FABRICATION OF MICROFLUIDIC CHANNELS WITH SYMMETRIC CROSS-SECTIONS FOR INTEGRATED NMR ANALYSIS

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Abstract

We present a glass micromachining technology with improved alignment in order to process channels with symmetric cross-sections. Two well-defined marks deep-etched on glass are superimposed to align the wafers on a standard mask aligner. The best alignment resolution obtained to date was ± 5 μm.

Keywords: Symmetric microchannel cross-sections, glass wafer-wafer alignment, NMR spectroscopy

1. Introduction

Integrated NMR detection in microfluidic devices has been recently reported [1,2]. However, the poor mass sensitivity of this spectroscopic technique means that it does not scale well with volume. Signal-to-noise ratios can be improved by reducing the radius of the planar coil while maintaining a constant sample mass underneath its centre. This can be accomplished by providing a rounded, symmetric sample cuvette rather than a flat, oblong channel. Symmetric channel cross-sections are possible by mating channels formed in two substrate surfaces. Theory and simulation show that imperfectly matched channel walls can lead to reduced homogeneity of the applied magnetic field. Therefore, alignment of wafers for channel formation is critical.

2. Experimental

Pyrex glass was chosen as a substrate for our integrated NMR-microfluidic devices. For alignment of structured glass wafers, it was decided to adopt an approach commonly used in silicon micromachining, which involves superimposing well-defined marks on different layers to align wafers. To make our device, three sets of alignment marks are required for wafer-wafer alignment and channel positioning with respect to the coil.

The process shown in Fig. 1 was developed for incorporation of alignment marks. These marks are patterned on the backside after poly-silicon is deposited at elevated temperature, so that they are not subjected to any further wafer heating before the final bonding step. During channel etching, alignment marks are protected mechanically by placing the wafer in a special holder. It is only after channel formation that the marks

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themselves are etched to a 300-nm depth with buffered HF. The two wafers are then aligned on a mask aligner equipped with an adapted chuck. After thermal bonding, one side of the wafer is thinned by mechanical polishing for improved coupling of the coil with the sample. The coil is formed after alignment with marks on the non-polished backside.

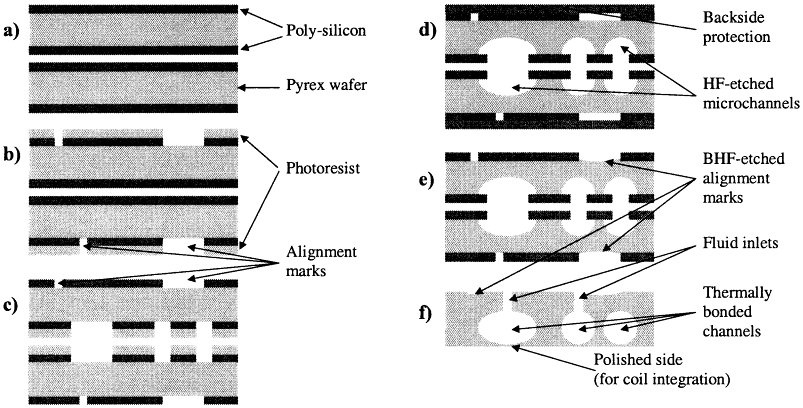


Figure 1. **a)** Parallel processing of two Pyrex-glass wafers with 400 nm of poly-silicon on both sides **b)** All alignment marks patterned on backside of wafers (photolithography and reactive-ion etching (RIE) of poly-silicon) **c)** Channels patterned on top side of wafers (photolithography with backside alignment, and RIE of poly-silicon) **d)** HF etching of the channels using a special chuck for backside protection **e)** Buffered HF etch of the marks **f)** Poly-silicon removal, holes drilled in top wafer, wafer alignment, thermal bonding, and polishing of the bottom side.

3. Results and discussion

With the first micro-cuvettes, wafer alignment was done by hand under a microscope before fusion bonding. However, as Fig. 2 indicates, the resulting misalignment errors were usually substantial, requiring development of a modified fabrication process for improved wafer-wafer alignment.

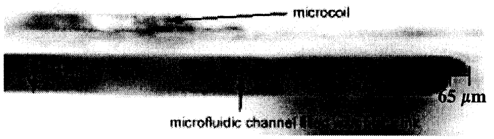
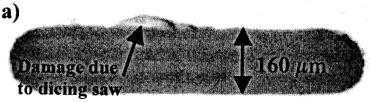


Figure 2. Cross-sectional view of a misaligned micro-cuvette, where alignment was done by hand. The error in the alignment is 65 μm.

Though incorporation of alignment marks should have been straightforward, we initially encountered technological problems with glass not usually met with silicon. This is because poly-silicon, the masking layer used for channel formation, is deposited at temperatures approaching the softening point of the glass (~600°C). If alignment marks were patterned before poly-silicon deposition, they appeared to "wander" up to 30 μm from their original positions, due to heat-induced curvature of the wafer during the deposition process. Chromium/gold or amorphous silicon masking layers deposited in low-temperature processes could protect pre-formed marks. However, they were not sufficiently robust to withstand 49 % HF long enough to obtain channel depths > 50 μm.

Initially, when the wafers were aligned using marks patterned on the backside, the alignment resolution achieved was not better than ± 15 μm. More recently, we have patterned high resolution marks on the same wafer surface and at the same time as the channels. This eliminated the need to align the mask for the channels with previously formed marks, and reduced alignment errors as a result. Using this approach, an alignment resolution of ± 5 μm (see Fig. 3) was obtained, which corresponds to the optical resolution of our mask aligner.



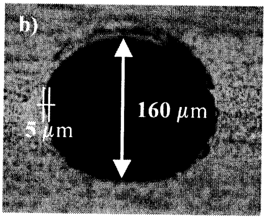


Figure 3. Cross-sectional view of aligned: **a)** micro-cuvette **b)** micro-channel
The error in the alignment is ± 5 μm.

4. Conclusions

Improved resolution of ± 2 μm (or better) could be possible by using other equipment with better optical resolution. This new process represents an advance in glass microfabrication, since it will facilitate the fabrication of more complex microfluidic devices with multilevel integration.

Acknowledgements

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References

1. J. D. Trumbull, I. K. Glasgow, D.J. Beebe, and R.L Magin, *Integrating microfabricated fluidic systems and NMR spectroscopy*, IEEE Transactions on Biomedical Engineering, Vol. 47, pp. 3-7, (2000).
2. C. Massin, A. Daridon, F. Vincent, G. Boero, P.-A. Besse, E. Verpoorte, N. F. de Rooij, and R. Popovic, *A microfabricated probe with integrated coils and channels for on-chip NMR spectroscopy*, in Micro Total Analysis Systems 2001, pp. 438-440.