Micro-MR coil construction by combining metal-on-glass inkjetting and MEMS techniques

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Introduction

This paper presents the inkjet printing of coils directly onto a cylindrical glass capillary and its integration and connection into a custom made MEMS holder for **batch NMR and MRI**. The holder ensures the electrical connectivity and the parallel alignment of multiple samples; it also eases the fluidic access to the capillary. The coils have been prepared using inkjet printing, which has emerged as a viable coil patterning technique. Conductive tracks are **printed directly** on a glass substrate using inks loaded with metal nanoparticles [1, 2].

Printing the 3D coil

Inkjet printing is a technique that ejects a small droplet out of a nozzle towards a substrate. The printhead and the substrate are not in contact, and apart from a precise spatial alignment, there is no other relation between the two. As a consequence, the technique is **highly flexible** and can be used to create sophisticated structures even on **non-planar substrates**.

An in-house made printer-setup with an 80 µm single nozzle printhead (MJ-AT-080, Microfab Technologies) was used. A rotational stepper motor was horizontally mounted on an precise XY-stage (Physik Instrumente GmbH, Karlsruhe). A 670 µm diameter, 30 mm long glass capillary was attached to the rotational axis of the stepper motor. This setup was placed under the printhead. By simultaneously shifting and rotating the cylindrical capillary under the printhead a solenoidal coil of silver ink was deposited on the capillary. After thermal curing, this formed a conductive coil (Fig. 1). By adapting the shifting and rotational speed, not only could homogeneous parallel lines be printed, as with other techniques [3], but **coils with heterogeneous winding densities** can also be produced.

Making the coil holder

The capillaries and the coils are fairly small and hard to handle on their own. However, their small size allows the coils to be arranged in parallel on a substrate for batch processing. To electrically and fluidically connect multiple capillary coils and also to align the coils, a holder made of SU-8 on silicon was produced using MEMS techniques. A 4 inch silicon or glass wafer holds two blocks of twelve parallel trenches. The trenches are ~20 µm wider than the 670 µm diameter of the glass cylinders to allow a easy and **stress-free positioning** of the fragile capillaries. Conductive tracks are sputtered onto the silicon underneath the SU8; they allow **a straightforward electrical connection** of the coils from the edge of the wafer.

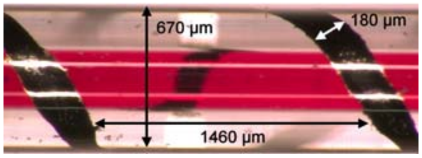

Fig.1: Close-up image of filled capillary showing printed silver solenoid windings

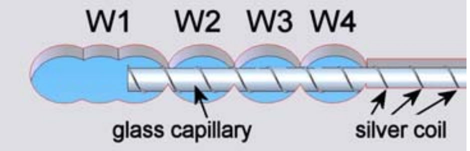

Fig. 2: Sketch of the holder design

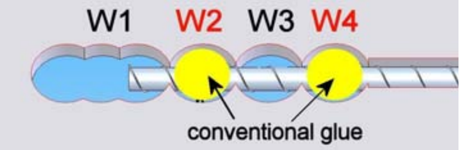

Fig. 3: Sealing and holding glue applied at W2 and W4

At each end of the capillary the trench is widened at four points. Fig. 2 shows the arrangement. After the coil capillary is put into the trench, W2 and W4 are filled with conventional glue (Fig. 3). The metal track that makes the electrical connection to the edge of the wafer is situated at the bottom of point W3; here conductive glue is deposited, which connects the coil to the track (Fig. 4). The isolation by conventional glue at W2 and W4 is needed to prevent the conductive glue at W3 from mixing with the analyte in W1 and stops the conductive glue from flowing along the glass cylinder in the other direction, and thereby short circuiting parts of the coil. The analyte which is deposited in W1 at the head of the capillary is dragged into the glass tube by capillary forces. The precise production method of the SU-8 using photo-lithography ensures a good alignment of the capillaries of about 0.1°. The conductive glue gives a good connectivity between the conductive tracks and the coil. Together with the fillings at W2 and W4 the conductive glue mechanically fixes the glass tube.

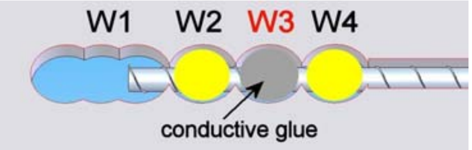

Fig.4: Connecting W3 to the tracks underneath

Fig.5: Filling analyte into W1

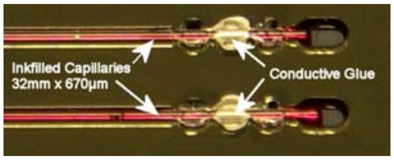

Fig.6: ink-filled capillaries in the MEMS holder

Conclusions and outlook

By using inkjet printing, prototypes of 3D µMRI coils have been **integrated on glass capillaries**. In combination with MEMS processes, a highly precise parallel holding and alignment setup was developed. The arrangement allows an **easy handling** of the fragile receiver coils, and batch MR analysis of analytes and cellular materials.

Optimising the coil printing process should allow the precise fabrication of numerically **optimized coil shapes** with varying track widths and pitches.

References

[1] Redinger et al: *An Ink-Jet-Deposited Passive Component Process for RFID,* IEEE transactions on electrical devices, 51, p.1978-1983, 2004 [2]Mager et al: *Inkjet Printing of structures for MRI coils,* Proc. Digital Fabrication 2008, p.891-894 [3] Rogers et al : Using microcontact printing to fabricate microcoils on capillaries for high resolution proton nuclear magnetic resonance on nanoliter volumes, Appl. Phys. Lett. **70** (18), 5 May 1997

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