LOW TEMPERATURE INDIUM-BASED SEALING OF MICROFABRICATED ALKALI CELLS FOR CHIP SCALE ATOMIC CLOCKS

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ABSTRACT

In this paper, the development of a low temperature bonding process focused on indium-based technology for microfabricated alkali cells is presented. The intended application is the use of these cells in chip scale atomic clocks. The existing technology is mainly based on anodic bonding. For some applications, such as where wall coating is used instead of buffer gas, anodic bonding cannot be applied because of the relatively high temperature of the process.

INTRODUCTION

During recent years, many efforts were made to develop and optimize the micro-fabrication of alkali cells for chip scale atomic clocks. Most of them are based on silicon-glass anodic bonding [1, 2]. For some applications, such as the use of a wall coating instead of buffer gas inside the cell, the temperature used during this process (typ. ~300°C), is too high and has to be avoided. For this reason, a new low-temperature indium-based sealing technique was developed and tested on alkali reference cells containing buffer gas. Part of these results was already presented in [3].
We will focus here on the sealing technique based on the use of an indium rim placed between two silicon cavities.

FABRICATION

The alkali reference cells preforms are fabricated using the technology described in [2], based on DRIE etching of silicon and anodic bonding of a glass wafer. These wafers are diced into single chips before being cleaned. A dedicated vacuum system allows injecting alkali (Cs or Rb) inside one preform, and the sealing can finally be performed in the same machine with a controlled atmosphere. The sealing itself is based on a relatively thick (125µm) indium rim placed between the two silicon surfaces of the preforms. The bonding is obtained by heating (up to 140°C) and applying a pressure (about 1 atmosphere) on the sample. By varying the silicon thickness of the initial wafers, several cavity depths were produced, allowing an increase of the optical thickness with cavity depth. The bonding process is based on thermo compression of indium rims. These rims are prepared by cutting an indium foil into pieces having the desired shape. The process is shown in Fig. 1.

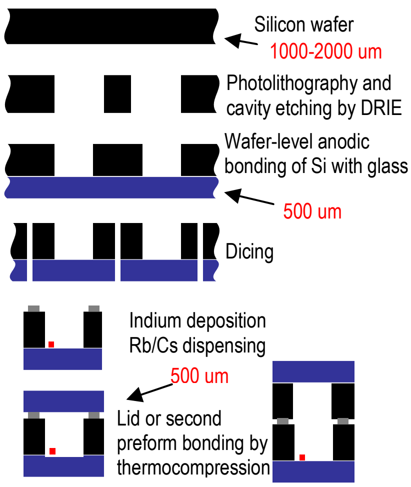

Fig. 1. Process flow of the cell fabrication.

a) b)

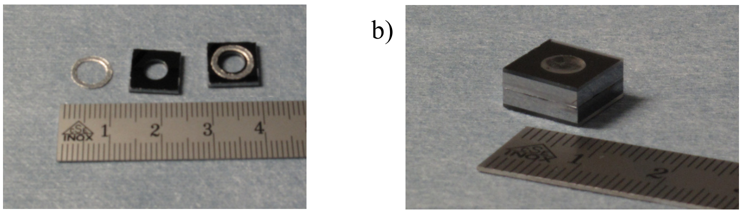

Fig. 2. Pictures showing: a) The indium rim and the preform before and after pre-assembly. b) A closed cell after low-temperature bonding.

Indium and Cell preparation

The indium rim is assembled manually on the silicon surface before being installed at its dedicated place in the filling/bonding machine. This technology allows bonding a silicon preform to a glass lid or a second silicon preform to increase the optical length of the cavity. Fig. 2 shows pictures of the indium rim and the preform before (Fig. 2.a)) and after (Fig. 2.b)) bonding. With a dedicated process, it is also possible to deposit indium or another metal by evaporation or sputtering.

Dispensing and bonding principle

A microfabricated preform is filled with alkali and closed in a controlled atmosphere. The dispensing of alkali is performed with a commercially available dispenser from SAES Getters. After being degassed, an applied controlled current heats the dispenser. Alkali gas is released and condenses inside the cooled preform. The next step consists in moving the trolley to the bonding position, controlling the chamber atmosphere with buffer gas if needed and moving the vertical piston to close the cell. To perform the bonding, the system is then heated up (max 140°C) and a pressure (1-2 bars) is applied. A schematic view of the system is shown in Fig. 3.

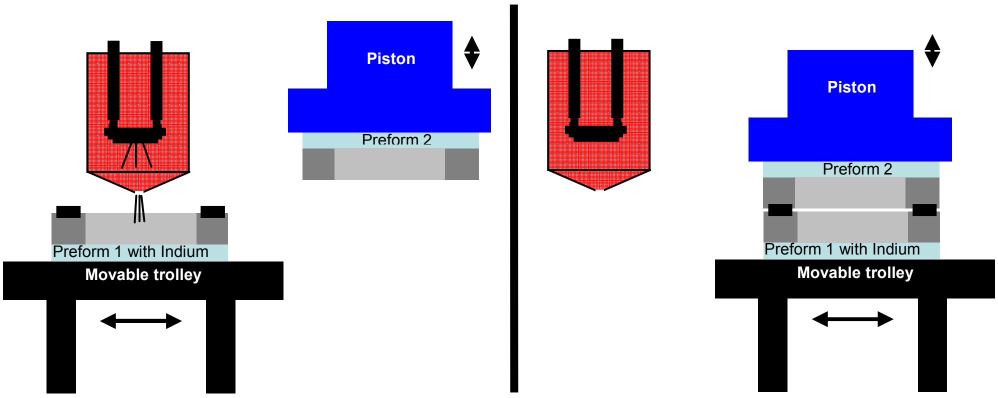

Fig. 3. Schematic view of the dispensing and bonding principle.

