Evolution and Progress in Material Science for Studying the Fleischmann and Pons Effect

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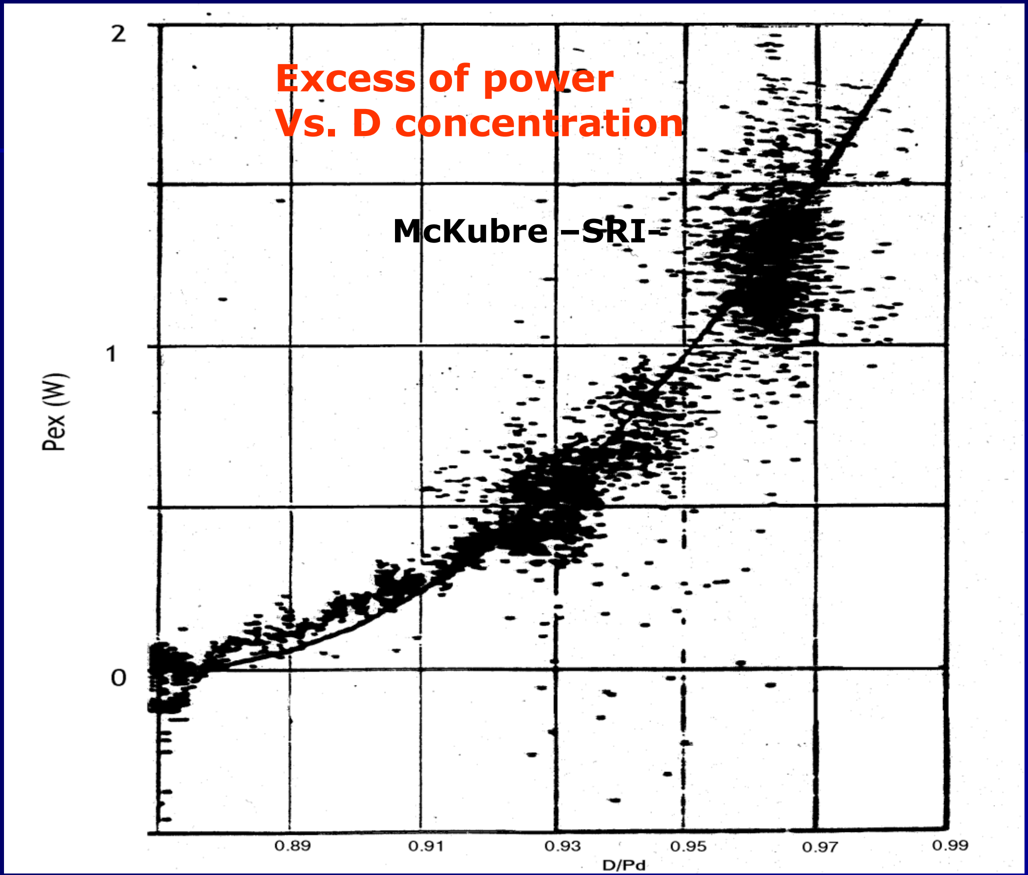
Reproducibility of Loading and of Excess of Power as a Material Science Problem



Threshold effect McKubre (SRI) e Kunimatzu (IMRA Japan) (1992)

Research Frame

Since 1996 in ENEA material status was identified to be responsible of the loading

⇓

1) Material science study to increase both reproducibility and signals

2) Calorimetric experiments conceived to have an appropriate signal/noise ratio

3) Theoretical work to identify methods to trigger the effect

Material Science on Metallurgy

H or D entering Pd lattice produces an elongation of the lattice parameter

Loading is not homogeneous and concentration gradients produce a stress field

The stress field modify the chemical potential of hydrogen dissolving into the lattice

$$\mu_H^* = \mu_H - V_s \sigma_h$$

(V solute molar volume, σ_h trace of the stress tensor)

In presence of a stress field the flux equation reads:

$$\bar{J} = -D(\nabla c - \frac{c\bar{V}}{RT} \nabla \sigma)$$

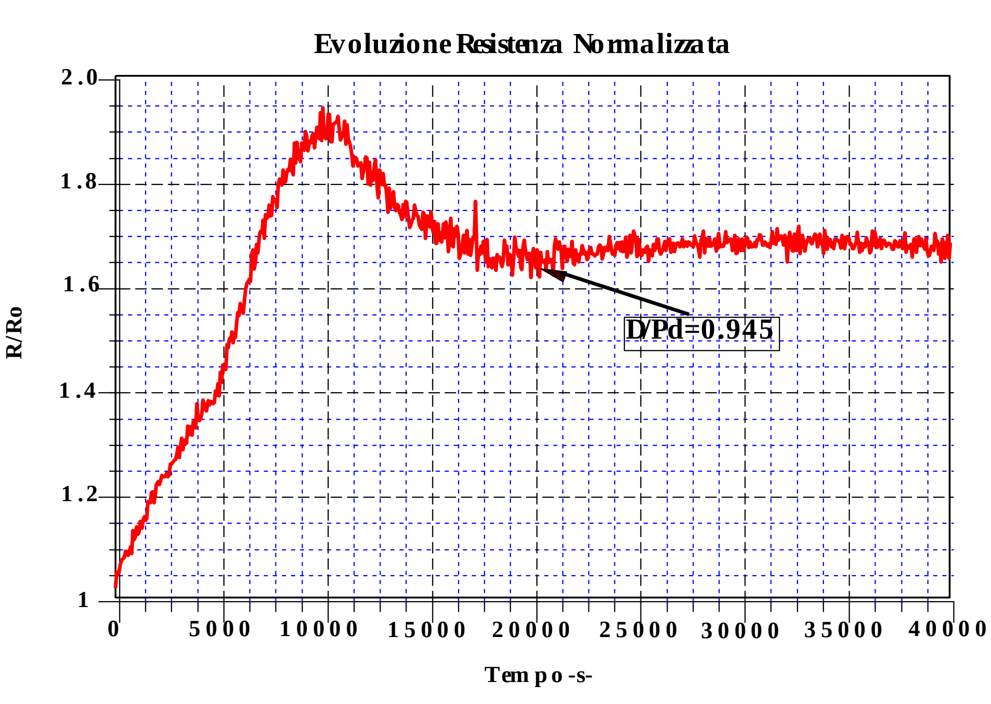
A metallurgy able to minimize the concentration gradients is required

Designed Metallurgy

A process has been defined to have a metallurgy enhancing mass transfer to reduce D concentration gradients and stress.

(Please see also S1_04)

Cold rolled and annealed at 850 °C Pd foil



Normalized Resistance evolution

Theoretical Frame

A theoretical model was developed that predicts intense E.M. field caused by charge density oscillations at the interfase leading to:

1) Deuterons interaction in Pd Lattice

2) Modified decay channel for D+D reaction

V. Violante, Lattice Ion Trap Confinement for Deuterons and Protons: Possible Interactions in Condensed Matter. Fusion Technology 35 (1999)361-368.

V. Violante, A. Torre, G.H. Miley, G. Selvaggi, Three Dimensional Analysis of the Lattice Confinement Effect on Ions Dynamics in Condensed Matter and Lattice Effect on the D-D Nuclear Reaction Channel. Fusion Technology 39 (2001) 266-281.

(Please see also S10_04)

Field Effect on the Decay Channel

The interaction Hamiltonian is calculated by using the same values of the field producing the close approach between deuterons

$$\hat{H}_I = \frac{e}{m}\hat{p}\vec{A}$$

Within the single particle approximation the probability amplitude results to be

$$\left|a_{fi}\right|^2 \cong \gamma^2[3-2(\cos(\omega_{10}T)+sin(\omega_{10}T))]$$

