ELECTROSTACTICALLY IN-PLANE DRIVEN SILICON MICROPUMP FOR MODULAR CONFIGURATION

S. Uhlig[1,2*], *M. Gaudet*[1,2], *S. Langa*[1,2], *K. Schimmanz*[2], *H. Conrad*[1], *B. Kaiser*[1], *H. Schenk*[1,2]
[1] Fraunhofer Institute for Photonic Microsystems, IPMS, Dresden and Cottbus, Germany
[2] Chair of Micro and Nano Systems, Brandenburg University of Technology, BTU, Cottbus, Germany

ABSTRACT

We present an in-plane reciprocating displacement micropump for liquids and gases which is actuated by a new class of electrostatic bending actuators capable of deflecting beyond the electrode gap distance. The so called "Nano Electrostatic Drive" (NED) actuator was introduced by us in 2015 for out-of-plane actuation. The device presented utilizes an in-plane actuation solution. Depending on the requirements of the targeted system, the micropump can be modularly designed to meet the specified differential pressures and flow rates by a serial arrangement of the actuators and parallel arranging pump-base units respectively.

KEYWORDS

MEMS; Micropump; Electrostatic Actuation; Nano e-Drive; In-plane reciprocating displacement micropump

INTRODUCTION

Electrostatic actuation has many advantages in microelectromechanical systems (MEMS), in terms of scalability, fast response time (<µs), simplicity in fabrication and low power consumption. However, the majority of integrated electrostatic drives in microfluidic handling systems such as micropumps [1] and microvalves [2] devices are limited in either deflection or driving voltage, which results in higher power consumption or low stroke volumes. With the novel concept of the "Nano Electrostatic Drive" (NED) driving principle, introduced in 2015 [3], we are able to deflect beyond the limiting gap distance.

In addition, the majority of mechanical reciprocating micropumps [1] work with an out of plane mechanism of a membrane clamped at its perimeter, that needs to be extended to large chip areas in order to increase the stroke volume. Furthermore, a hybrid assembly mechanism of actuator and pump is necessary in many cases. We propose a monolithic fabricated device by CMOS-compatible bulk micromachining processes that can be modularly designed to meet flow rate and differential pressure specifications for pumping liquids and gases.

ACTUATION

The NED-actuators commonly consist of a series of defined shaped electrodes separated by an electrostatic gap and insulating spacers [3]. Upon applying a control voltage V, the electrostatic force cause to curve the actuator. As a simple approach, the NED can be considered as a Bernoulli beam with a constant bending moment M, i.e. constant radius of curvature R along the beam, defined positive as in Fig. 1.

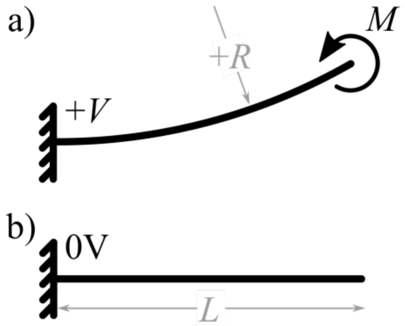

Figure 1: Working principle of clamped-free NED-actuator with length L. (a) Actuated state - circular bending line, with constant bending moment M i.e. const. radius of curvature R. (b) Non-actuated state.

By adding four of these NED-Actuators and rearranging them to a clamped-clamped (c-c) configuration with a length $4L = L'$ and use of alternating radius scheme $+R$, $-R$, $-R$, $+R$, the effective bending Moment M_{eff} is $2M$.

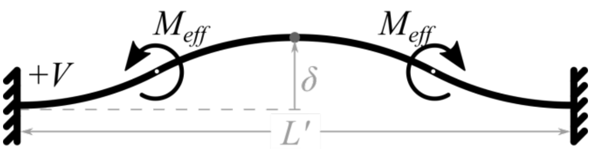

Figure 2: Bending line of four rearranged NED-actuators to c-c configuration, when actuated.

The maximum deflection δ_{max} can be derived for the case of pure bending to:

$$\delta_{max} = \frac{M_{eff}\,L'^2}{32\,EI},$$

where EI is the bending stiffness of the actuator. Thus, the stroke volume ΔV of the NED-actuator is the area passed over by the actuator multiplied by its height h, $\Delta V = \left({L'}/{2}\ \delta_{max}\right)\ h$.

WORKING PRINCIPLE

The maximum pressure P_{max} that a single NED-actuator in c-c configuration is able to generate can be estimated by its force at middle point at zero displacement $F_{BL}(\delta = 0)$. The so called "blocking force" given by: