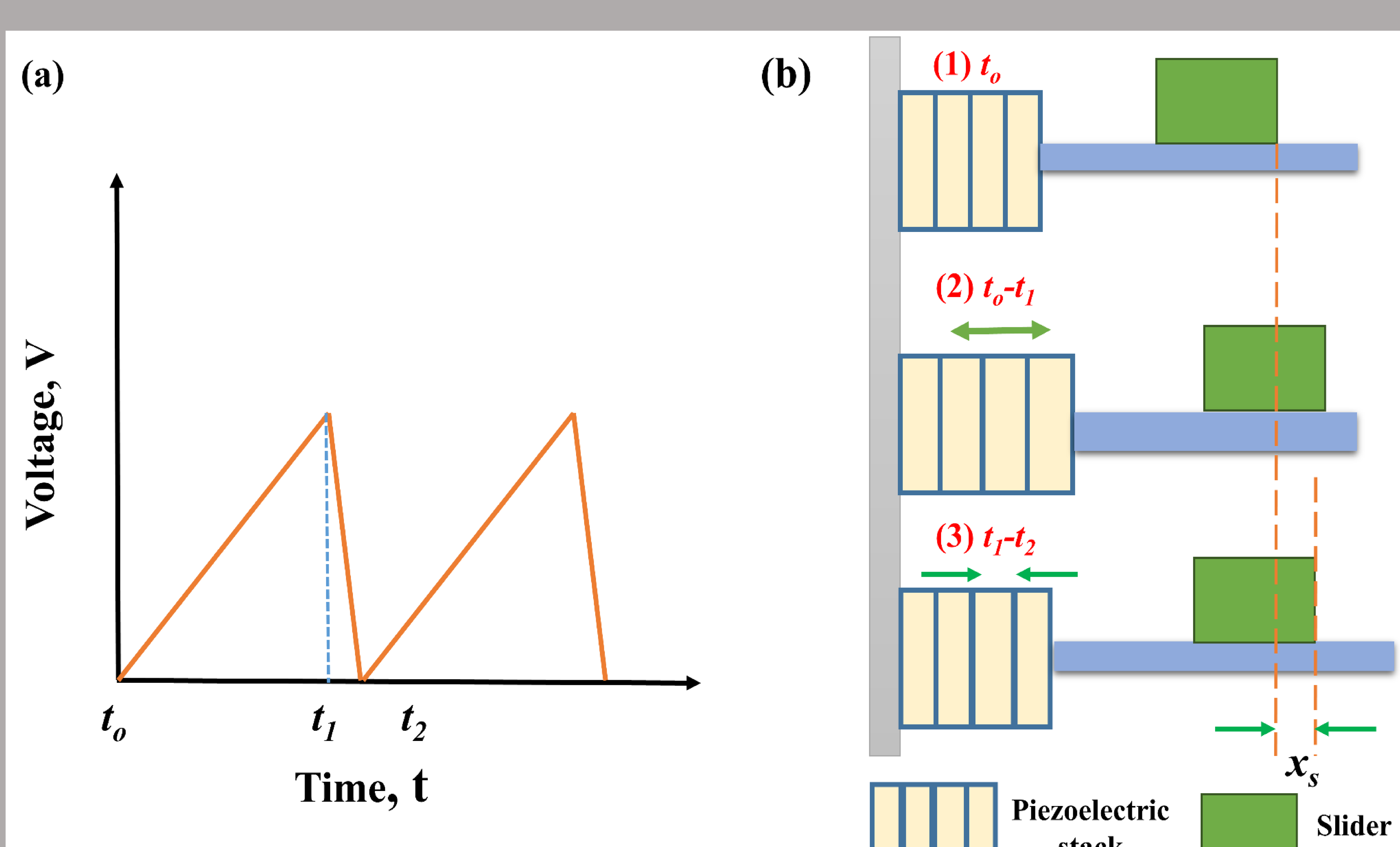
Structure and Operating principle

- Each microrobot is composed of three core components: a mobile platform, a manipulation unit, and specialized end effectors.
- The mobile platform is designed to offer 3 degrees of freedom (DOF), enabling transla-tional movement along the x-y plane and rotational movement around the z-axis. This movement is powered by a slip-stick mechanism
- When a voltage is applied to the piezoelectric actuator, it induces displacement and force, which are transferred to the guiding mechanism to move the platform.

Working principle of the piezoelectric stick-slip actuator driven by sawtooth wave voltage

Step 1: Initially, the piezoelectric stack remains at its natural length with no volt-age applied. Both the slider (depicted in green) and the frictional rod (in blue) remain stationary.

