

# Visualisation of the Cochlea Implant/Tissue Interface

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## Aims

The cochlear implant is an electroneural implanted device which helps to restore communication in patients with profound auditory deafness.

The implant, works on the concept of direct electrical stimulation of the spiral ganglion cells, within the cochlea. The cochlea is a snail-like coiled structure, apart of the inner-ear labyrinth; its role is to convert hydro-dynamic vibrations to electro-chemical signals that travel up the auditory nerves to the brain.

The electrode array of the cochlear implant is inserted into either, the round window or through a cochleostomy surgically drilled anterior-inferior to this structure. Insertion of the electrode array is without visual guidance and this may sometimes lead to damage to the delicate receptor structures within. Such damage may affect performance or result in complications such as: bleeding, meningitis, tinnitus, vertigo and poor hearing results (Kempf et al. 1999).

Development of optimal insertional procedures, including the ability to assess the precise location of the electrode array and changes and /or damages caused during insertion is of high priority in the field of cochlea implantation.

Histological techniques have been the traditional approach towards assessment of post-operative positioning of the electrode array and structural displacement within the cochlea. Samples are dehydrated, embedded in resin, sectioned and stained. The main limitation to this technique is the lack of 3D configuration between sections due to 'information' loss from sectioning.

The conventional approach of clinical CT scanners to visualise the implant within the cochlea has been limited, due to both low resolution (>300µm) and the metallic nature of the device. The low resolutions of clinical CT mean that delicate membranes of the inner ear are not visually resolved (Aschendorff, A., et al. 2004). With the development of microCT systems capable of sub micron (<20µm) resolution and contrast staining techniques, detailed visualisation of the inner labyrinthine structures along with membranes have been successful (Uzun, H., Curthoys, I.S., Jones, A.S., 2006, Uzun-Coruhlu, H., Curthoys, I.S., and Jones, A.S., 2007). However when the sample contains metallic components (Platinum, Platinum alloys) within implanted electrode arrays, x-ray interaction causes scattering artefacts. Such scattering often masks the underlying nature of the tissue structures surrounding the implant, leading to imprecise analysis of the implant-tissue interface. To overcome this problem we are developing electrolytic processing to dissolve or partially dissolve the implant in-situ. Thereby minimising or completely removing most of the metal components which impede good visualization of the tissue-implant interface.

## Method

Two different electrolytes were utilised in experimentation; Polyethylene glycol 200 (50/50vol. 50%EtOH, 0.5M NaCl) and Karnovsky's fixative (3% Paraformaldehyde, 0.5% Glutaraldehyde, 0.1M NaCl, PBS). Experimentation on the electrolytic dissolution of Platinum involved a platinum wire (200 $\mu$ m) which acted as the anode and a carbon rod as the cathode electrode. The Platinum wire electrode was driven by a function generator delivering unbalanced biphasic pulses with an duration of 15ms and a repetition of 50 pulses per second, respective charge and current were; Karnovsky's: 5.88V, 85.4mA and PEG200: 5.11V, 85.7mA.

In experimentation which simulated implant insertion, a Platinum wire was pierced through a 10X10X10mm cow muscular tissue, prepared via Karnovsky's fixation or Guinea Pig (GP) brain tissue, prepared via intracardiac perfusion with Karnovsky's fixative.

With charge and current settings; Karnovsky's cow muscle: 6.34V, 62.2mA, PEG200 cow muscle: 6.25V, 80.3mA, Karnovsky's GP brain: 2.46V, 1.2mA, PEG200 GP brain: 3V, 2.4mA.

Further experimentation aiming to simulate insertion of the electrode array utilising the full Guinea Pig temporal bone was investigated. A Pt wire was inserted into the GP cochlea via the vestibular fenestra. Specimen was immersed in PEG200 electrolyte with electrolytic parameters: 8.86V and 30.2mA.

## Results

In both electrolytes (PEG and Karnovsky's fixative) Platinum wire was successfully dissolved within 24hrs.

