Design and testing of a silica glass microfluidic device for quantum sensing based on NV centers

Carmen María Martínez López, Javier Prior Arce

Abstract

This work explores the integration of Nitrogen-Vacancy (NV) center defects in diamonds with microfluidic platforms for advanced studies in fluid dynamics and potential biomedical applications. We have developed and analyzed three distinct silica glass chip designs, aiming to achieve optimal compatibility with a confocal microscope system. Additionally, we present preliminary relaxometry measurements performed using deionized water, which demonstrate that the device functions as intended. This innovative approach seeks to contribute to progress in early disease detection, intracellular environment exploration, and the analysis of fluids at the nanoscale.

NV centers and confocal microscopy

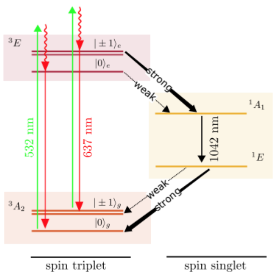

Figure 1. NV center's energy scheme.

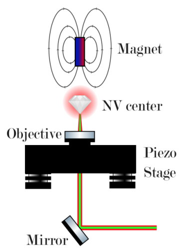

Figure 2. Piezo stage.

Microfluidics. Silica design

Microfluidic devices are a new alternative to handle and manipulate fluids in microscopic-scale channels, and can be used for biomedicine and biochemistry applications, as well as for making measurements of fluids in the nano and microscale.

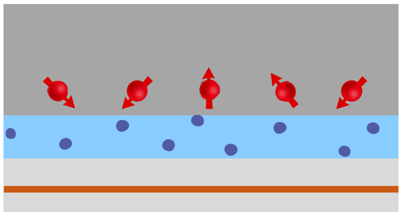

Figure 3. Scheme (not at scale) of the channel configuration with the diamond containing the NV centers (red arrows) placed on top and the MW wire at the bottom.

The proposal consists in an integrated silica glass lab-on-a-chip from LightFab. Up to now, we have made three different designs, each of them solving the problems encountered on the previous proposal.

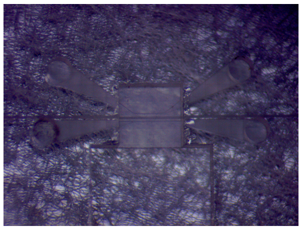

Figure 4. First silica design.

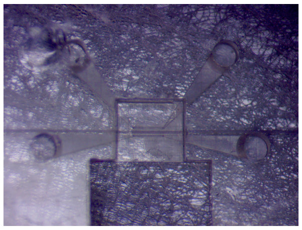

Figure 5. Second silica design.

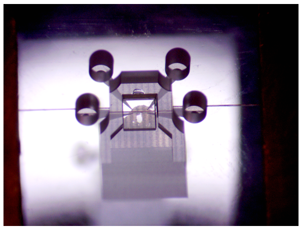

Figure 6. Third design with diamond and MW wire.

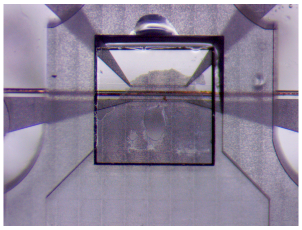

Figure 7. Detail showing the two 20 μm microchannels.

Some past complications from designs 1 and 2 include diamond cavities being too small, difficulties with the glue used to place the diamond, clogged channels, and uneven spreading of the immersion oil. The newest design takes all these obstacles into account, making it the most promising structure in our laboratory.

Problem encountered	Solution provided
Small diamond cavity	Rearrangement of the dimensions of the diamond cavity
Clogged channels	New, more protected design to ensure coverage
Difficulties to add tubes	Cylindrical, more adjusted inlets and outlets
Uneven oil objective's spreading	Switching to a completely squared chip
Diverse struggles to insert the diamond	Tilted entrance to facilitate the process

Table 1. Design challenges encountered and solutions implemented to address them.

First measurements

To test the operability of the last design, we perform some Hahn-Echo measurements on NV centers situated on top of one of the microchannels while filled with deionized water. The results obtained give us insights on further issues to fix and will serve as a first comparison for future results with other liquids.

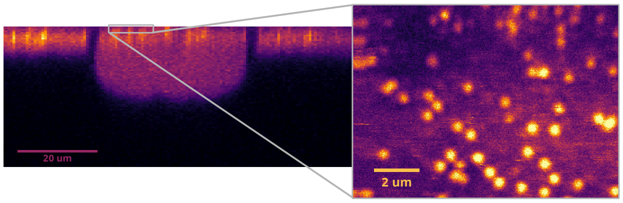

Figure 8. Confocal image of a microchannel of the third design. **Inset**: single NV centers located on the channel.

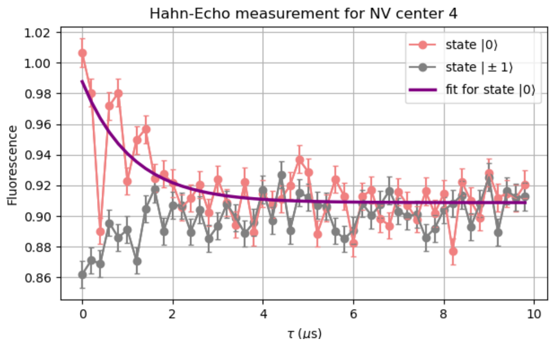

Figure 9. Hahn-Echo measurement on a NV center located on top of a microchannel filled with deionized water.

Future Work

- Find a better procedure to attach the wire to the chip.
- Enhance the implementation protocol to ensure reproducibility.
- Delve into other proposals, like PDMS or diamond-print nanochannels.
- Realize static measurements with paramagnetic and diamagnetic fluids. Study the implementation requirements needed to perform dynamical measurements.

MINISTERIO DE CIENCIA, INNOVACIÓN Y UNIVERSIDADES
Cofinanciado por la Unión Europea
AGENCIA ESTATAL DE INVESTIGACIÓN
UNIVERSIDAD DE MURCIA