SMAC+ – Assembly Processes for a Miniature Atomic Clock

J. Pierer, R. Jose James, S. Grossmann, L. Balet, J. Haesler, S. Lecomte

The development of a low-power miniature atomic clock (MAC) system requires a smart and efficient assembly solution. This paper reports on the different assembly and integration processes developed for a low-cost and low-power MAC physics package (PP) within the Swiss-MAC project.

The Swiss-MAC project [1] targets a miniature atomic clock for telecom applications for which the assembly and integration processes are key aspects to reach the requirements in terms of manufacturability and low production costs.

Standard materials and processes, known from the electronic packaging industry, were selected for the assembly of the MAC physics package (PP). Hence, it consists of several stacked printed circuit boards (PCBs), assembled and connected using adhesive and wire bonding, and used to mechanically and electrically connect the different components of the MAC. Figure 1 shows the individual PCB layers as well as a partially assembled MAC, with the atomic vapor cell and part of the magnetic shielding on the top.

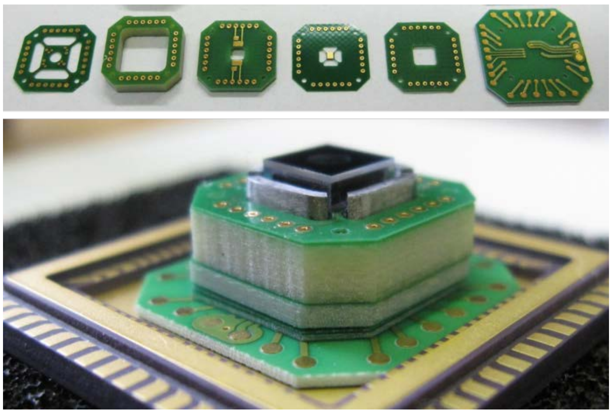

Figure 1: (top) Individual PCB layers to be stacked; (bottom) Partially assembled MAC physics package with the vapor cell on the top.

The lower part of the physics package contains a miniature heating plate with a VCSEL on top. This laser assembly is suspended for a better thermal insulation and is connected by gold wire bonding and electrically conductive adhesive. The challenging wire bonding process connects the suspended laser layer to a lower PCB through open cavities (Figure 2). The optical module (with prisms, quarter-wave plate, filter and photodiodes) is assembled around a central beam splitter cube using optically transparent UV curable adhesive and then stacked on top of the laser module. An optional collimating lens can be aligned to the laser emitter if needed.

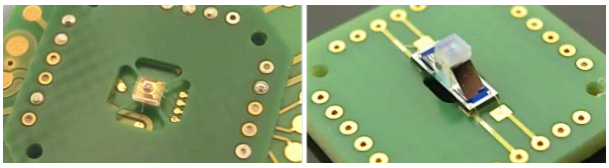

Figure 2: (left) PCB with assembled heater and laser; (right) PCB with optical assembly (optional collimating lens not shown).

The heart of the Swiss-MAC is the atomic vapor cell, which has the particularity to integrate a printed temperature sensor, resistive heaters and coils onto both of its glass windows [1]. It is mounted on a dedicated suspended and thermally isolated PCB. The electrical connection between both sides of the cell is obtained by wrapping the cell with a flexible PCB. Handling and bending the tiny flexible PCB turned out to be easier if it is cut in 3 individual PCBs, which are fixed around the cell using temperature curable adhesive. Conductive adhesive is then used for the electrical connection between those 3 flexible PCBs (top, bottom, edge). The atomic vapor cell is electrically connected to the flexible PBCs by conductive adhesive on one side and by wire bonding on the other side (Figure 3).

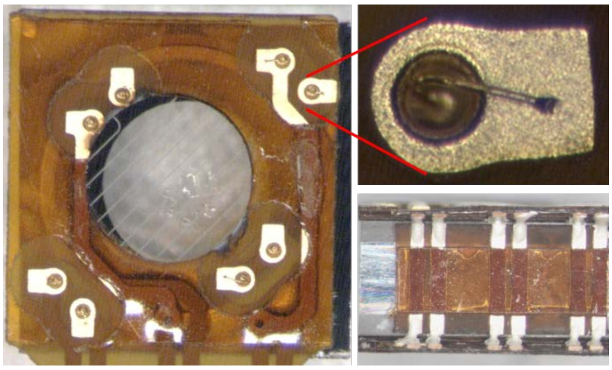

Figure 3: (left) Top view of the cell with attached flexible PCB; (top right) Gold wire bond; (bottom right) Flexible PCB on the cell edge.

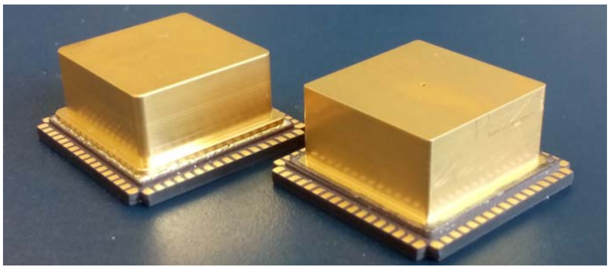

Figure 4: Vacuum encapsulated PPs (left) traditional soldering; (right) Seam welding followed by laser soldering of a hole on top of the lid.

Reducing the convective heat transfer in the PP and hence the power needed for heating the laser and the cell is obtained by vacuum encapsulation (Figure 4). Two different low temperature (<200°C) methods have been studied: i) low temperature solder based sealing and ii) localized sealing using a combination of seam welding and laser soldering. The best results were obtained with the second approach. This approach enabled a higher vacuum (<10 mbar) and a more reliable seal.

CSEM would like to thank the Swiss Confederation, the Canton of Neuchâtel, the Canton of Baselland and the Cantons of Central Switzerland for their financial support.

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[1] J. Haesler, *et al.*, "Miniature atomic clock: route to further miniaturization", CSEM Scientific and Technical Report (2013), 17