Copper Electroforming at the Canfranc Underground Laboratory

Status Report

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Low
Radioactivity
Techniques
2006

Laboratorio Subterráneo
de Canfranc

Universidad
de Zaragoza

OUTLINE

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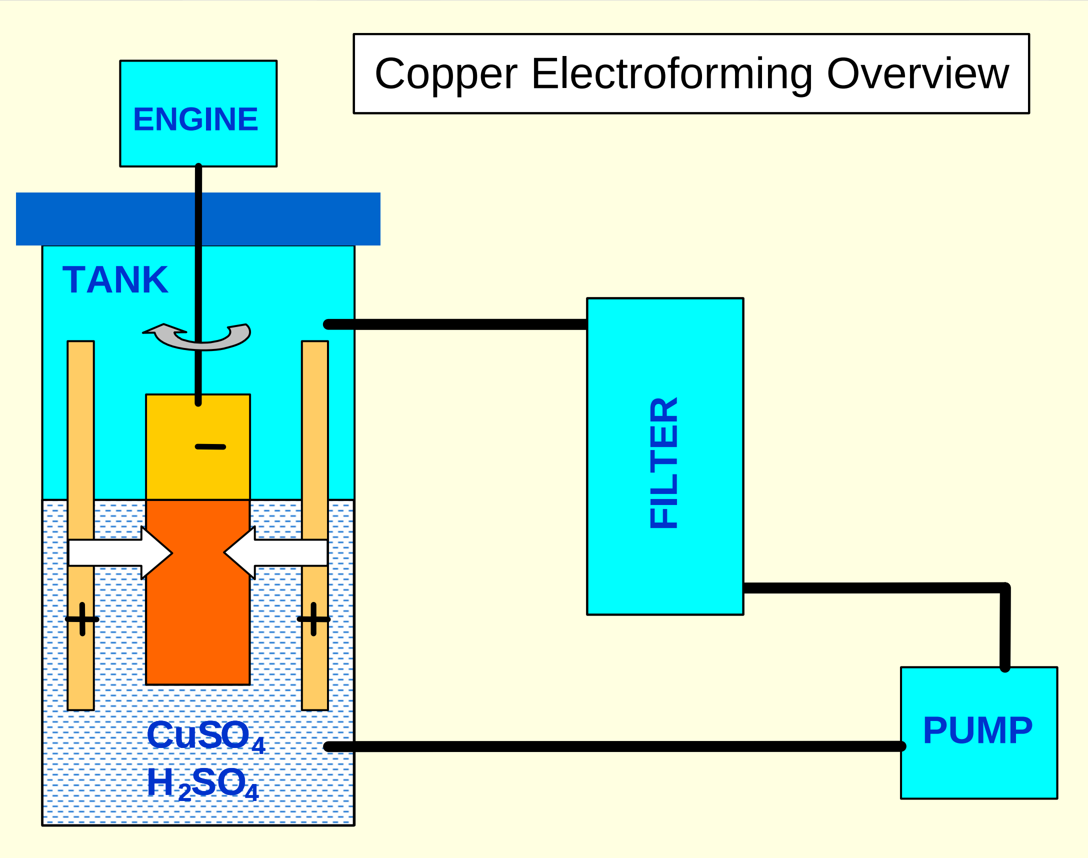
Motivation

- Copper is an attractive material for constructing ultra-low-background detector components.
- The electroforming process can be done underground, providing a potential way to eliminate cosmogenic activation.
- Additional chemical and electrolytic improvements can be combined resulting in extreme purity electroformed copper parts.
- Some copper pieces with complicated geometries are easier to fabricate by electroforming in steps.

