Scanning micromirrors with thermal actuation

A. Zarzycki[a,b], W. Gambin[b], S. Bargiel[a], K. Laszczyk[a], L. Nieradko[a], Ch.Gorecki[a]

[a] *Département MN2S, FEMTO-ST, Université de Franche-Comté,*
16 Route de Gray, 25030 Besançon Cedex, France
e-mail: arthur.zarzycki@femto-st.fr

[b] *Warsaw University of Technology, Department of Applied Mechanics*
ul. Sw. Andrzeja Boboli 8,02-525 Warszawa, Poland
e-mail: a.zarzycki@mchtr.pw.edu.pl

New designs of two types precise, thermally actuated scanning micromirrors or shortly microscanners are proposed. The first micromirror is capable for one-dimensional scanning and the second for two-dimentional one. In both cases a thermal actuation is used. Thermal actuators, provide large scan angle, nearly linear deflection versus power relationship, moderate power consumption and high mechanical robustness. Moreover, fabrication of such microscanners bases on a quite simple technology. Thermal actuators do not operate with as high frequency as electrostatic or piezoelectric actuators, but high enough for some optical applications. Limited frequency is mainly determined by thermal time constants, but it can be improved by using materials with high thermal conductivity.

The first, simpler type of microscanner consists of a micromirror and two actuators placed on the opposite sides of the mirror. The actuators have a form of bimorph cantilever beams. Different coefficients of thermal explanation of the composing layers in connection with applying thermal energy cause bending of the beam.

The second type of microscanner consists of a micromirror, moveable~~,~~ rigid frame and four actuators. Actuators has the same form as described above. One pair of parallel actuators is fixed directly to the mirror and to the movable frame. The second pair of the bimorph beams, situated perpendicularly to the first one, joins the frame with a silicon substrate.

The fabrication process is very simple and bases on typical materials and technique. The same process can by apply to one- and two-dimensional microscanner. In both cases micromirrors are composed of thick silicon base covered with an aluminum layer on one side. The aluminum layer assure a very ~~a~~ good reflexivity, whereas thick silicon provides a good flatness of the mirror, both static and dynamic mode of the scanner's work. The movable frame is made of silicon and has the same thickness as the base of the mirror. This part of the device is partly covered by aluminum paths which are used for applying electric current to the actuators. Actuators, as it has been mentioned, have layered structure. The two most important layers are the bottom one (made of 3 μm thick silicon) and top one (made of 2.2 μm thick aluminum). The silicon layer has a low coefficient of thermal expansion, so it is called a passive layer. The aluminum layer has a large coefficient of thermal expansion and is called an active layer. Between those two layers a platinum resistive heater is placed. The heater is additionally encapsulated by silicon dioxide. It protects against passing electric current thru other parts of the device then the heater. The heater has a form a meander line of the thickness of 0.2 μm and 5 μm width. The thickness of silicon dioxide is 0.1 μm on both side of the heater.

The proposed designs of the scanners have some advantages in compare to other similar devices. It has been obtained by a special position of the mirror's rotating axes with respect to the actuators' beams. In the presented work, the axes of rotation lie on the surface of the mirror and cross its center. Due to this fact the distance of the center of the mirror from the light source is the same during the whole scanning process, so it causes that the point of the light reflection from the mirror is immovable. Moreover, because the actuators are submitted pure bending only, the inertial moments of movable parts, as well as the influence of air damping are minimized. It allows to achieve higher work frequency. Additionally, there is neither thermal nor mechanical coupling between the perpendicular actuators in the case of the two-dimensional scanning micromirror. It is very important, when the device would be used for image displaying.