Implantation simulation experimentation gave varying results. MicroCT analysis showed in both cow muscle samples, partial dissolution of the Pt wire with regions of full electrolytic dissolution (Fig.1, 2). MicroCT scans of the specimens showed scatter-free tissue conformation, whilst scattering still occurred where Pt was present. In initial tests for the GP brain tissue experimentation; partial dissolution of the pt was evident in Karnovsky's specimen (Fig. 3), MicroCT scan shows extensive scattering at region where Pt wire was still embedded. The PEG200 specimen showed full electrolytic dissolution of the wire, resulting in scatter free imaging from the MicroCT (Fig. 4).

GP temporal bone experimentation, showed scattering in initial scans, where Pt wire is inserted into the cochlea. The Pt wire within the cochlea was dissolved electrolytically but the challenge remains in controlling the amount of displacement to surrounding tissue due to gas evolution during electrolysis.

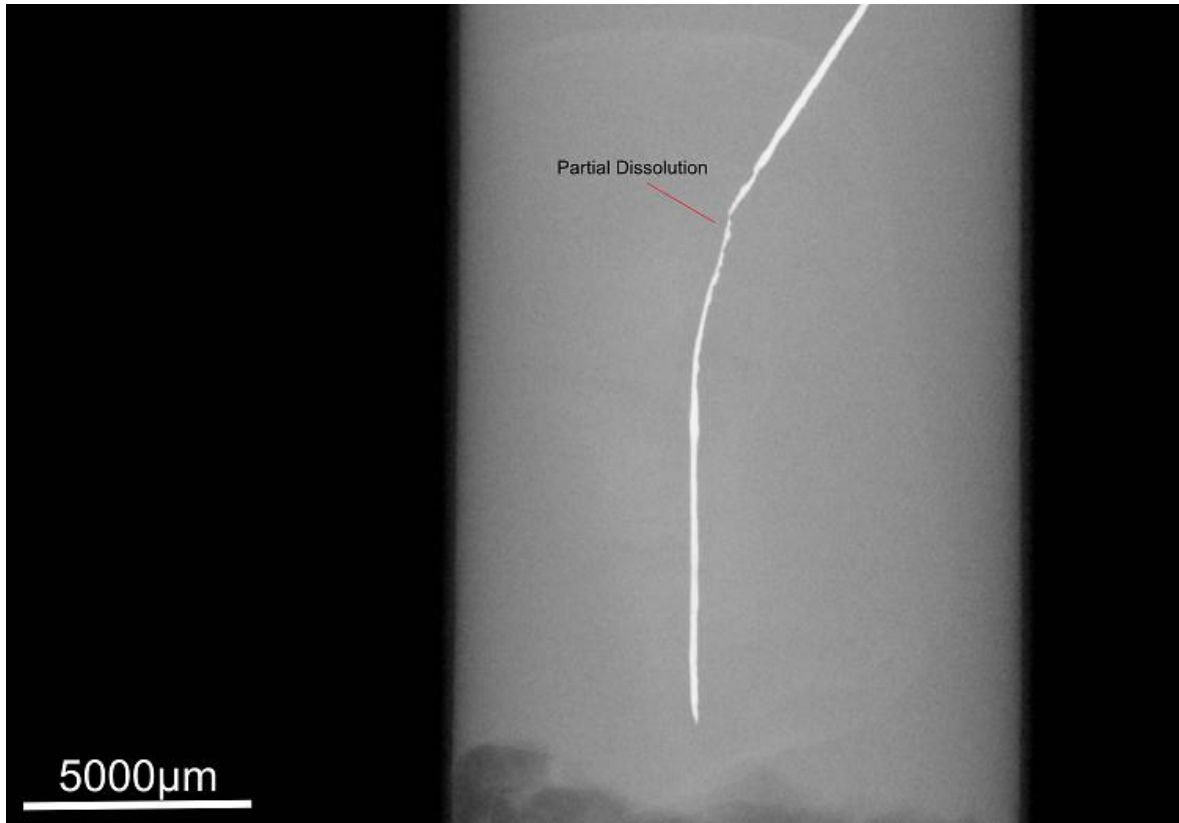


Fig. 1. Absorption radiograph of a Platinum wire pierced through a cow muscle tissue. Red indications show region of partial dissolution of wire in PEG200 electrolyte. Specimen was scanned at 80kV, 124µA, with 17µm resolution at 10°.

