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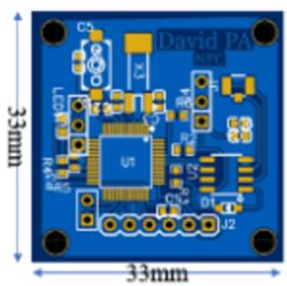
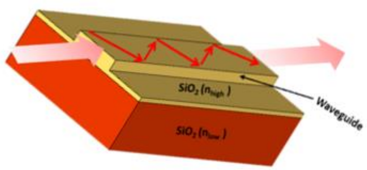
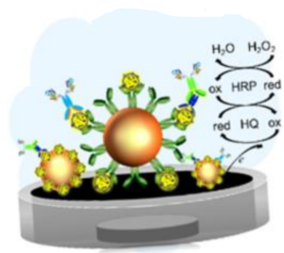
UNA MIRADA A LOS SENSORES EN LA PENÍNSULA IBÉRICA Y AMÉRICA LATINA: AÑO 2022

A LOOK AT SENSORS IN THE IBERIAN PENINSULA AND LATIN AMERICA: YEAR 2022







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M. Teresa S. R. Gomes e Marta I. S. Veríssimo

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MEMS RUBIDIUM VAPOR CELL FOR OPTICALLY PUMPED MAGNETOMETERS

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Introduction

Magnetoencephalography (MEG) is the technique that allows direct imaging of the human brain electrophysiology, through the measurement of the magnetic fields generated by the neuronal currents in the brain scalp [1,2]. MEG technology uses superconducting quantum interference devices (SQUIDs), which require a cryogenic cooling system, and, consequently, thermal isolation. The main disadvantage of the SQUIDs is the loss of the neuromagnetic field detection, as the distance between magnetic source and sensor increases. In very recent years, there has been a scientific effort in the development of alternatives to SQUIDs, eliminating the need for cryogenic cooling equipment [3,4]. Optically pumped magnetometers (OPM) based on vapor cells of alkali-metals have emerged as a promising alternative to SQUIDs [5]. The main benefit of OPMs compared to SQUIDs is the precision of measurement in very low magnetic fields, without the requirement of complex cryogenic equipment, which reduces the volume of the MEG system and the maintenance costs [1–3,6,7]. The vapor cells allow for precise measurement of the magnetic fields using optical spectroscopy: the spin of the atoms forms a collective moment that changes in the presence of an external magnetic field, resulting in the variation of the transmittance of the vapor cell containing the atoms of the alkali-metal [3]. One significant advantage of OPMs is the microfabrication possibility [3,8], which is addressed in this work. The two most used and commercially available alkali-metals vapor cells (cesium and rubidium) were firstly compared. As a result of this comparison, a miniaturized cell fabrication based on the generation of alkali-metal vapor inside a sealed MEMS structure is proposed.

Methods

In OPMs, the increase of the external magnetic field is translated into a decrease of the light transmitted by the pump beam through the alkali-metal vapor cell.

This phenomenon is more prominent if the direction of the magnetic field is perpendicular to the light beam emitted. To compare the most used alkali-metal vapor cells for low magnetic field applications, a convenient optical-magnetic setup was created. Two commercially available alkali-metal vapor cells, from Thorlabs, were acquired for this purpose: rubidium-87 (^{87}Rb) isotope [9] and cesium (Cs) [10]. According to the results of this study, a complete design of the vapor cell miniaturization is here addressed. The fabrication process is based on the conventional glass-silicon-glass sandwich structure. Three main chemical reactions are currently used for the production of Rb/Cs considering the MEMS cells application, and are summarized in **Table I**.

Table I: Summary of the main chemical reactions used for alkali-metals production. X is Rb or Cs.

Chemical reaction	Temperature	Observations	Ref.
$BaN_6 + XCl \rightarrow BaCl + 3N_2 + X$	200 ºC	Reversible reaction could be occurred which limits the sensitivity of the magnetometer.	[8]
$2XN_3 \rightarrow 2X + 3N_2$	450 ºC	Azide decomposition through UV light.	[11]
$2XCl + Ca \rightarrow 2X + CaCl_2$	720 ºC	Deformation of glass windows due to high temperature reaction. Granular Ca forms limits dispensing in MEMS cells.	[12]

Considering the proposed reactions, the alkali-metal azide decomposition is the most promising method for our proposed MEMS cells. It presents itself as a cost-effective solution, without the need for complex technological equipment, and the UV activation simplifies the decomposition process. Moreover, the photodecomposition method is advantageous in the sense that the azide product form is more stable at room temperature than the metal form of the material.

Results

Figure 1 represents the transmittance of the commercially available 87Rb and Cs vapor cells for D1 transitions, 795 nm and 895 nm, respectively. The results obtained follow a biphasic exponential decay, characterized by being the sum of two decay processes happening at the same time: an initial fast decay for weak magnetic fields and a slow decay for stronger magnetic fields. Therefore, these results show a higher sensitivity for Rb vapor cells, as a more significant drop in the light transmittance is observed as a function of the magnetic field increase. According to this analysis, the Rb alkali-metal vapor cell is more suitable to be incorporated in OPMs.

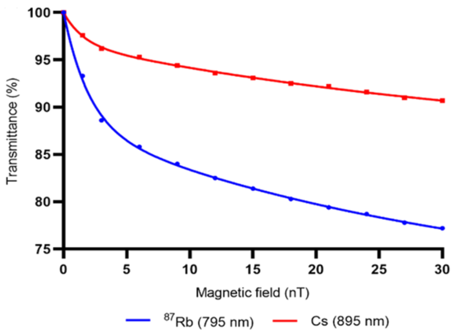

Figure 1 - Transmittance of light (%) as a function of magnetic field (nT), for the D1 transition of ^{87}Rb and Cs vapor cells, respectively.