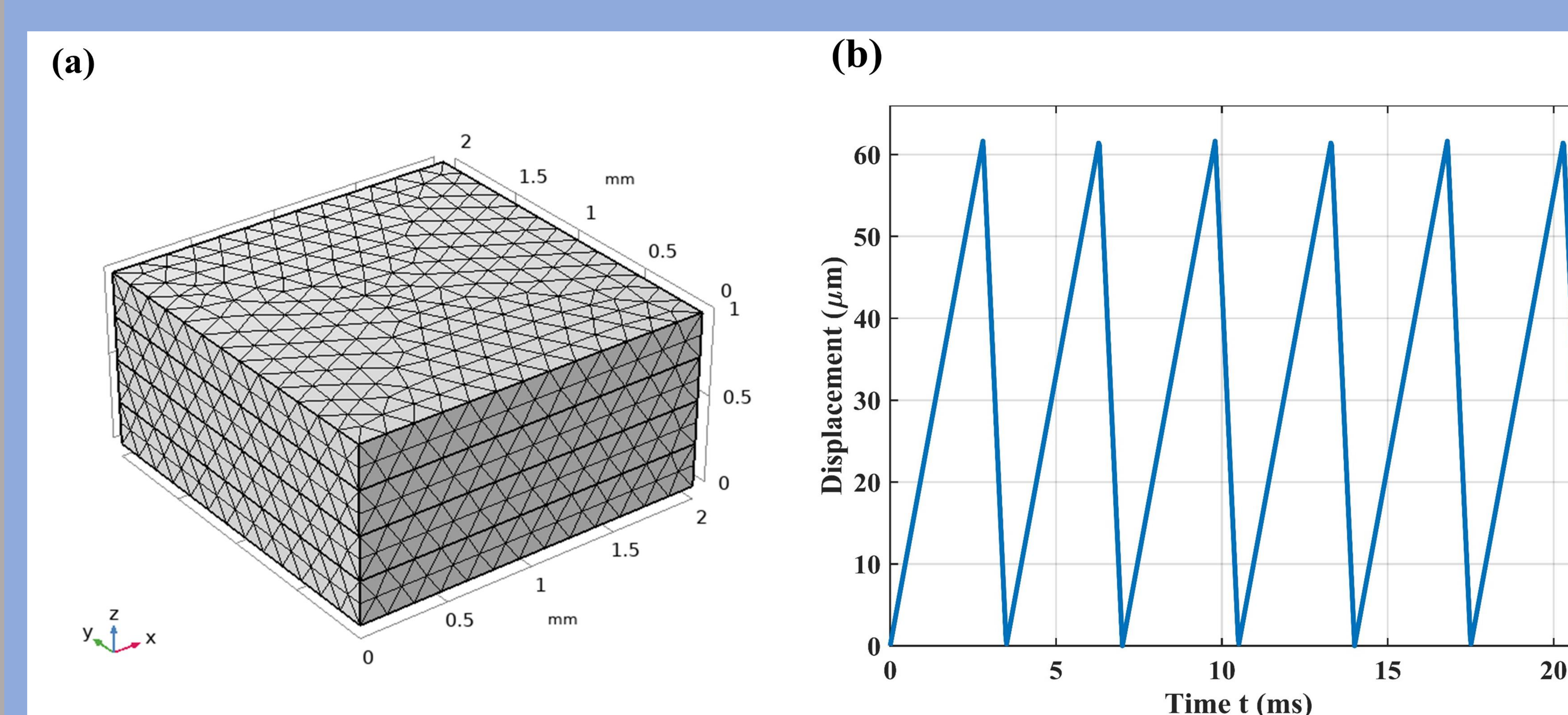
Step 2: As the external voltage is gradually applied from time t0 to t1, the slow de-formation stage of the sawtooth wave begins. The stator slowly powers up and ex-tends. Due to static friction, the slider moves in tandem with the stator during this phase.