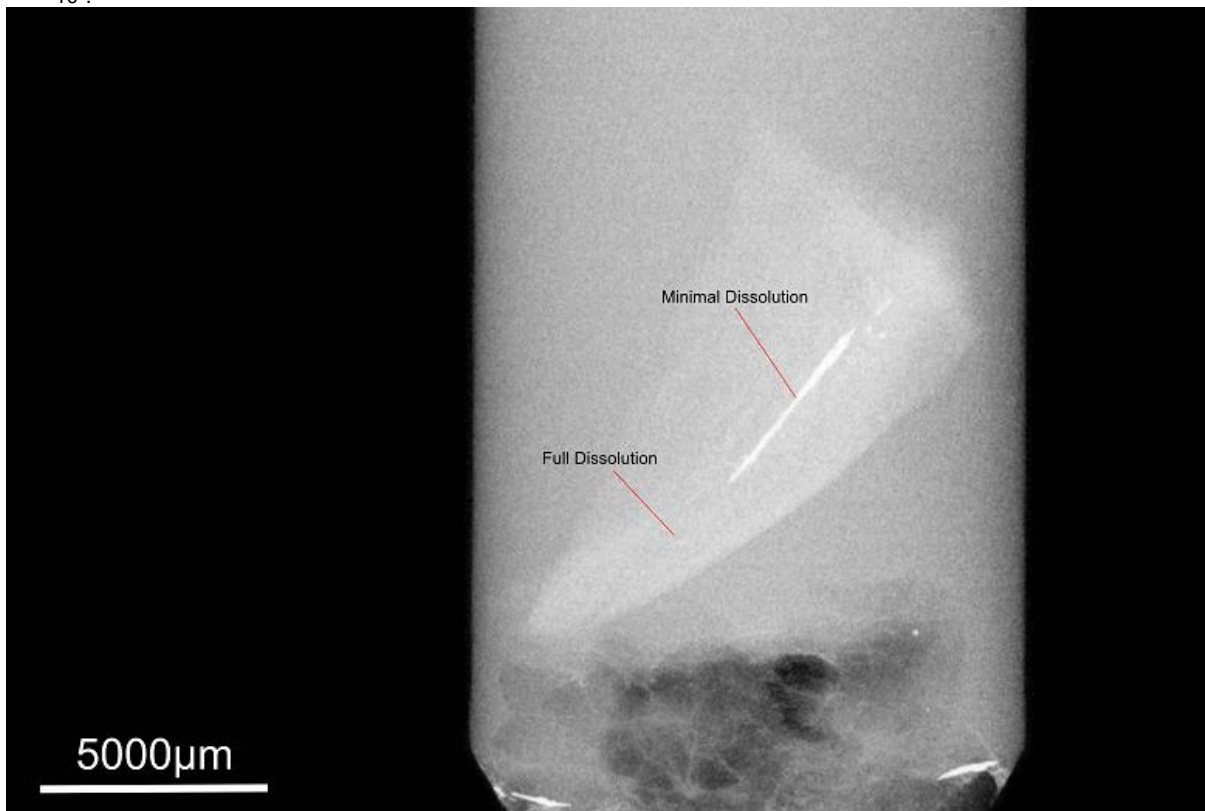


Fig. 2. Absorption radiograph of a 200µm Platinum wire pierced through Bovine muscle tissue. Red indications shows the regions of partial and full dissolution of the wire within the specimen in Karnovsky's fixative electrolyte. Specimen was scanned at 59kV, 167µA with 17µm resolution at 13°.