Copper Electroforming Process

Electroforming is a method of producing pieces by the deposition of a metal onto a mold (mandrel) which is subsequently removed


Copper Electroforming Overview

Copper Electroforming Process

Process Parameters & Key Elements

- Mandrel turns during the whole process producing a homogeneous deposition
- Bath circulates with continuous filtration to remove oxides and precipitates
- Covered bath avoids air and dust contamination
- Plating is done over polished and cleaned stainless steel mandrels with the same shape of the relevant copper parts
- H_2SO_4 improves the electric conductivity
- HCl and Thiourea affect copper crystal nucleation and grain size

Constituents of the Electrolyte

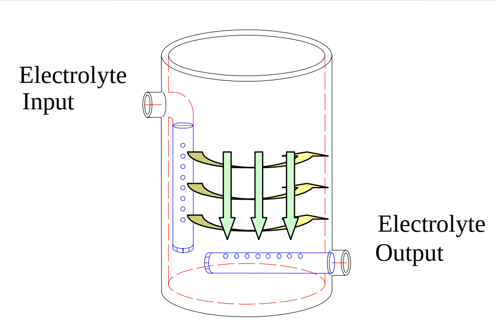
Constituent	Concentration
$CuSO_4 \cdot 5H_2O$	188 g/l
H_2SO_4	75 g/l
HCl	30 mg/l
Thiourea	3 mg/l

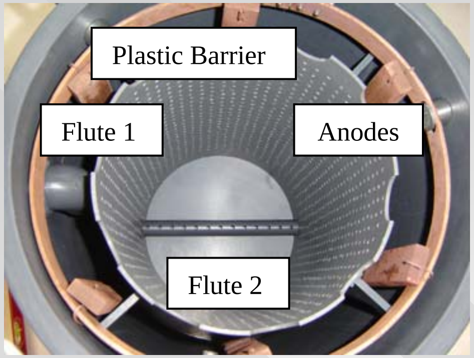
(Brodzinski et al.,A292 (1990) 337)

Equipment Improvements (I)

After its initial operation several upgrades to the design have been made:

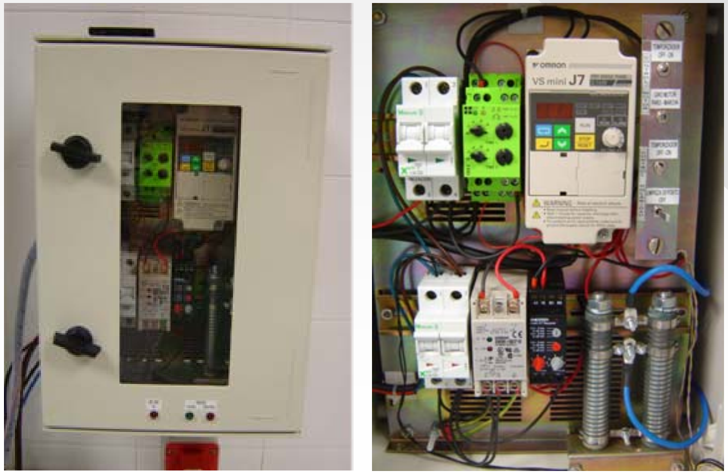
- **“Flutes” and a Plastic Barrier into the electrolitic bath**





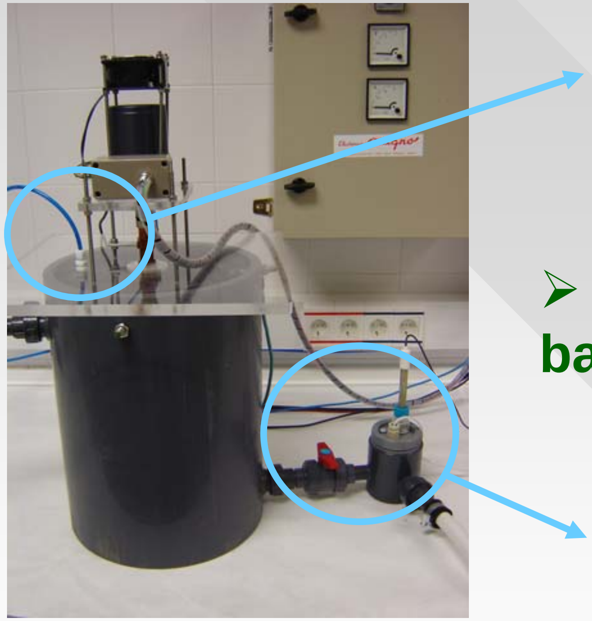
- Electrolyte circulation improvement
- Electric field homogeneization into the bath