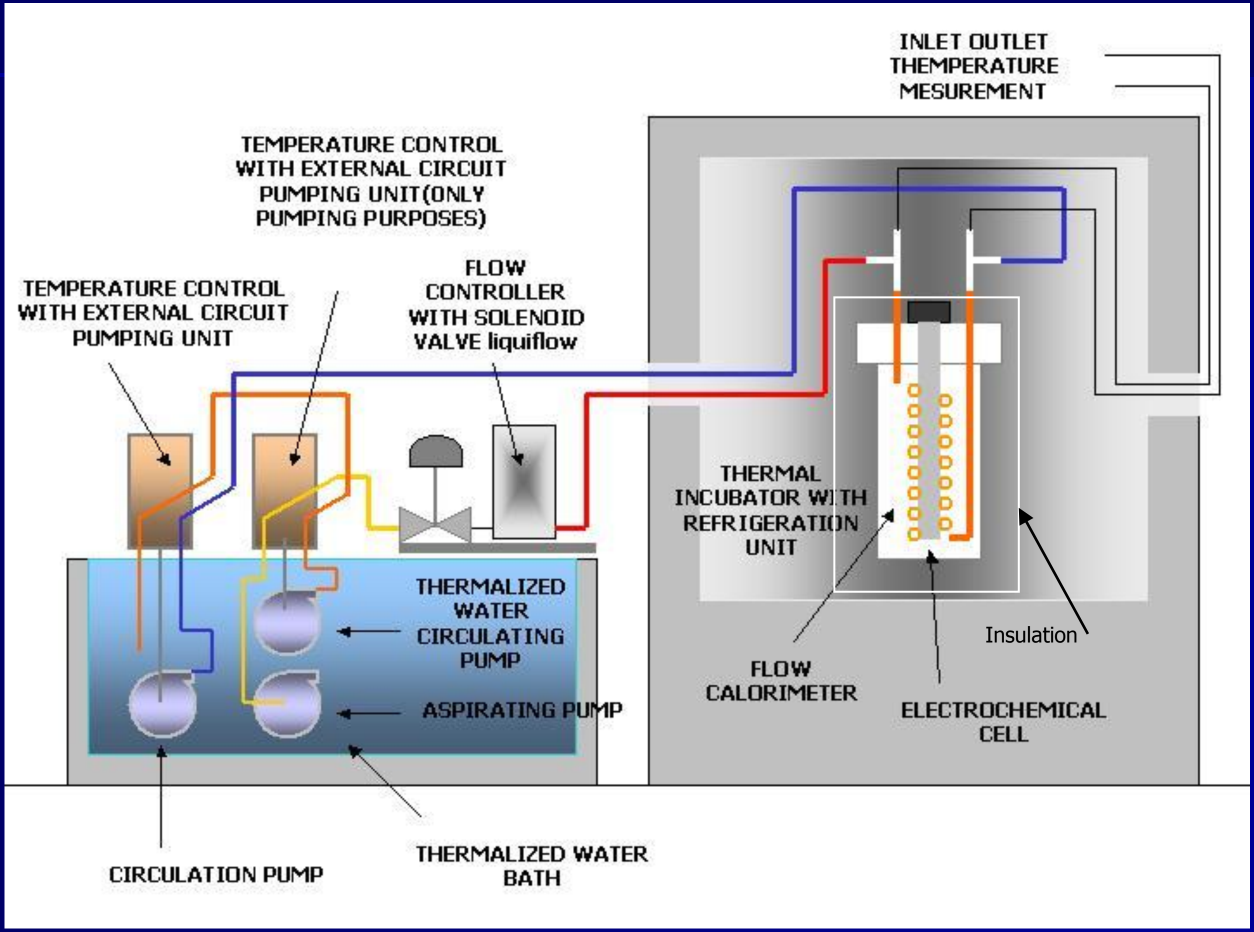
$$\gamma = f(\langle 1|H_I|0\rangle)$$

leading to

$$\frac{\sigma^*_{(D,n)}}{\sigma_{st}} < 10^{-5} \ (if\ A_0 = E_0/\Omega > 10^{-2})$$

2002-2004 Experimental Campaign

Calorimetry

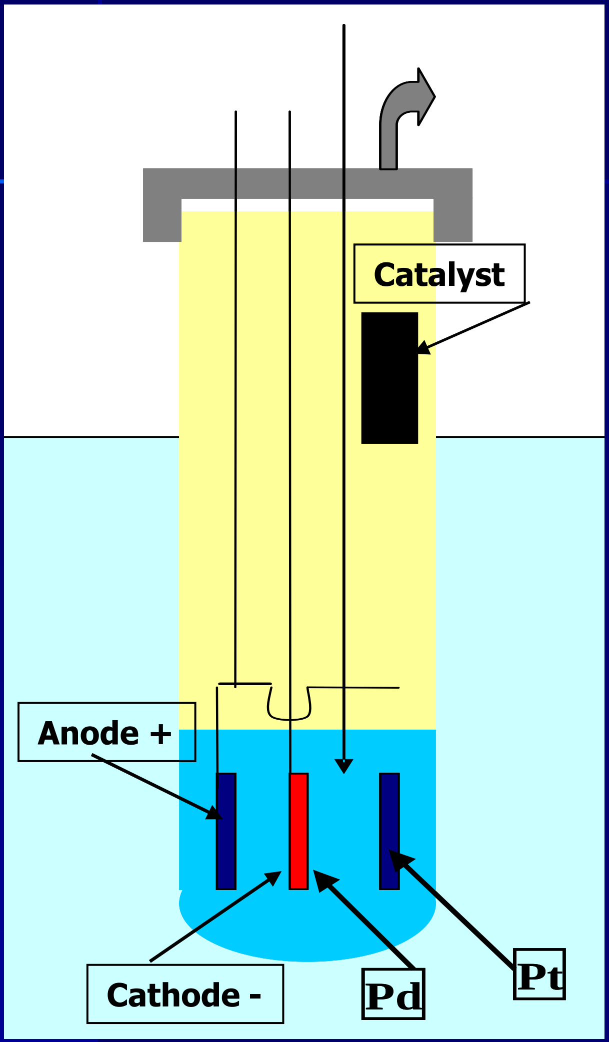


Flow Calorimeter

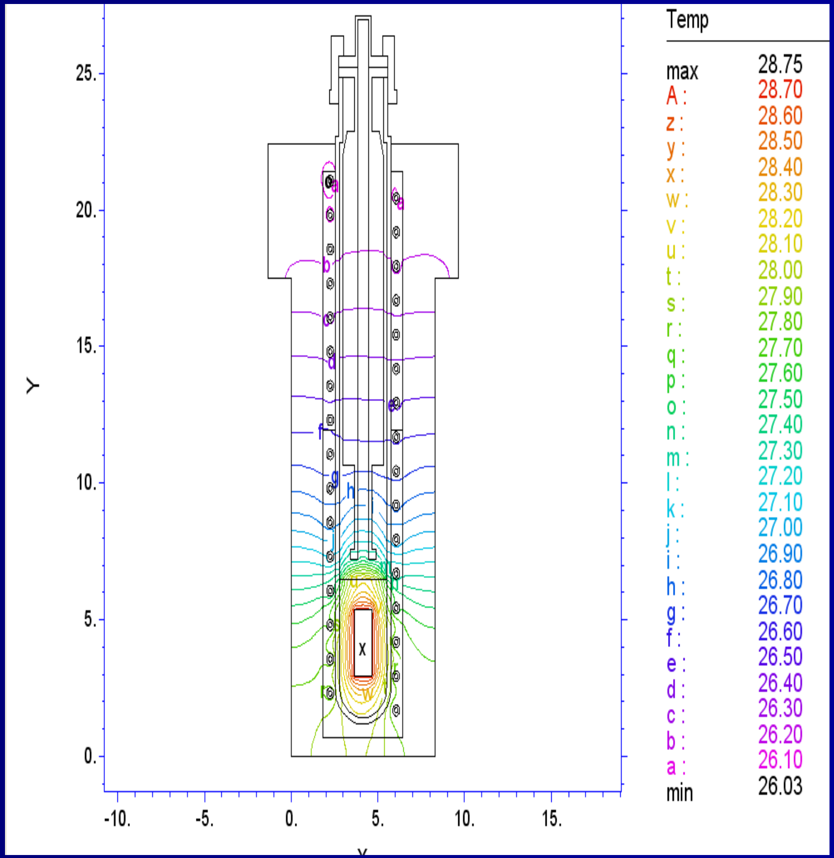
Closed Electrochemical Cell

$P_{IN}=VxI \qquad P_{OUT}=WCp(T_{OUT}-T_{IN})$

$P_{EX} = P_{OUT}/Efficiency - P_{IN}$



Cell scheme



FEM Modelling

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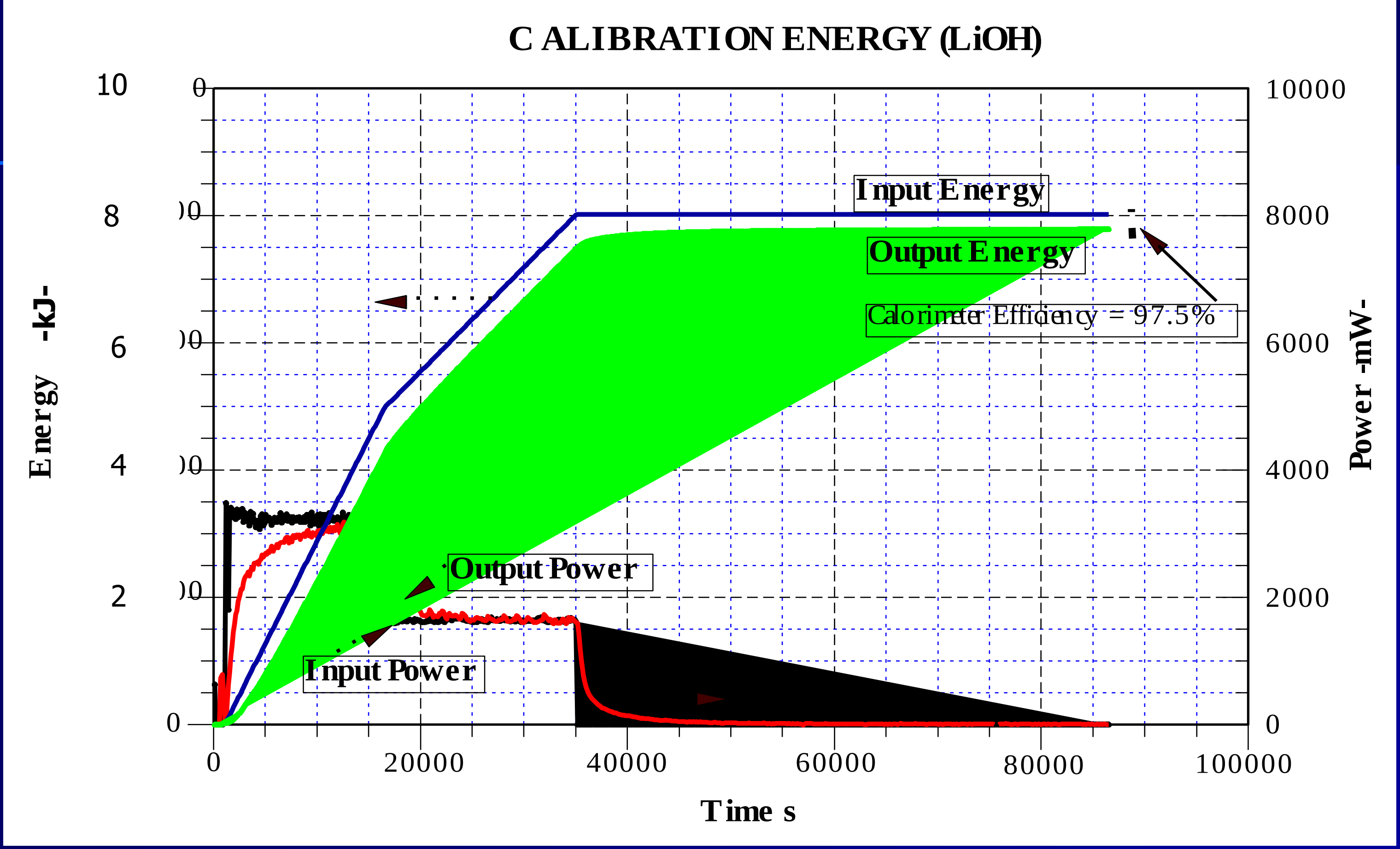
Light water experiment (typical calibration)



Input and output power and energy with H_2O. Calorimeter efficiency = 97.5%.

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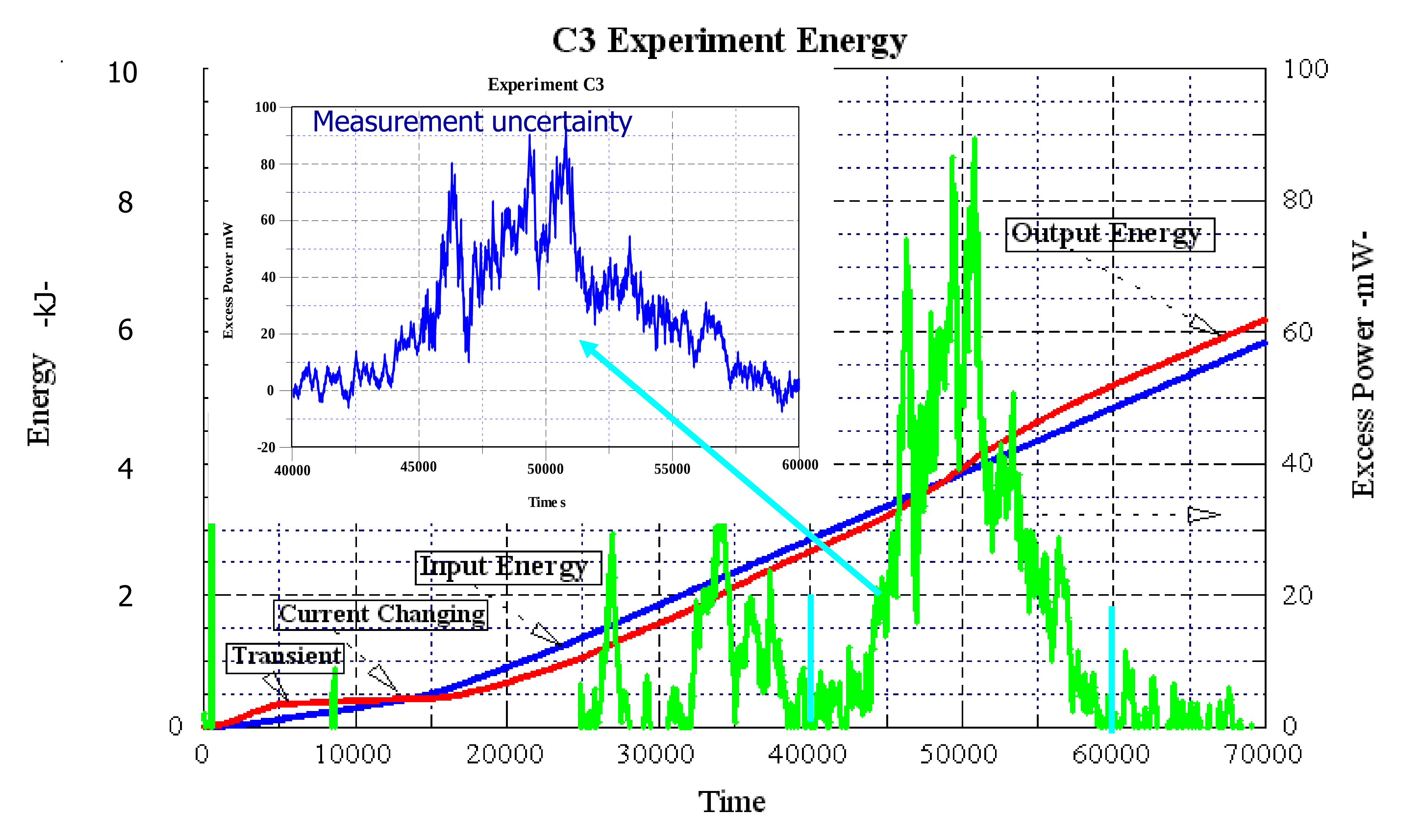
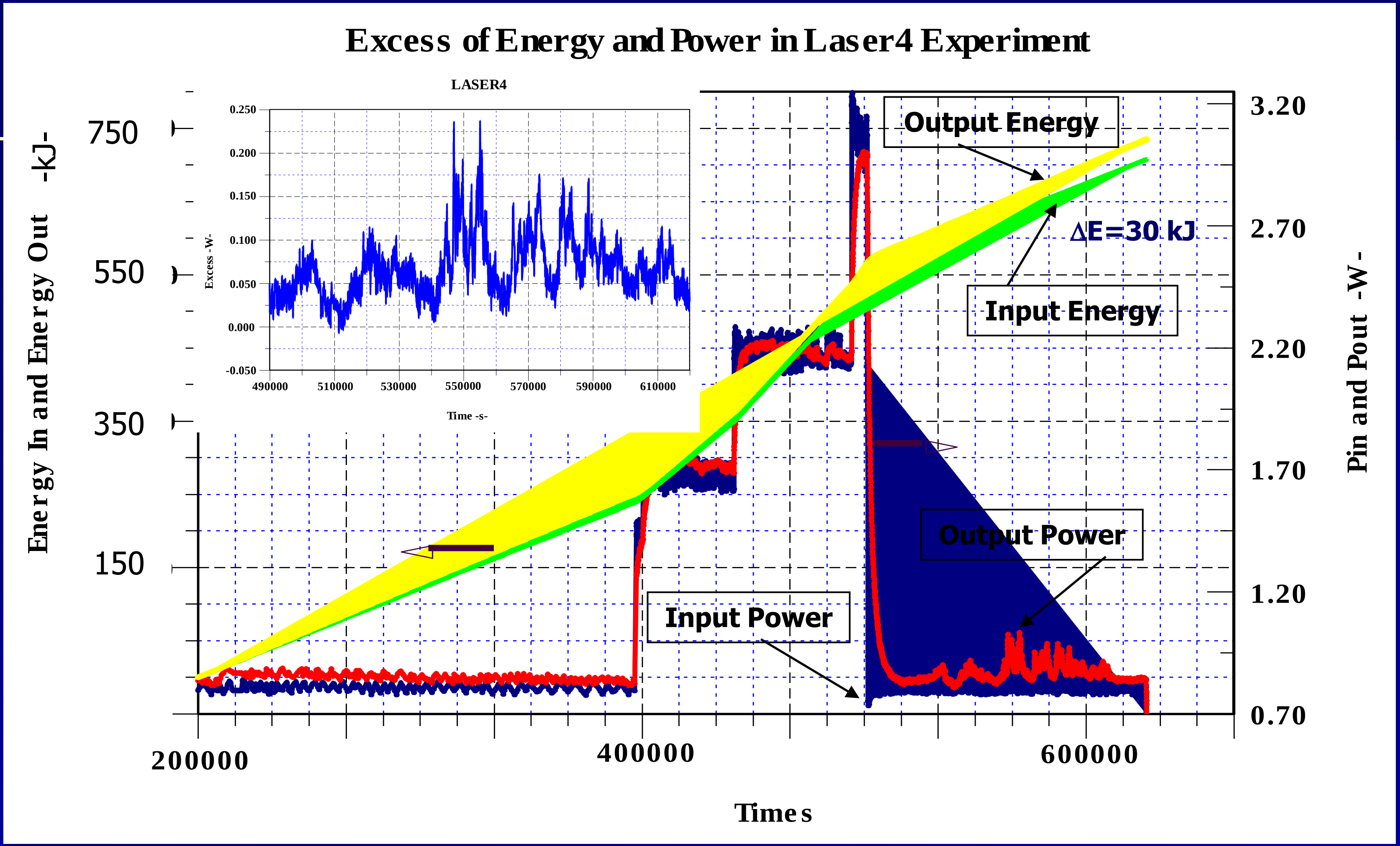
C3 Experiment



Excess of power and energy gain C3 (R/Ro=1.8, I=25 mA, V=4.1 Volt).

Laser Triggering Experiment:
Calorimetric Results



Excess of power and energy gain obtained by HeNe laser triggering

2002-2004 Experimental Campain Remarks

The concentration threshold is always overcome

Observed power excesses are 5 over a total number of 20 experiments

Samples qualified by ENEA showed similar results at other Institutes

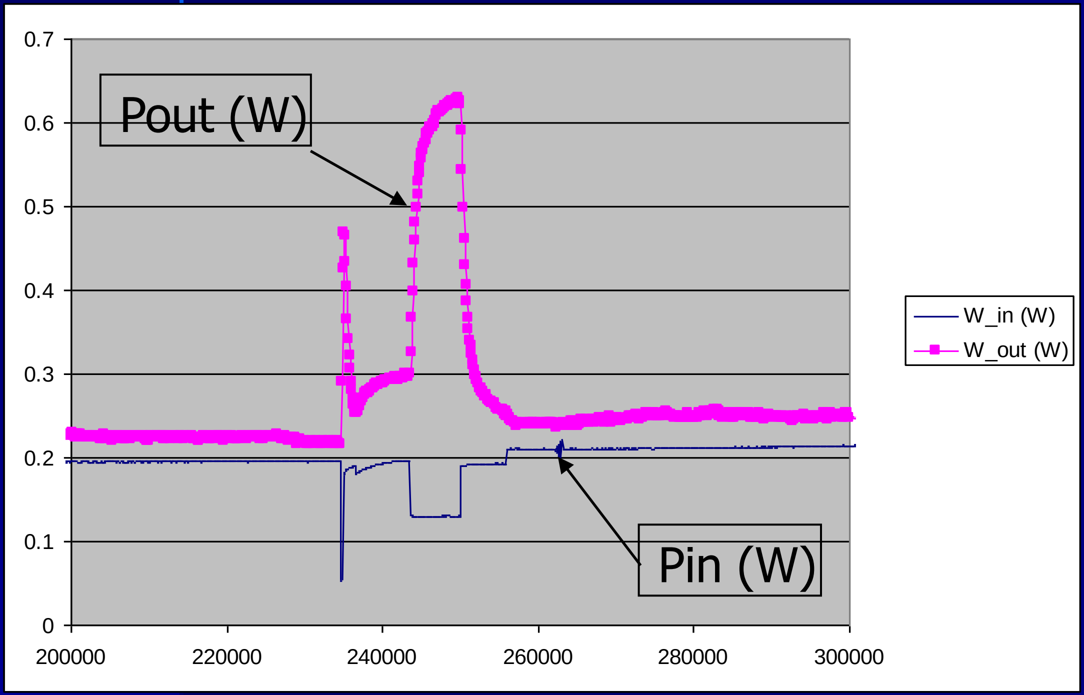
The effect is observed with deuterium but not with Hydrogen

