Development of all-plastic needle coils made using silicon technology

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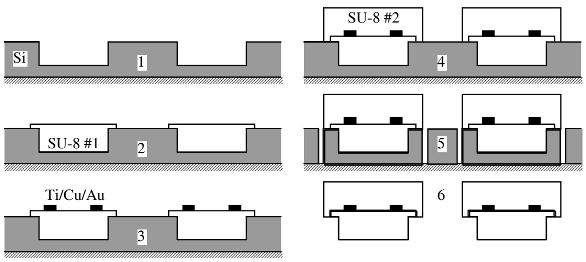
INTRODUCTION:

Last year we showed the first *in vivo* ^{31}P spectra obtained from rat leg muscle using needle shaped MR-detector coils made with silicon technology (1). However, despite the advantage that they could be made extremely cheaply in large quantities, it was apparent that the brittleness of single crystal silicon was likely to be a serious concern for any medical applications. In this report we describe how, via further *in vivo* studies focusing on protons, we have developed needle coils made with silicon technology that end up with no silicon in them. The needle coil design concept, of two conductors embedded in plastic, has been previously described (2). Avoiding the use of silicon as well as addressing safety issues has the added benefit that plastics have much higher resistivity compared to silicon substrates previously used.

MANUFACTURING PROCESS:



The process is illustrated in ***Figure 1*** (left) where a silicon wafer is used as mold and substrate before being discarded at the end:

0. Start with intrinsic Si wafer, with oxide step at rear
1. Form partial trenches by deep reactive ion etching
2. Planarise and pattern with thick SU-8 epoxy photoresist
3. Deposit seed layer; form photoresist mould; electroplate conductors
4. Planarise and pattern with thick SU-8 photoresist
5. Deep etch Si to segment needles
6. Remove residual Si.

Figure 2 Photograph of the older silicon-based needles (lower) and the new all plastic ones (upper).

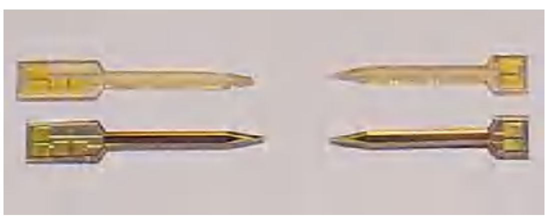


Figure 3 Axial GRE image

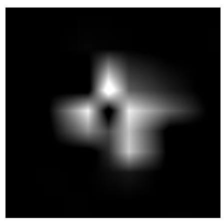


Figure 4 *In vivo* ^{1}H MRS of muscle

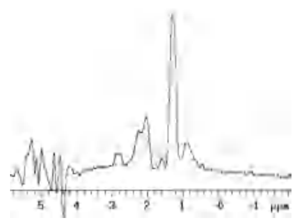
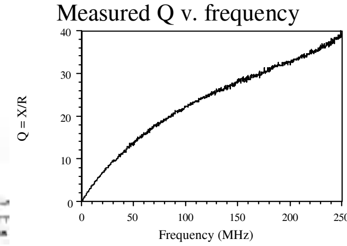


Figure 5 Measured Q v. frequency



PERFORMANCE:

The current silicon coil design has been used at 81MHz for ^{31}P at 4.7T (1), and at 200 MHz for ^{1}H as is illustrated in ***Figure 3***, an axial gradient echo image obtained using a coil to demonstrate the cross-sectional sensitivity profile (dark rectangle is nominal 1mm square coil cross-section), and ***Figure 4***, an *in vivo* ^{1}H spectrum obtained from rat thigh muscle using a binomial STEAM sequence (TR 1000msTE 40ms TM 100ms 256 averages). The new plastic coils have been tested electrically and have a Q of greater than 40 at 250 MHz. The coils appear to work up to 400 MHz, but results at the upper extremity of the range were less solid than is found at lower frequencies. ***Figure 4*** is a plot of Q against frequency for a typical all plastic needle coil.

DISCUSSION:

While we have been able to make all-plastic needles for some time, their manufacture has been tedious in the extreme, with a very low yield of satisfactory units. Only very recently have we been able to develop a flow process which is potentially useful. The result is that we have been able to test the coils electrically, but evaluation of their mechanical robustness and their performance *in vivo* has not yet been started, though we plan to begin them immediately.

This study is, we believe, the first application in which the huge resource available for processing silicon has been deployed to make something which includes no silicon in it at all. It should be possible to retain the scale – and, so, ultimate low cost of silicon based devices – as long as volumes are sufficient. The needle coil can, we project, be made cheaply enough that it can be used as an on-line diagnostic tool in some ways comparable to the biopsy needle. The coil was originally conceived for use in brain tumor resection, when multiple samples are taken from the region round the place from which the tumor has been taken in order to try to assess whether everything that should desirably be removed has been taken. As many as 12 or more samples are taken, so that, if the process were being performed in an interventional MRI system, the same number of coils would be required, with each being discarded as soon as it has been used.

REFERENCES:

1) F A Howe et al. "^{31}P spectroscopy using a silicon-based needle coil" Proc. 14th ISMRM p. 3101 (2006).
2) R R A Syms et al. "Microengineered needle micro-coils for magnetic resonance spectroscopy" J. Micromech. Microeng., accepted for publication, (2007)

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