- **Electronic Control System**

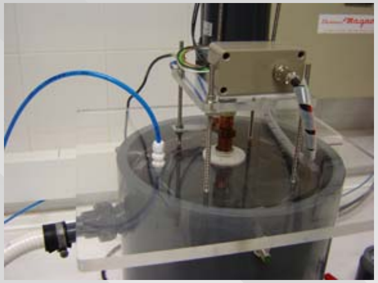


- Engine control Section
  - Rotation Speed
  - Rotation Direction
- Bath polarity control Section
  - Direct Current Plating (DC)
  - Pulse - reverse Current Plating (PR)

Equipment Improvements (II)



- **Inert cover gas (N_2) in plating tank**

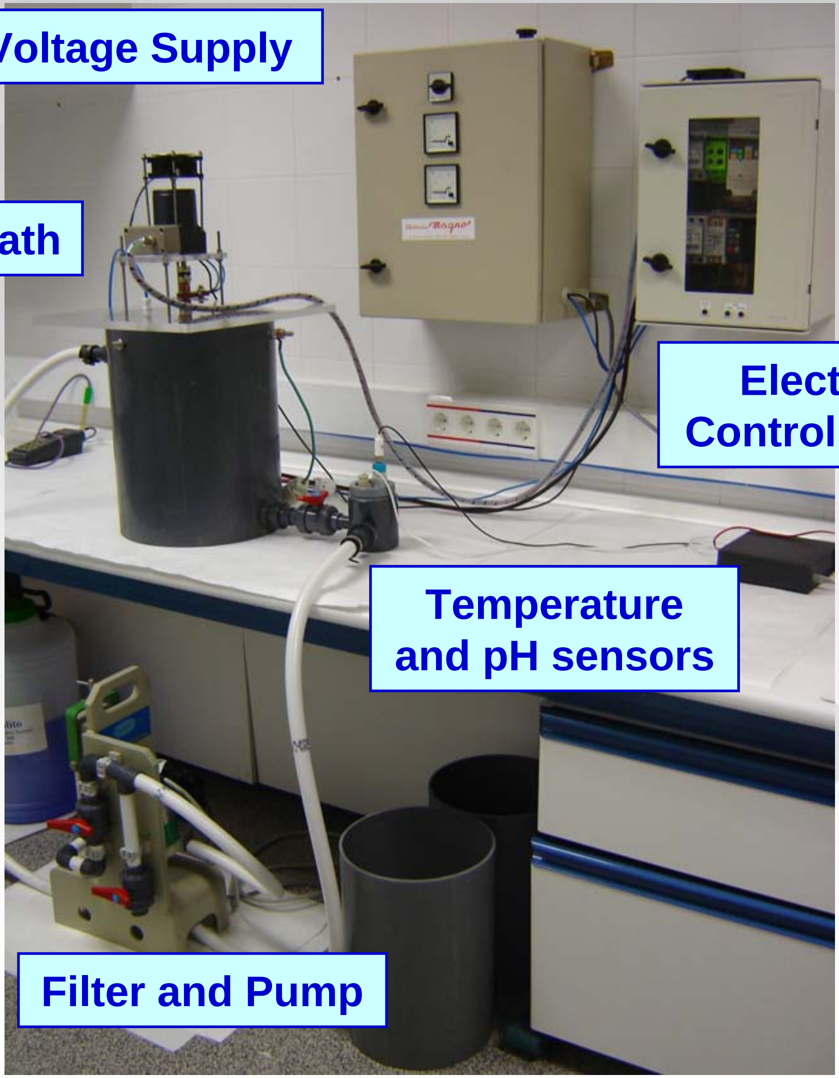


To reduce oxide formation into the bath

- **A new electronic facility to monitor bath parameters during the process**

- Temperature sensor and pH electrode in the electrolyte
- Data acquisition during the whole electroforming process

Electroforming Set-Up



Voltage Supply

Electrolitic Bath

Electronic Control System

Temperature and pH sensors

Filter and Pump

Starting…

Electroformed copper part obtained at 4 A dm^{-2} with a rotation speed of 4 rev s^{-1} by direct current plating