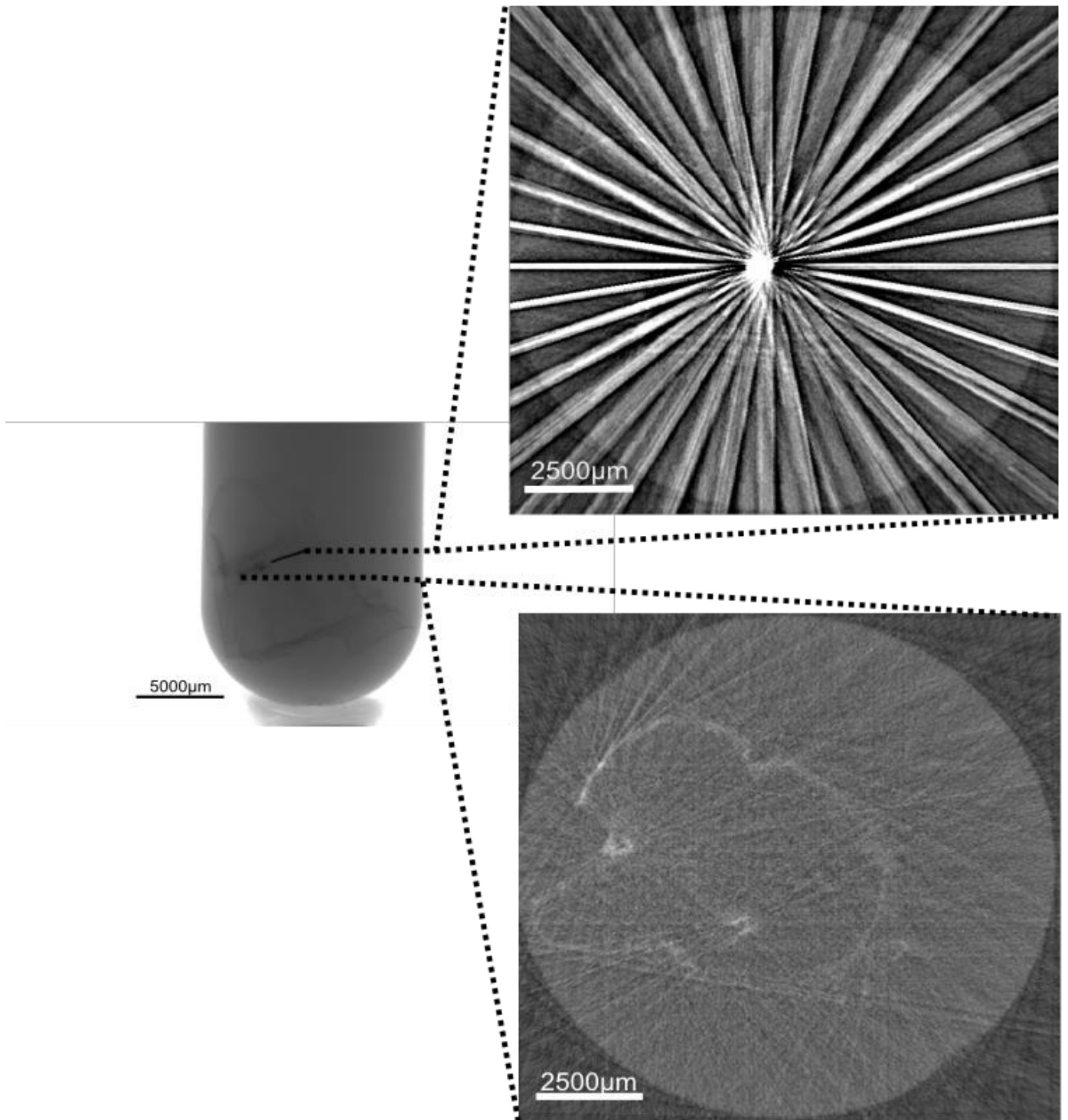


Fig.3. Absorption radiograph of a Platinum wire pierced through Guinea Pig Brain tissue. Regions of full electrolytic dissolution (bottom right) and minimal dissolution (top right) within the specimen are marked by corresponding dotted lines. Specimen was scanned at 62kV, 161µA, with 17µm resolution at 10°.

