A Hybrid Electrostatic-piezoelectric Integrative Actuated Microsystem for Robot-assisted Laser Phonomicrosurgery

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Several forms of microactuators have been investigated for microrobots, for example, electrothermal actuators [1,2], electrostatic actuators [3], piezoelectric actuators [4], electromagnetic actuators [5], acoustic actuators, pneumatics actuators, and shape memory alloys. Key enable technology for these miniaturized actuators is microfabrication processes for microelectromechanical systems because the processes can create submicron features with high precision, mass productive, and low cost. Examples of fabricated systems have been developed and some medical applications have been reported [1-5].

This talk provides literature reviews to compare advantages and disadvantages of micro actuators for biomedical applications. Then, we propose a new device that is devoted to medical applications (laser phonomicrosurgery) within the European µRALP-project [6]. Based on precise micromachined electrostatic and piezoelectric actuators, the platform is assembled using micro assembly approach. With sizes less than 5mm x 5mm x 5mm, the proposed design has three degree-of-freedom: two rotational motions around the in-plane axis and one out-of-plane translational motion. Static and dynamic analysis of the device is simulated by Finite Element Analysis and compared to theoretical calculations. Fig. 1 depicts the CAD-scheme of the designed device. This system preserves outstanding characteristics of both actuators for fast response and low power consumption. Moreover, challenge of electrostatic actuator for a high driving voltage and challenges of piezoelectric actuator for hysteresis effects and charge leakage problems are reduced with collaborated controls and operations of two sets of actuators.

By integrating two types of actuators, the speed and range of motion can be improved. The target applications of this system include laryngeal microsurgery, optical coherence tomography (OCT), and minimally invasive surgeries (MIS) that require high speed and accuracy.

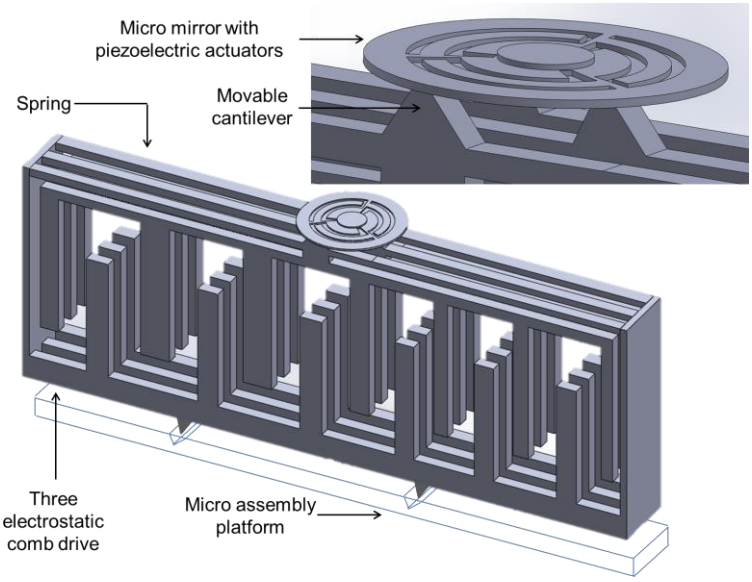

Fig. 1 Schematic of micro robot design for robot-assisted laser phonomicrosurgery with two sets of micro actuators.

References

[1] J. Sun, S. Guo, L. Wu, L. Liu, S. Choe, B. S. Sorg, and H. Xie, "3D In Vivo optical coherence tomography based on a low-voltage, large-scan-range 2D MEMS mirror," Opt. Express **18**(12), 12065 (2010).

[2] J. Singh, J. H. S. Teo, Y. Xu, C. S. Premachandran, N. Chen, R. Kotlanka, M. Olivo, and C. J. R. Sheppard, "A two axes scanning SOI MEMS micromirror for endoscopic bioimaging," J. Micromech. Microeng. **18**, 1 (2008).

[3] A. D. Aguirre, P. R. Hertz, Y. Chen, J. G. Fujimoto, W. Piyawattanametha, L. Fan, and M. C. Wu, "Two-axis MEMS scanning catheter for ultrahigh resolution three-dimensional and en face imaging," Opt. Express **15**(5), 2445 (2007).

[4] K. H. Koh, T. Kobayashi, and C. Lee, "A 2-D MEMS scanning mirror based on dynamic mixed mode excitation of a piezoelectric PZT thin film S-shaped actuator," Opt. Express **19**(15), 13812 (2011).

[5] K. H. Kim, B. H. Park, G. N. Maguluri, T. W. Lee, F. J. Rogomentich, M. G. Bancu, B. E. Bouma, J. F. de Boer, and J. J. Bernstein, "Two-axis magnetically-driven MEMS scanning catheter for endoscopic high-speed optical coherence tomography," Opt. Express **15**(26), 18130 (2007).

[6] The European µRALP project: http://www.microralp.eu/