68 mm diametre

50 mm height

Dendritic Growth

Spiral dendritics at the bottom of the copper part

NEXT STEP ⇒

PROCESS PARAMETERS TUNING

Current Density

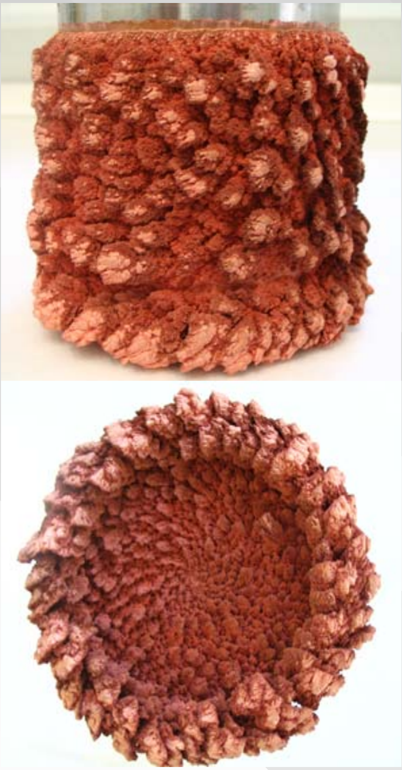
Rotation Speed

Rotation Direction

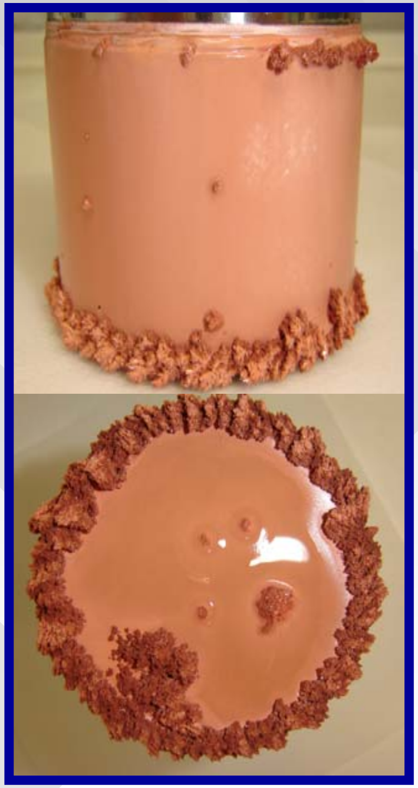
Rotation Speed Tuning

Electroformed copper parts obtained at different rotation speeds with a current density of 4 A dm^{-2}

4 rev s^{-1}



3 rev s^{-1}



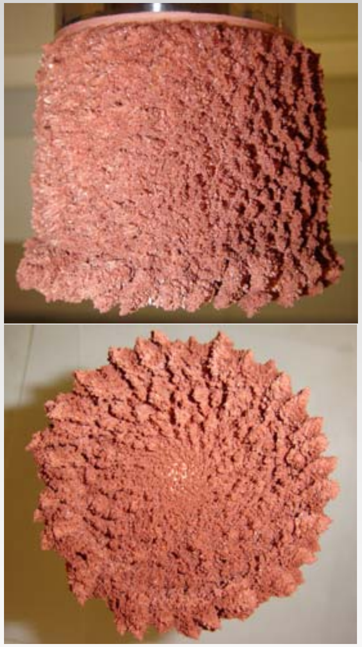
2 rev s^{-1}

Poor dendritic growth

No spiral dendritics

Current Density Tuning

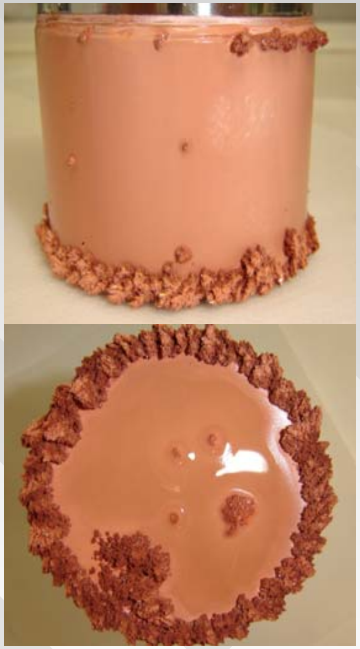
Electroformed copper parts obtained at different current densities with a rotation speed of 2 rev s^{-1}



