IMEC’s ultra-low power actuator suitable for in-vivo biomedical applications

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Introduction: Actuators in Biomedical Applications

- Actuators applications in the human body:
  - Imaging/Scanning
  - Positioning
    - µProbes for neural stimulation/recording
  - Surgery
    - µGrippers
    - µRobots

Arizona State & Sandia (2005)

Receveur et. al. (2007)
Actuators in Biomedical Applications: Requirements and challenges

- Minimal invasive/obtrusive
  = miniaturization
- Long (battery) life time
  = ultra low power actuation
- Safe
  = low voltage
- Operational in aqueous environment
  = hermetic packaging

Actuator implementation options?

- Electrostatic?
- Thermal?
- Inchworm
- Polymeric?
- Piezoelectric?
- Chemical Reaction?
Design:
A New Electrostatic Inchworm Actuator

Fabrication:
SOIMUMPs Process

- Simulation & design: IMEC
- Fabrication: Multi-User MEMS Process (SOIMUMPs) based on SOI wafers
Results:
Actuators with different characteristics

11 V, ± 50 μm range, ~1 μm step size, 195 μN

~50 steps/sec

A-Probe-1
Results:
Actuators with different characteristics

9 V, ± 50 µm range, ~ 0.4 µm step size, 306 µN
~300 steps/sec

A-Probe-2

Results:
Actuators with different characteristics

12 V, ± 50 µm range, ~ 130 nm step size, ~0.4 mN
~600 steps/sec

A-Probe-3
Results:
Typical displacement curve

![Graph showing displacement curve](image)

**Results:**
- Typical displacement curve
- 12 V, ± 50 µm range, ~130 nm step size, ~0.4 mN

**Actuator packaging:**
Challenges

- MEMS are vulnerable: protection is required
- Operation in liquid environment: hermetic package is required to avoid
  - sticktion of MEMS device
  - electrolysis
  - corrosion
Actuator packaging: Solution

- Flip-chip bonding of glass cap

Actuator packaging:
How to combine a moving device with a hermetic packaging?

- Solution: use hydrophobic coatings (Teflon)

- Body liquid is repelled by hydrophobic surface
- Large contact angle + small gap
- No extra spring constant
Actuator Packaging Results: Glass capped device

operation in air

Actuator Packaging Results: Glass capped and Teflon coated device

operation in water
Conclusions:
Comparison with state of the art

Conclusions

• Low voltage inchworm actuator
  - Lowest operating voltage inchworm actuator (6 V)
  - Reliable and large force prototypes:
    • 11 V, 0.2 mN
    • 9 V, 0.3 mN
    • 12 V, 0.4 mN
  - Lifetime tested up to 20 million steps
  - Max. speed up to 2 mm/sec

• Packaging
  - Packaging using glass cap
  - Hydrophobic coating
  - Working actuator in aqueous environment

• Outlook:
  - Biocompatible coating for full compatibility with human body