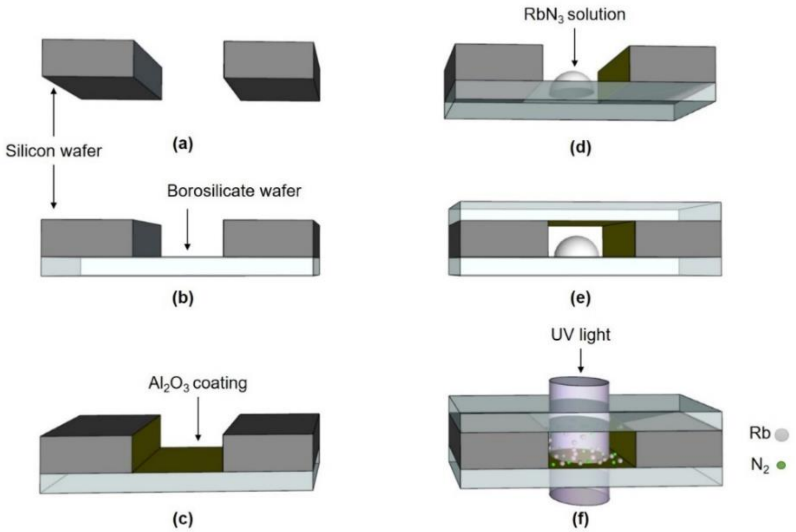

Figure 2 - (a-f) Process steps for obtaining the millimeter-level Rb vapor cell through decomposition of the alkali-metal azide by UV photolysis (not to scale).

One of the methods of MEMS cell fabrication includes the alkali compound decomposition induced by exposing encapsulated cells to UV radiation (see **Table I**). As a result, Rb and N_2 are obtained inside the cell. The steps of the proposed cell fabrication are shown in **Figure 2**, which include the preparation of silicon and borosilicate wafers; deep reactive ion etching (DRIE) of a silicon wafer, to obtain a millimeter-level cavity (Figure 2 (a)); anodic bonding between the first glass wafer and the bottom of the Si wafer (Figure 2 (b)); coating of all the cell walls with a Al_2O_3 thin layer to improve the vapor cell lifetime (Figure 2 (c)); micro-dispensing of the rubidium azide (RbN_3) aqueous solution into the millimeter-level cavity and dried at ambient atmosphere (Figure 2 (d)) and second anodic bonding of the top glass wafer, that will be performed at low temperature, in order not to thermally decompose the alkali-metal azide compound (< 300 ºC), under controlled Ar atmosphere (Figure 2 (e)). In the last step, the metallic Rb and N_2 buffer gas will be created through UV irradiation of the RbN_3 aqueous solution, following the decomposition reaction: $2RbN_3 \rightarrow 2Rb + 3N_2$ - Figure 2 (f). For this purpose, a low-pressure lamp emitting at UV (peak wavelength of 254 nm) will be used. Long exposure is necessary to get a high yield decomposition of RbN_3.

Conclusions

The transmittance results show that the ^{87}Rb alkali-metal vapor cell is more suitable to be incorporated in OPMs over the Cs cell. The fabrication of a millimeter-level alkali-metal vapor cells by using borosilicate and silicon wafers, through microfabrication technology is here proposed. This approach opens the perspective for massive production of OPMs and, therefore will contribute to the new generation of MEG based on OPMs, that will have high impact in diagnoses of some neurological diseases affecting the worldwide population, such as epilepsy and dementia.

References

1. T. H. Sander, J. Preusser, R. Mhaskar, J. Kitching, L. Trahms, and S. Knappe, Biomed. Opt. Express **3**, 981 (2012).
2. E. Boto, N. Holmes, J. Leggett, G. Roberts, V. Shah, S. S. Meyer, L. D. Muñoz, K. J. Mullinger, T. M. Tierney, S. Bestmann, G. R. Barnes, R. Bowtell, and M. J. Brookes, Nature **555**, 657 (2018).
3. C. Johnson, P. D. D. Schwindt, and M. Weisend, Appl. Phys. Lett. **97**, (2010).
4. M. Xie, J. F. Schneiderman, M. L. Chukharkin, A. Kalabukhov, B. Riaz, D. Lundqvist, S. Whitmarsh, M. Hamalainen, V. Jousmaki, R. Oostenveld, and D. Winkler, IEEE Trans. Biomed. Eng. **64**, 1270 (2017).
5. T. M. Tierney, N. Holmes, S. Mellor, J. D. López, G. Roberts, R. M. Hill, E. Boto, J. Leggett, V. Shah, M. J. Brookes, R. Bowtell, and G. R. Barnes, Neuroimage **199**, 598 (2019).
6. V. K. Shah and R. T. Wakai, Phys. Med. Biol. **58**, 8153 (2013).
7. V. Shah, S. Knappe, P. D. D. Schwindt, and J. Kitching, Nat. Photonics **1**, 649 (2007).
8. L.-A. Liew, S. Knappe, J. Moreland, H. Robinson, L. Hollberg, and J. Kitching, Appl. Phys. Lett. **84**, 2694 (2004).
9. Thorlabs - Rb, (2012).
10. Thorlabs - Cs, (2012).
11. L.-A. Liew, J. Moreland, and V. Gerginov, Appl. Phys. Lett. **90**, 114106 (2007).
12. W. Wei, J. Shang, W. Kuai, S. Qin, T. Wang, and J. Chen, in *2012 13th Int. Conf. Electron. Packag. Technol. High Density Packag.* (IEEE, 2012), pp. 1639–1641.

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