The active electrodes showed similar characteristics

2005-2007: USA-Italy Revisions Projects
ENEA-MSE and SRI Experiments

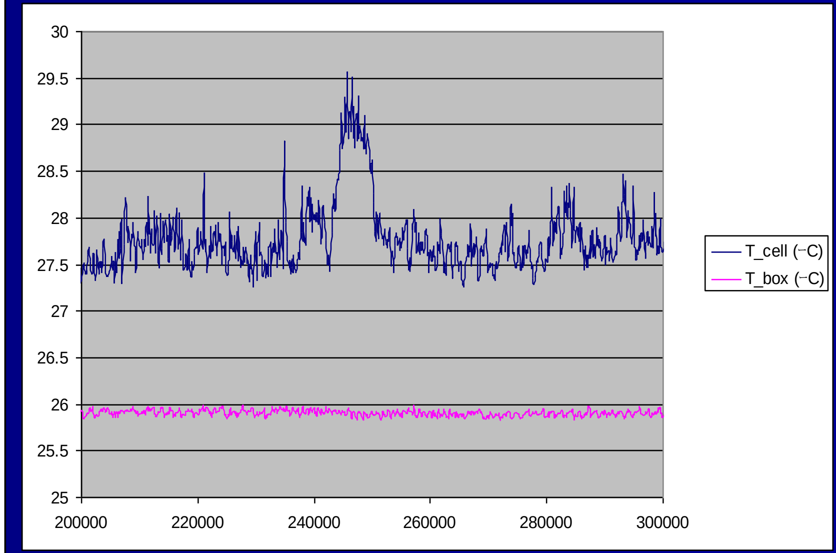
Research Projects having Government support are carried out both in Italy and US to verify the existance of the effect

(Please see also S1_03)



L17 experiment. Excess of power: the output power becomes 5 times larger than the input.

Electrolyte temperature



Electrolyte temperature increasing during the excess

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Transferred Reproducibility Synoptic

Electrode	Original Lot	Excess %	MJ/Mol
ETI 17	L1	20 (SRI)	
ETI 011	L5(2)	25-60 (SRI)	
ETI 35 7a	L17	10 (SRI)	
ETI 35 8a	L17	15 (SRI)	11
	L17	500 (ENEA)	
ETI 43 7a	L14(2)	80 (SRI)	
	L14	80 (ENEA)	
ETI 051 7	L25B(1)	12 (SRI)	
ETI 051 8	L25A(1)	NO (SRI)	
	L25A(1)	23 (ENEA)	
ETI 051 8	L18	NO (SRI)	
ETI 056 7	L24F	25 (SRI)	19
ETI 056 8	L24D	NO (SRI)	
ETI 056 9	L25B(2)	5 - 6 (SRI)	1
ETI 58 9	L25A	200 (SRI)	
ETI 61 7	L25B(1)	50 (SRI)	
	L26	69 ENEA	

Reproducibility was 60% in ENEA and 70% at SRI

2005-2007 Experimental Campain Remarks

High loading is a necessary, but not sufficient condition to have the F&P effect

The focus was moved on other features of the samples correlated with the occurrence of the effect.

