Micromechanical Step-by-step Switchgear

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Introduction

Technical applications often require mechanical structures which make it possible to very rapidly start up different predefined switch positions and to maintain them subsequently. The same applies to microsystem technology. For this purpose analogously operated components generally require a highly dynamical position registration and control. In precision engineering mechanical step-by-step switchgears are frequently used in such cases [1]. This well-know operating principle has been taken up, miniaturized, and adapted to microtechnologies [2]. Since single-crystal silicon exhibits excellent mechanical properties [3], the SOI technology [4] has been chosen.

Working principle

Figure 1 depicts the working principle of such a device. Advancing to the next position by one tooth is effected in six individual steps, at least one of the shift dogs having to be engaged in each case in order to keep the current position. The lower shift dog (C) can be engaged with the teeth by means of a straight-line infeed movement. In addition to this, the upper shift dog (B) can be deflected upwards and downwards by half a cycle size, i.e. 2.5µm.

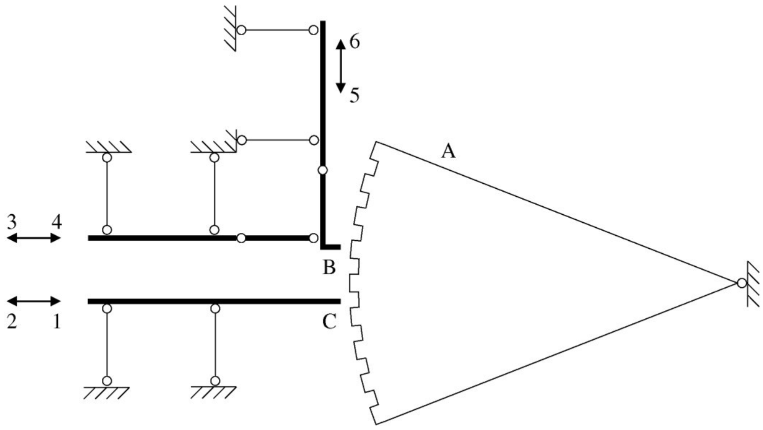

Fig. 1:Working principle of a step-by-step switchgear; A: toothed segment; B,C: shifting dogs; 1...6: stops

Design

The radius of the toothed segment (A) of approximately 1.9mm results from the designing guidelines that a make-and-break cycle has to correspond to a length of arc of 5µm and an angle of 0.15°. Thus an overall angle of 15° can be passed through in one hundred cycles.

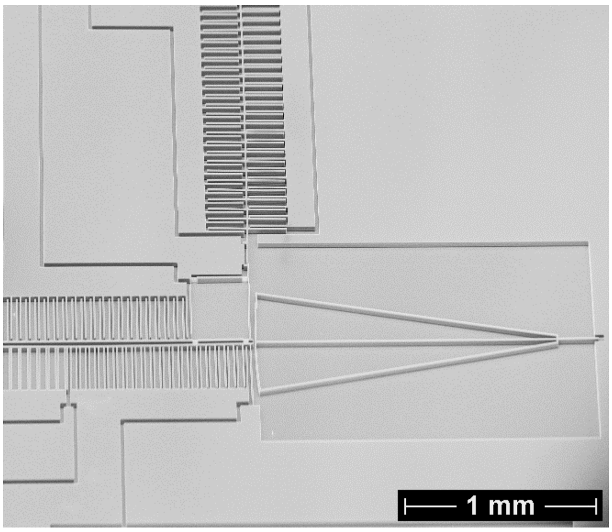

Figure 2: Step-by-step switchgear with toothed segment and electrostatic comb drives

Figure 2 is a SEM micrograph of a manufactured element. The toothed segment is good to be seen as well as the electrostatic drives. The latter have been designed for an operating voltage of 30 V. The individual electrodes are insulated from each other by separation grooves and the oxide situated below them. Stops limit the travels. This renders superfluous any control, and the activation can take place by means of a logical circuit, which drives the individual electrodes via driver transistors. Figure 3 shows the individual trapeziform teeth along with the shifting dogs and the typical profile which is produced in vertical plasma etching (STS). The movable structures were released by isotropically etching the oxide out using HF.

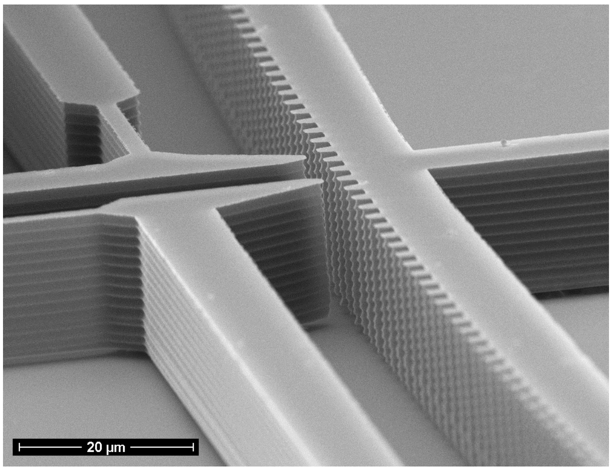

Figure 3: Close-up SEM micrograph of the individual teeth and the shifting dogs

The thickness of the upper wafer and thus freely movable structures amounts to 15 µm. All local compliances [5], the circles in Fig.1, are 25µm long and 3µm wide. The functional efficiency of the mechanism could be proved. Reliably advancing to the next position was possible both in single-step operation and at frequencies of up to 1kHz, the switching speed being mainly limited by the inertia of the drives.

Summary

We succeeded in scaling down the operating principle of a step-by-step switchgear as it is known from precision engineering to micromechanical dimensions, adapting it to the SOI technology and proving its functionality. High working frequencies could be reached because of the small masses of the structure. The results of this work have been published [6-8].

References

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