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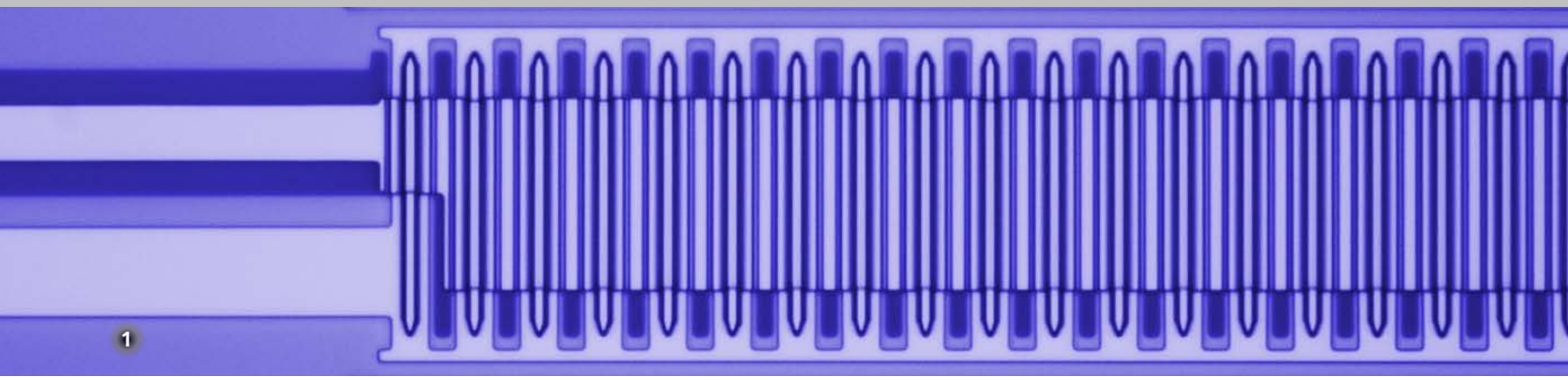


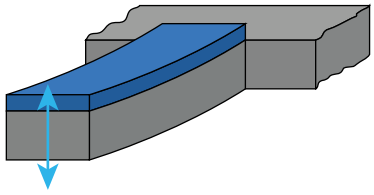
1 *Out-of-plane electrostatic bending actuators.*

NANOSCOPIC ELECTROSTATIC DRIVES

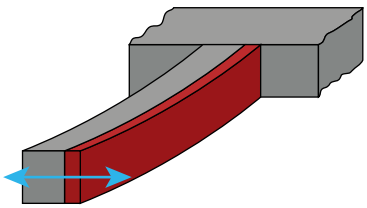
We offer research, development and design solutions for micro components and systems containing actively movable parts (MEMS). For this purpose a novel class of electrostatic bending micro actuators – so-called "Nanoscopic Electrostatic Drives" (NED) – was developed. NED actuators enable large quasi-static deflection at low power consumption and moderate control voltages. The novel actuator class is compatible with existing MEMS technologies – like surface and bulk micromachining as well as with CMOS technologies. Fraunhofer IPMS deploy these technologies in MEMS-based microsystems on various fields of applications.

The novel MEMS-based bending actuator features:

V-NED: Enables vertical deflection (out-of-plane movement)



L-NED: Enables lateral deflection (in-plane movement)



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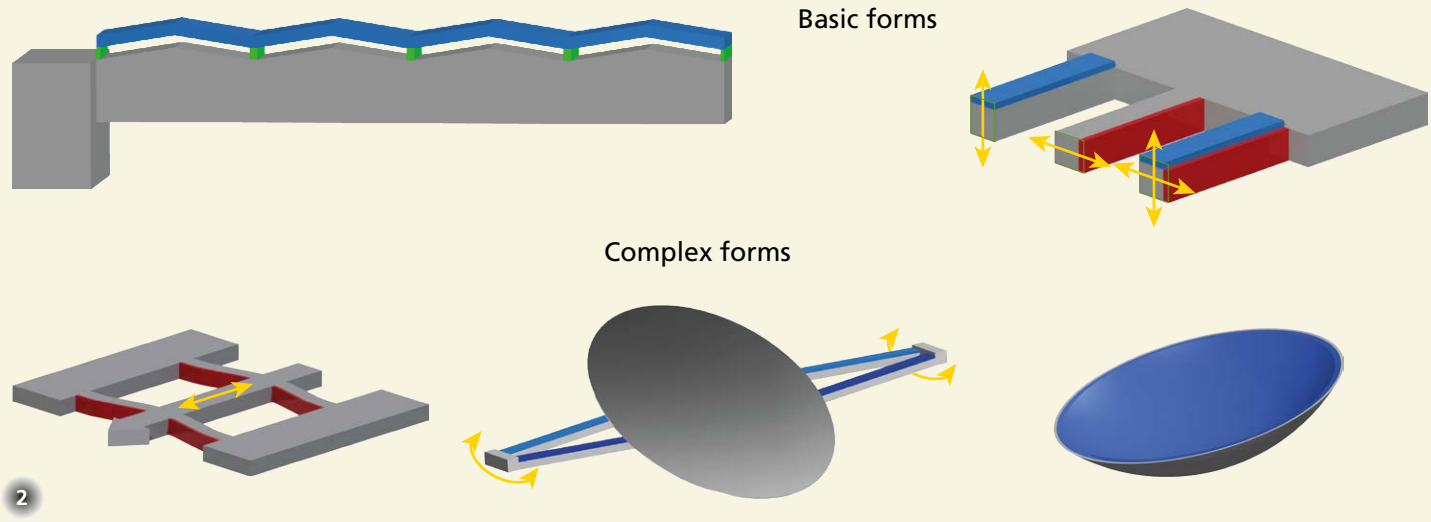


2 *Basic movement patterns.*

Functionality

Huge electrostatic forces at moderate control voltages are generated by up to 200 nm thin electrode separations. Due to a suitable electrode topography the electrostatic forces will be transformed into lateral forces that bend the cantilever:

- **NED being**: MEMS-based bending actuators, that are an alternative to bimorph actuators (piezoelectric or thermomechanical effect). They are made with surface or bulk micromachining on silicon wafer substrates.
- **Novelty**: On basis of the novel actuation principle the NED quasi-static deflection is larger than the electrode separation. Large cantilever tip deflections are possible at low control voltages. We have developed verified technologies that allow nanometer-high precision and up to 100 µm large quasi-static actuation (2 mm long cantilever, 60 V) as well as binary-coded digital deflections.
- **NED actuators feature**: Quasi-static, resonant and digital deflections.

CMOS compatibility

Enables an electronic integration into the bending actuators and the integration of the NED actuators into CMOS integrated circuits as well. Perspective: Strong integration of actuators, sensors and electronics within a semiconductor device.

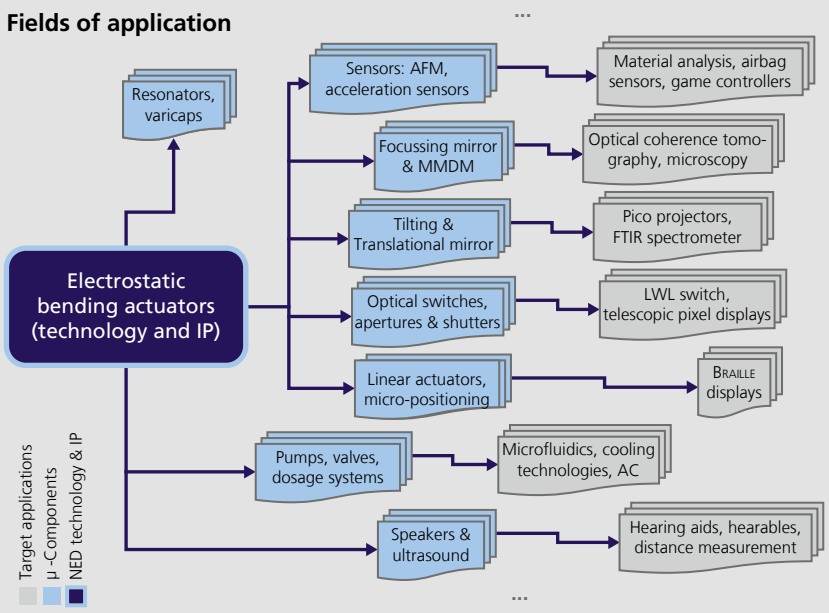
No Hysteresis

Enables determined deflection. A closed-loop (feedback) control is not required.

RoHS compatibility

Enables bending actuators that are compliant with RoHS directive and demonstrates an alternative solution for piezo ceramics.

Fields of application



The novel actuator class can greatly improve the performance of present microsystems. In addition, the actuator class provides completely new design solutions for microsystems and their applications. The possible range of application is large. Currently, the use of NED actuators in quasi-static tilting mirrors, micropumps and MEMS-based loudspeakers for hearing sound and ultrasound are being developed. Electrostatic bending actuators – to use as electroacoustic transducers – are developed for the future usage in hearing aids, hearables and in-ear-headphone devices. The use of MEMS-based speakers in smartphones, tablets or other gadget is further aimed by our developments.