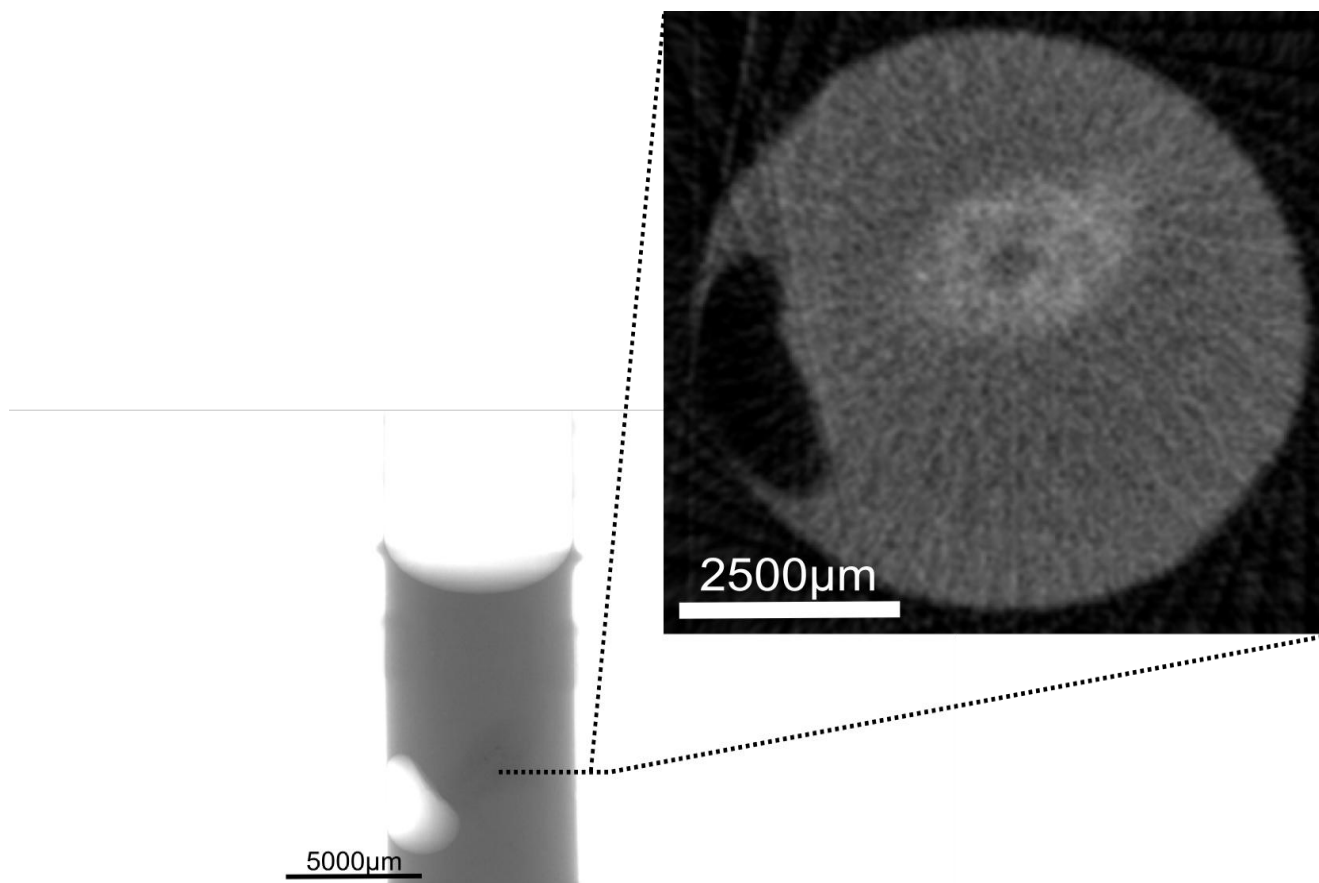


Fig. 4. The absorption radiograph and reconstructed axial slice of Guinea Pig brain specimen. The axial slice image corresponds to the sample position as marked by the dotted line. The 'hole' (approx. 500µm) seen in the axial scan marks the fully dissolved platinum wire position within the specimen in PEG electrolyte. Specimens scanned at 64kV, 155µA with 17µm resolution at 10°.

## Conclusion

Initial testing of the electrolytic dissolution of implants shows promise. Full platinum dissolution was previously thought to be impossible due to noble metal passivation preventing full electrolytic dissolution. This however is not the case. Full dissolution is possible using unbalanced biphasic current and suitable electrolytes. This opens up the possibility of visualizing the inner ear membranes in animal models used for implant studies. At this point in time further modification to the dissolution parameters are required to minimize tissue damage whilst still allowing removal of the implant material.

## References:

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