^{31}P Spectroscopy using a Silicon-Based Needle Coil

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INTRODUCTION:

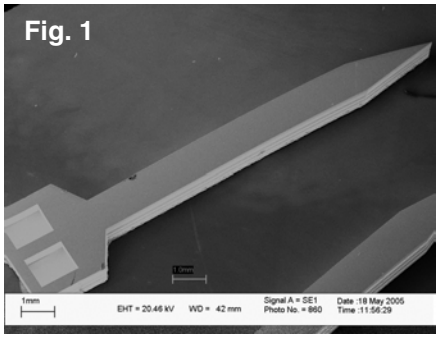
Silicon-based microcoils of planar (1,2), solenoid (3) and Helmholtz (4) design have been recently investigated, with the main intention of developing extremely cheap local coils for clinical MRS, which would not have to be cleaned but could simply be discarded. We have been developing a needle coil design for insertion into tissue. Needle coils have a very small field of view orthogonal to the longitudinal coil axis. The two parallel conductors that form most of the coil have a quadrupolar H field and a coil of such open design immersed in a uniform medium would yield little signal in receive-only mode, due to signal cancellation from the regions of opposite polarity. Our needle coil design encloses the conductors with a solid resistive material (SU-8) to eliminate most of the signals from one pair of the regions with the same polarity. This design is optimal for receiver-only mode, but also suitable for use in transmit/receive mode.

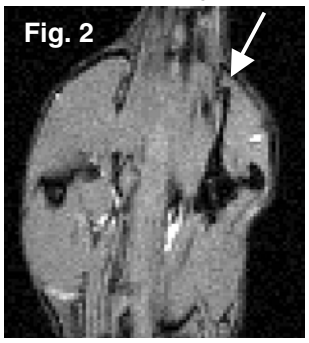
METHODS:

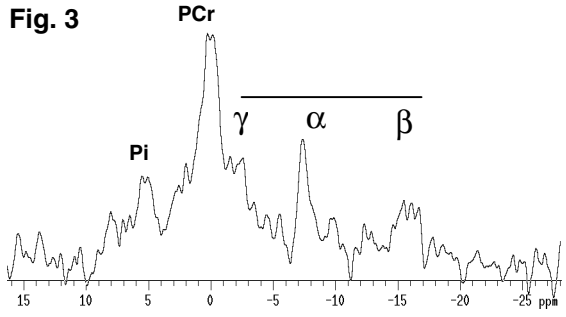
Conductors were formed by electroplating 14µm of copper, followed by 4µm of gold on a silicon substrate, and 100 needle coils can be manufactured per silicon wafer. Conductor separation was 2 mm along a length 10mm and joined at the tapered end. Figure 1 shows an electron scanning micrograph of a typical needle prior to addition of microchip tuning capacitors. Coil geometry is such that maximum signal reception is adjacent to the two flat faces. This single-turn coil design was tuned to 81.1MHz using discrete components. Coil Q measured using a network analyser (Agilent E5061A) was typically 10. Losses due to the silicon substrate mean that above 100MHz it is necessary to increase the insulation between the silicon and the conductors substantially; new masks are being made to permit this. The coils were matched to 50Ω, attached to small strips of printed circuit board and ultra-thin co-axial cable, to facilitate their handling. ^{31}P MRS and MRI were performed using a 4.7T small bore animal system (Varian).

A small spherical bulb was filled with 100mM Pi and 50mM ATP, pH 7.2 and with 10µmol Mn doping was used for calibrating the coil in transmit/receive mode operation. The needle coil was inserted into the bulb to its full length and spectra acquired with TR 1s, 8kHz bandwidth and 128 averages (2 minute acquisition time) to find the signal maximum.

Animal studies were performed by making a small incision on the thigh of an anaesthetised Wistar rat into which the needle coil could be easily inserted parallel to the muscle fibres. Gradient echo images (contiguous 1mm thick slices) were acquired with a volume coil to locate the needle track and allow localised shimming over the whole thigh muscle using PRESS localisation. ^{31}P MRS was performed with same pulse width and power that gave maximum signal in the phantom, but with TR 2s and 1024 averages.







RESULTS:

Maximum signal from the phantom was with a 150µs hard pulse and 11W transmitter power. The Pi and 3 ATP peaks were clearly identifiable in a 2-minute acquisition and the Pi peak SNR was 7.3.

A coronal gradient echo image through both rat thighs is shown in Fig. 2 where the top structure is the tail. The arrow indicates the signal void in the thigh muscle where the needle coil had been inserted. The muscle localised shim was 80Hz. PCr was clearly observed in a 1024 average block. In addition, Pi and the 3 ATP resonances could be clearly observed in a sum of two blocks (90 minute total acquisition time) as shown in Figure 3, after 30Hz line broadening ; the SNR of the PCr peak is 9.

DISCUSSION:

We have demonstrated the feasibility of manufacturing cheap needle-like coils for *in vivo* spectroscopy and their practical use. With the present design the Q is very low compared to the 100 typical of small surface coils used in animal studies. For ^{1}H MRS at 1.5T (64MHz) the proton concentration for the CH_3 moieties most commonly observed is similar to PCr in muscle. If the Q can be increased by an order of magnitude we would expect to obtain similar SNR as in Figure 3 at metabolite concentrations expected in tissue in 5 minutes. Improved shimming using the coil itself would further improve SNR. The design can be refined in a number of directions with the aim of improving the Q, improving the mechanical robustness and further integrating the components needed to make them compatible with MR–systems, and work is proceeding along these lines.

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