Microfabricated Cells With Small On-Chip Rb Dispensing Component

Ryo Murakami, Shun Kiyose, Yoshikazu Hirai
Kyoto University, Kyoto daigaku-Katsura, Nishikyo-ku, Kyoto 615-8540, JAPAN

We present a wafer-level fabrication technique for small rubidium (Rb) cells using a silicon (Si)-based alkali-metal dispenser. This method enables the decomposition of rubidium azide (RbN_3) with Si pillars featuring multiple re-entrant structures to produce Rb by thermal heating process. Conventional grid dispenser designs have limited the miniaturization of these cells [1]. To overcome this problem, we propose a radial dispenser design surrounding the pipetting cavity, which significantly reduces the cell size while maintaining efficient Rb production in the cell (Fig. 1a). The proposed approach successfully fabricated miniaturized cells at the wafer level.

Microfabricated alkali-metal vapor cells are essential for coherent population trapping (CPT) atomic clocks [2]. Current techniques for filling these cells with pure alkali metals and buffer gases involve thermal or UV decomposition of RbN_3, requiring high temperatures or prolonged irradiation times [3]. In contrast, the microfabricated Si pillars with re-entrant structures enable rapid, low-temperature Rb production, reducing outgassing and enhancing long-term frequency stability. However, existing cell sizes (e.g., 64 mm^2) are too large for integration into MEMS atomic clocks, limiting the number of cells per wafer.

Our newly designed Rb vapor cell integrates a CPT optical cavity and an Rb-dispenser component connected via microchannels, that is fabricated using a single-mask Si microfabrication process (Fig. 1b). The re-entrant structures along sidewalls were fabricated by isotropic and anisotropic deep reactive ion etching. The radial dispenser design reduces the cell size by approximately 55% compared with conventional grid designs.

The experimental results confirm that re-entrant structures with a high ratio of groove width to scallop size enhance Rb production efficiency. The fabricated cells with a footprint of 36 mm^2 demonstrated successful Rb production at 370 °C within 10 min (Fig. 1c). Spectrophotometer measurements of the Rb-D_2 line peak showed a sufficient Rb filling for atomic clocks. Therefore, this wafer-level fabrication technique advances the miniaturization and performance of Rb cells, contributing to the development of compact, high-performance MEMS atomic clocks.

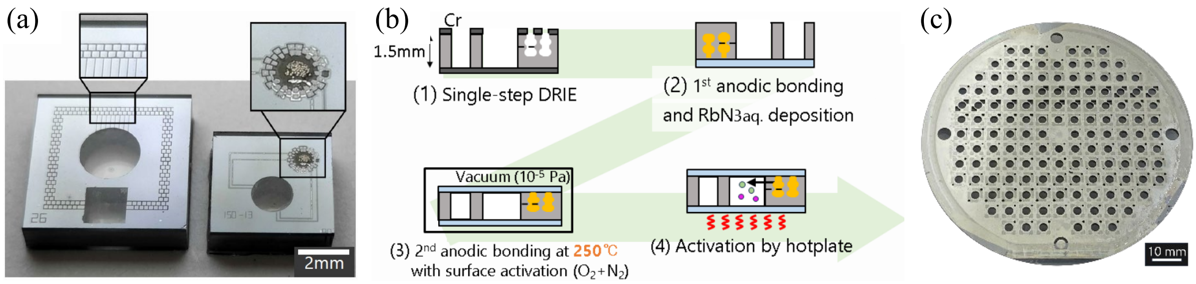

Figure 1. (a) Left: conventional dispenser design in the 64-mm^2 cell. Right: present 36-mm^2 cell with the radial dispenser. (b) Wafer-level fabrication of the Rb-filled cell: (1) Two cavities (through holes) and re-entrant structures were simultaneously fabricated. (2) RbN_3 solution was injected. (3) RbN_3 was sealed by Si-glass bonding. (4) RbN_3 was decomposed by the thermal heating process. (c) Optical image of the fabricated cells at the wafer level (4-inch wafer).

1. S. Kiyose, Y. Hirai, O. Tabata and T. Tsuchiya, Microfabricated alkali metal vapor cells filled with an on-chip dispensing component, Jpn. J. Appl. Phys. **60**, SCCL01 (2021)
2. J. Kitching, Chip-scale atomic devices, Appl. Phys. Rev. **5**, 031302 (2018)
3. P. Knapkiewicz, Technological assessment of MEMS alkali vapor cells for atomic references, Micromachines **10**, 25 (2019)