12 A dm^{-2}

6 A dm^{-2}

5 A dm^{-2}



4 A dm^{-2}

3 A dm^{-2}

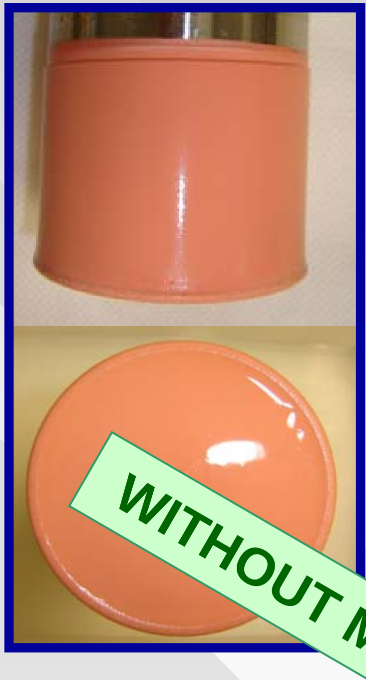
Smooth surface

Spiral at the bottom

Rotation Direction Tuning

Electroformed copper parts obtained at 3 A dm^{-2} and 2 rev s^{-1} with different rotation direction process

Forward direction process



Both forward and reverse direction process

(10 min each direction)

Smooth surface

No spiral at the bottom

WITHOUT MACHINING !!

Electroformed copper parts

Tests for NaI crystal encapsulation

ANAIS experiment

(Prototype III)

NEXT STEP

Design of a new encapsulation for NaI crystals

- **Low background materials**
- **A perfect assembly**

Electroformed copper hexagonal part

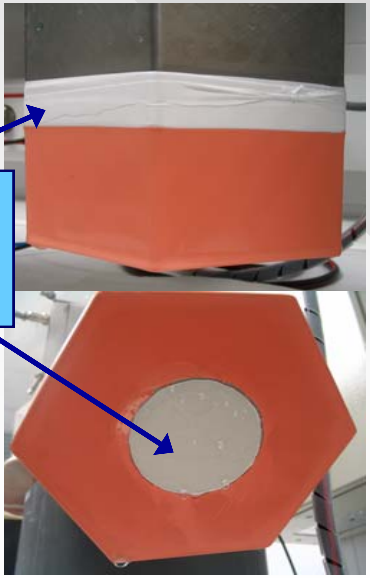
Electroformed copper part obtained at 3 A dm^{-2} and 1 rev s^{-1} with forward and reverse direction process using as mandrel the stainless steel NaI crystal container

Isolated Areas with Teflon and silicone

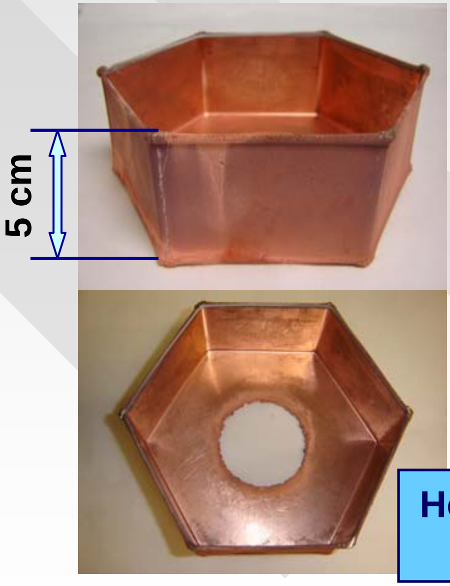
MANDREL

80 mm between sides

232 mm height



Mandrel with copper deposit



Electroformed copper part

- **Smooth surface**
- **Reproduce surface detail with fidelity (corners)**
- **A final machining process will be necessary**

