A FULLY CHIP-SCALE INTEGRATED X-RAY SOURCE

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ABSTRACT

In this work, we present a pioneering accomplishment: the world's first X-ray source entirely fabricated using MEMS technology, unlike traditional and other miniaturized X-ray sources, where microtechnology is applied only to some elements, most often to electron emitter [1,2]. The developed MEMS X-ray source is constructed from silicon and glass wafers. The chip contains silicon electrodes: a cathode with a field emitter, an extraction gate, a focussing electrode, and a target [Fig.1]. Borosilicate glass is utilised for spacers between the electrodes. The electron source is formed from a composite of carbon nanotubes and PVP deposited onto a silicon substrate using thermo-mechanical method. The extraction electrode, made of silicon, has an etched through-hole and is used to control the emission current and, as a result, the intensity of the X-rays. The focussing electrode enables electrostatic focussing of the electron beam. The target is a silicon chip with a thin membrane of about 15 µm, which can be covered with a thin nanometric metallisation layer. The X-ray source is integrated with an ion-sorption pump to maintain high vacuum conditions. The external dimensions of the complete structure are 30×12 mm², with a column height of 6.2 mm. Anodic bonding is employed for connecting silicon and glass elements, with the final bonding conducted under vacuum conditions to ensure initial vacuum inside the structure. The hermetically sealed MEMS X-ray source [Fig.2a] is sheathed in a polymer layer to prevent electrical breakdown between the electrodes. As a result, it is a complete self-contained device [Fig.2b].

The characterization of the MEMS X-ray source was conducted outside a vacuum chamber. The ion-sorption pump maintained a stable high vacuum within the structure during device operation. The CNT electron source provided a high emission current, even at low voltages on the extraction electrode, ultimately leading to efficient X-ray beam generation, showcasing excellent performance in capturing precise images of small objects [Fig. 3]. This opens a way for new applications in medical diagnostics, particularly when integrated with microfluidic systems, materials research, or space exploration.

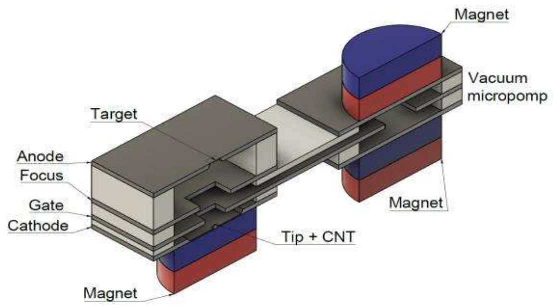

Fig. 1. Construction diagram of a MEMS X-ray source

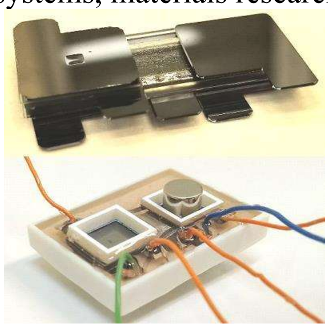

Fig. 2. a) Image of the MEMS X-ray source structure, b) complete, encapsulated MEMS X-ray source with a protective polymer layer

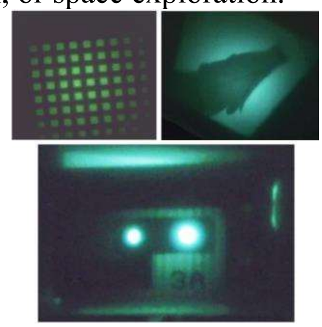

Fig. 3. X-ray image of: a) a silicon mesh (UA = 10kV), b) a leaf (UA = 12kV, c) PCB: light spots – via-holes, black area – metal, green area – laminate (UA = 30kV)

References

[1] T. Grzebyk, K. Turczyk, A. Górecka-Drzazga, J. A. Dziuban, „Towards a MEMS transmission point X-ray source", 34th IVNC (2022).

[2] A. Górecka-Drzazga, "Miniature X-Ray sources", Journal of Microelectromechanical Systems, vol. 26, 1 (2017) 295-302.

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A2:Vacuum-Microelectronics and Vacuum-Nanoelectronics Technologies
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