Flexible Microcoils for In-vivo Biliary Imaging

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Introduction: Flexible microcoils are being developed for in-vivo internal imaging of biliary carcinomas during endoscopic retrograde pancreatography, with the aim of increasing the likelihood of early detection through improved resolution. The coils are designed to pass down the 3.2 mm diameter biopsy channel of a non-magnetic endoscope in a catheter package. The coils have to turn through in the region of 90º as they are rotated by a deflector plate from passing down the axis of the gastroscope (as access for this procedure is via the mouth) and move out along the bile duct to be studied. The coils are disposable, and are thus desirably cheap to produce as well as being very efficient. Silicon technology is clearly very attractive as the means of manufacture suitable detectors but silicon as a material is both highly incompatible with biological material but is extremely brittle and inflexible. We have developed methods to enable us to make flexible biocompatible coils using silicon manufacturing processes.

Methods: The coils which have been developed, designed to operate at 63.8 MHz in a GE Excite 1.5T scanner, have two turns of 200 micron wide track. Their layout is shown in Figure 1a. The microcoils are planar structures formed on silicon wafers using multilayer deposition of a photopatterned SU-8 resist and multilayer electroplating of Ti/Cu. As shown in Figure 1b.

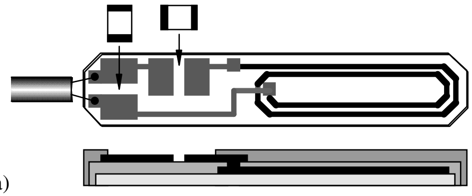
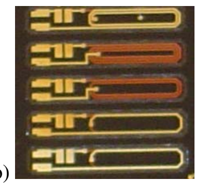
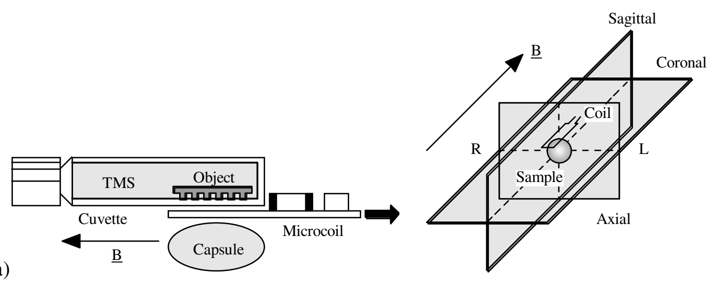
a)  b) 

Figure 1 a) Microcoil layout; b) processed coils on the silicon carrier.

After fabrication, coils are detached from the silicon by thermal shock. A Q-factor of 20 is obtained after tuning to 63.8 MHz and matching to 50 Ω.

Results: Coils have been assessed for hydrogen MRI using a 1.5T GE HD Excite system. The test sample was a combination of an ellipsoidal cod-liver oil capsule measuring 10 mm dia x 15 mm long and a polished glass cuvette containing a resolution test object immersed in tetramethyl silane as shown in Figure 2a. The microcoil was placed in the coronal plane at the bore centre, between the capsule and the resolution test object as shown in Figure 2a. The resolution test objects were photopatterned plastic structures formed in SU-8 containing 300 micron deep bar patterns. A fast recovery fast spin echo sequence was used with T_R = 33 ms; T_E = 15 ms, NEX = 4 and FOV = 8 cm. The scan time was 12 mins. A resolution of 1 mm is shown with a useful field of view of 5 mm as shown in Figure 2b. Further experiments have shown a resolution limit of 0.5 mm.



a)

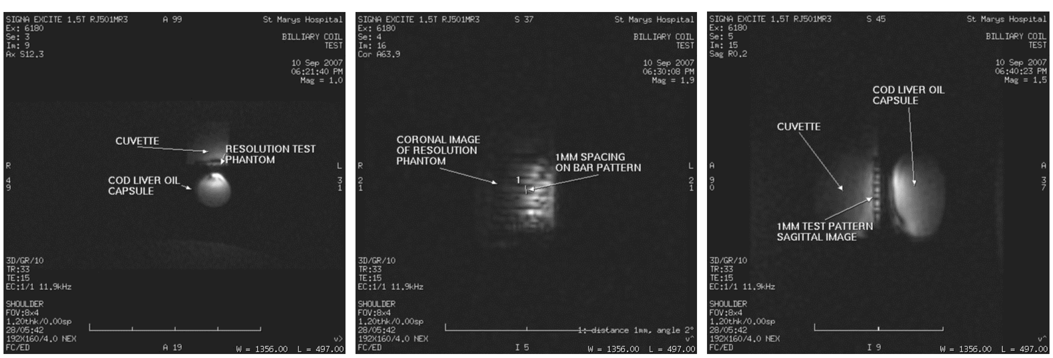
b) 

Figure 2. Resolution test experiment: a) arrangement and b) 1H MRI at 1.5T.

Discussion: The use of silicon technology to create flexible MRI sensors is quite new (as it is for most other applications of silicon technology). The possibility of making flexible systems using a technology which has been developed very extensively to enable semiconductors to be as cheap as they are is important for a wide range of small medical devices. Catheters, for example, made using this approach, could be very much cheaper than those currently available. Catheters containing cheap RF detectors are likely to be an essential requirement for the widespread adoption of interventional MRI, and the kinds of device described here will, hopefully, fulfil that requirement.

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