Hole for a quartz window

Electroformed copper parts

Electroformed copper cylindrical part

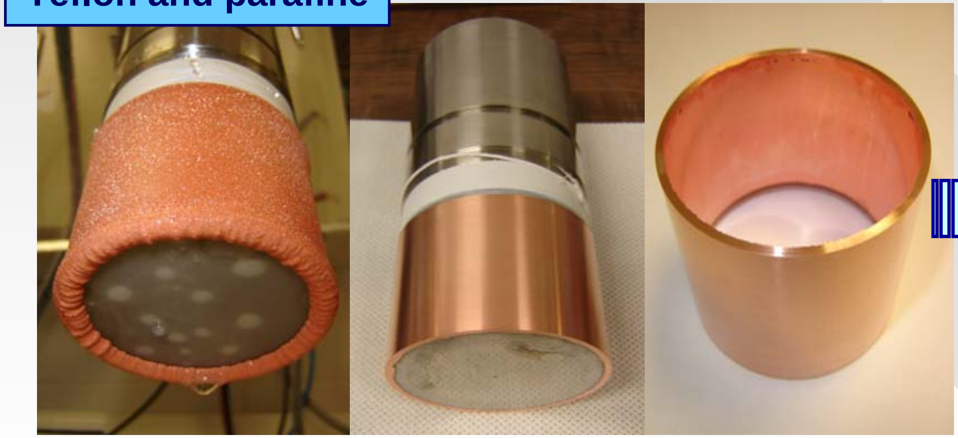
Crystal encapsulation assembly

By manufacturing the required pieces - copper parts and quartz windows - and sealing them with epoxy (low background glue)

A preliminary scaled- down prototype of the NaI crystal encapsulation

Electroformed copper part obtained at 3 A dm^{-2} and 2 rev s^{-1} with forward direction process (1.5 mm thickness)

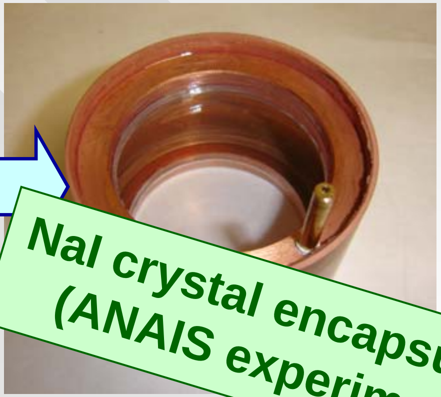
Isolated Areas with Teflon and parafine



Smooth surface

Crystalline morphology

Electroformed copper part after machining process



NaI crystal encapsulation in process (ANAIS experiment Prototype III)

Tests of epoxy assembly

Heating
Cooling
He leak detection

Good results!

S. Borjabad. Aussois, October 2006

Radiopurity measurements

Radiopurity measurements of electroformed copper parts

The levels of radiopurity in electroformed copper parts are being measured with a HPGe detector (1Kg Ge) at the Canfranc Underground Laboratory (LSC), in Spain.

An example of a standard- electroformed copper part measurement (commercial chemicals & at sea level) is presented below:

Copper mass: 161 g

Measuring time: 5 d

	Radionuclide	**Units (mBq/kg)**
Th series	^{212}Pb	≤ 16
	^{228}Ac	≤ 25
U series	^{234}Th	≤ 32
	^{234}Pa	≤ 90
	^{226}Ra	≤ 24
	^{214}Pb	≤ 3
	^{214}Bi	≤ 6
	^{235}U	≤ 1.4
	^{137}Cs	≤ 7
	^{40}K	≤ 90
	^{60}Co	≤ 7
	^{56}Co	≤ 3
	^{57}Co	≤ 8
	^{58}Co	≤ 5

Copper part into a Marinelli container

Copper around the HPGe detector

Summary and Prospects

SUMMARY

- Copper electroforming combines high purity with cosmogenics elimination.
- Is being used in a current generation of research detectors.
- Electroformed copper parts with smooth surface can be manufactured by means of the tuning of process parameters
- Copper parts with different geometry (hexagonal, cylindrical) can be achieved by easy modifications.

PROSPECTS

- Electroforming in steps: electroformed Cu parts for cryostats.
- Electroformed copper part for PMTs encapsulation (ANAIS experiment).
- Chemical & electrolitic improvements: $CuSO_4$ purified by recrystallization, high- purity acids and anodes, $CoSO_4$ and $BaSO_4$ to reduce Co and Ra isotopes.
- This facility will be installed at the new (enlarged) Canfranc Underground Laboratory as soon as the clean room is ready.