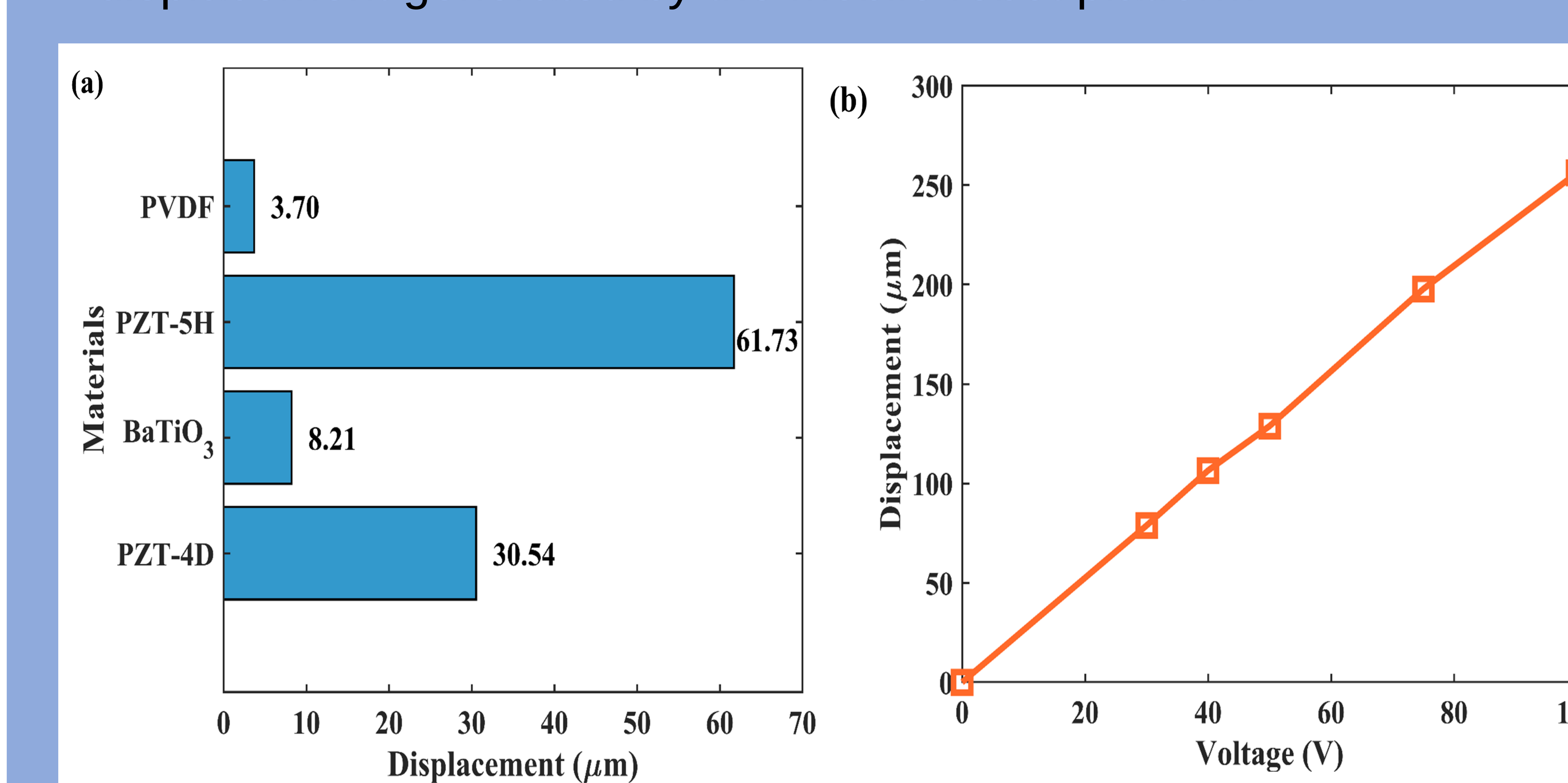
Step 3: During the rapid deformation stage (t1 to t2), the stator quickly loses power and retracts to its original position. In this phase, the slider slips against the stator due to inertia, moving a small distance backward. Kinetic friction between the slider and the frictional rod causes this reverse movement.

Results & Discussion

- Four different piezoelectric materials—PVDF, PZT-5H, $BaTiO_3$, and PZT-4D to determine the best actuation performance under a fixed applied voltage



- PVDF exhibited the lowest actuation, while PZT-5H achieved the highest displacement of 61.73 µm.
- PZT-5H produced 16.6 times more actuation than PVDF and more than twice that of the second-best material, PZT-4D
- positive linear relationship between the applied voltage and the displacement generated by the mobile robot platform



Conclusion

- Superior performance of ceramic-based PZT-5H, which outperformed other materials, including flexible PVDF.
- exceptionally high piezoelectric coefficients of PZT-5H make it ideal for enhanced actuation and potential energy harvesting applications

References

- Meyer C, Sqalli O, Lorenz H, et al. Slip-stick step-scanner for scanning probe microscopy. *Rev Sci Instrum*; 76.