MEASUREMENTS

Absorption spectrum (Fig. 4.a)) and CPT signals [3] could be observed with these cells during a limited period of time. More details concerning the intended application and measurements conditions can be found in [4].
CPT measurements were performed on cells containing Rb and various buffer gas mixtures based on nitrogen and argon. Initial measurements show a good reproducibility of the cell buffer gas pressure and mixture but the current drawback of this method is the short cell lifetime limited to about 4 days when kept at high temperature (between 65 and 85°C) as shown in Fig. 4.b). In this graph, to represent the loss of signal, the contrast measured is the difference between the peak and the local minimum next to it. This lifetime issue is currently under investigation.
Even though the lifetime is limited, we have been able to record CPT resonances with indium bonded cells. The CPT resonance is observed in the optical transmission of a VCSEL (vertical cavity surface emitting laser) beam propagating through the cell. The VCSEL carrier frequency is locked on the Doppler broadened absorption line from the F=3 level in 85 Rb (D1-line at 795 nm). In addition the VCSEL current is modulated at 3 GHz to generate a first order sideband

close to resonance with the F=2 level in 85Rb. When we sweep the sideband (modulation frequency) across this resonance the DC level of the optical transmission increases by a few percent. The change in optical transmission is fitted by a Lorentzian curve to extract the linewidth and contrast. In Fig. 5 we show a CPT resonance recorded with a 2 mm long cell with a diameter of 5 mm (internal dimensions). The cell is filled with 30 mbar nitrogen buffer gas and heated to 85 °C. In addition the VCSEL current is modulated with a power of -6.5 dBm and the optical power is attenuated to 65 µW (before the cell). With these settings we observe a CPT contrast of 1.81 % and a linewidht of 1.55 kHz.

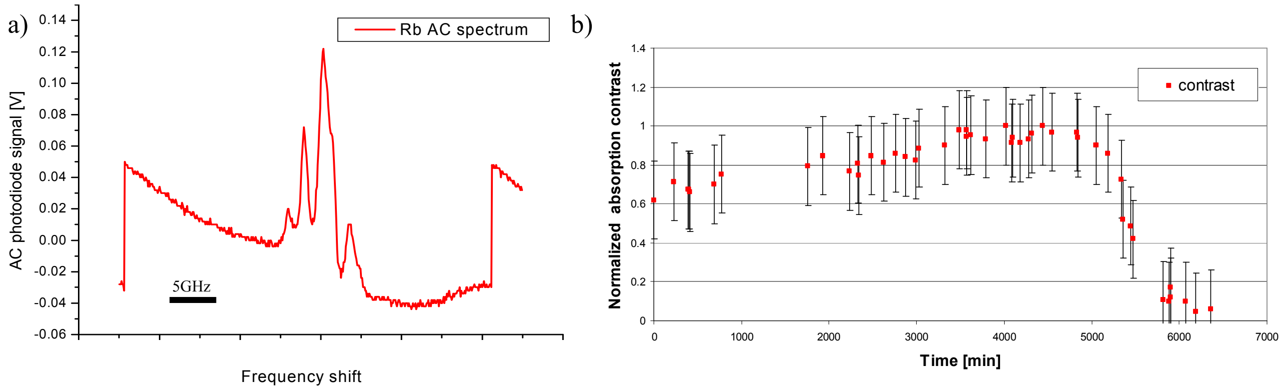

Fig. 4. Graphs representing: a) Absorption spectrum of a Rb-filled cell. b) Evolution of the absorption contrast versus time. The signal disappears after a couple of days at high temperature.

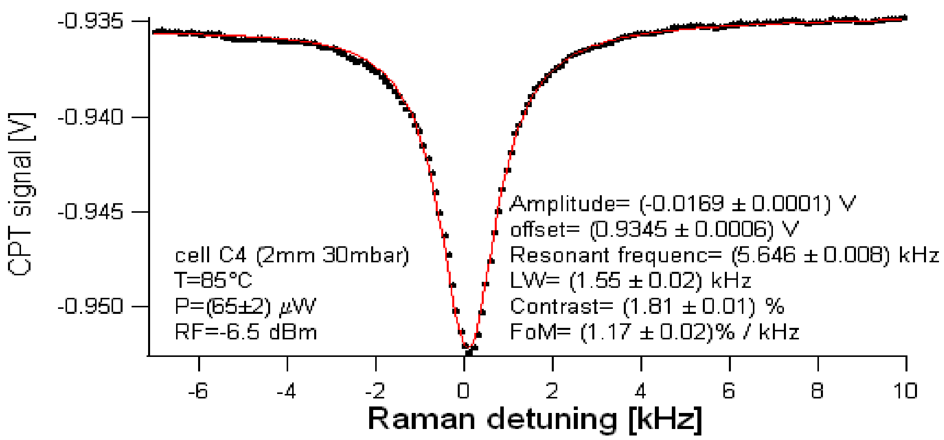

Fig 5. CPT resonance recorded with a micro-fabricated and indium sealed vapour cell.

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