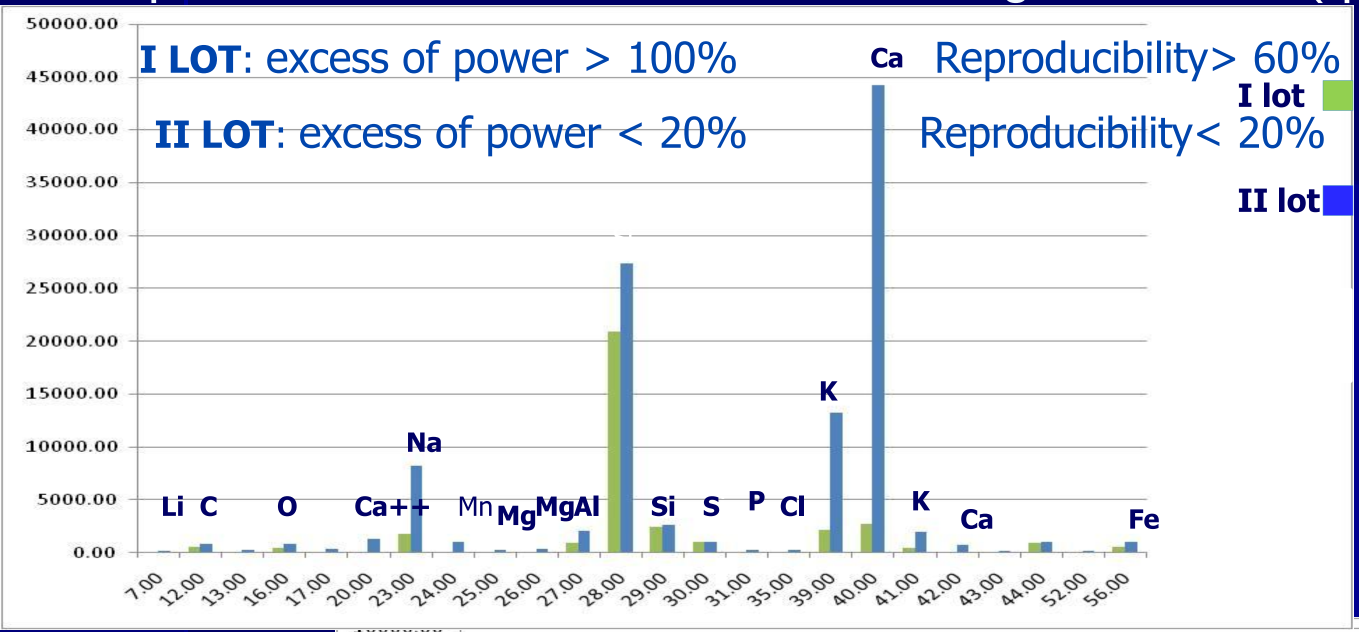
Other conditions are required to increase the excess of power reproducibility.

A different behavior was observed with Pd cathodes loaded above The threshold D/Pd =0.9:

1) High power gain during the excess.
2) Low power gain during excess.
3) No excess.

Differences in Two Lots from the Same Producer

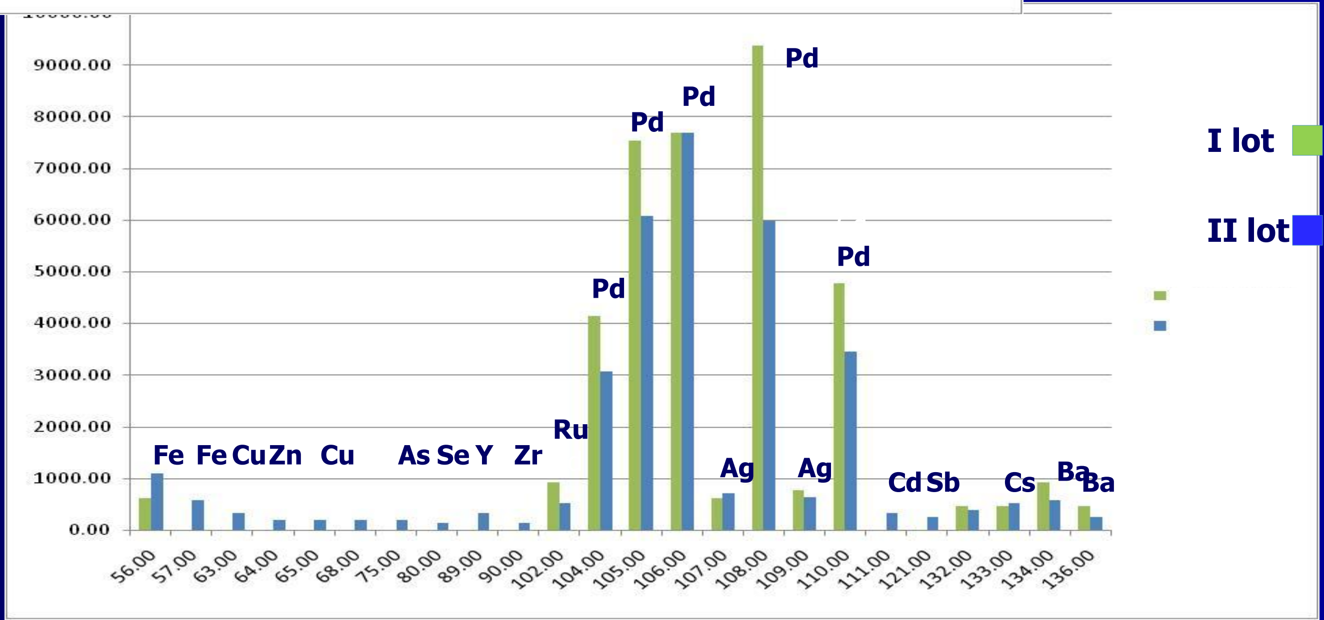
Spectrum of Contaminants in the Rough Materials (qualitative study).



SIMS analysis

Both lots were 99.95%

Reproducibility reduced under 20% with Lot II

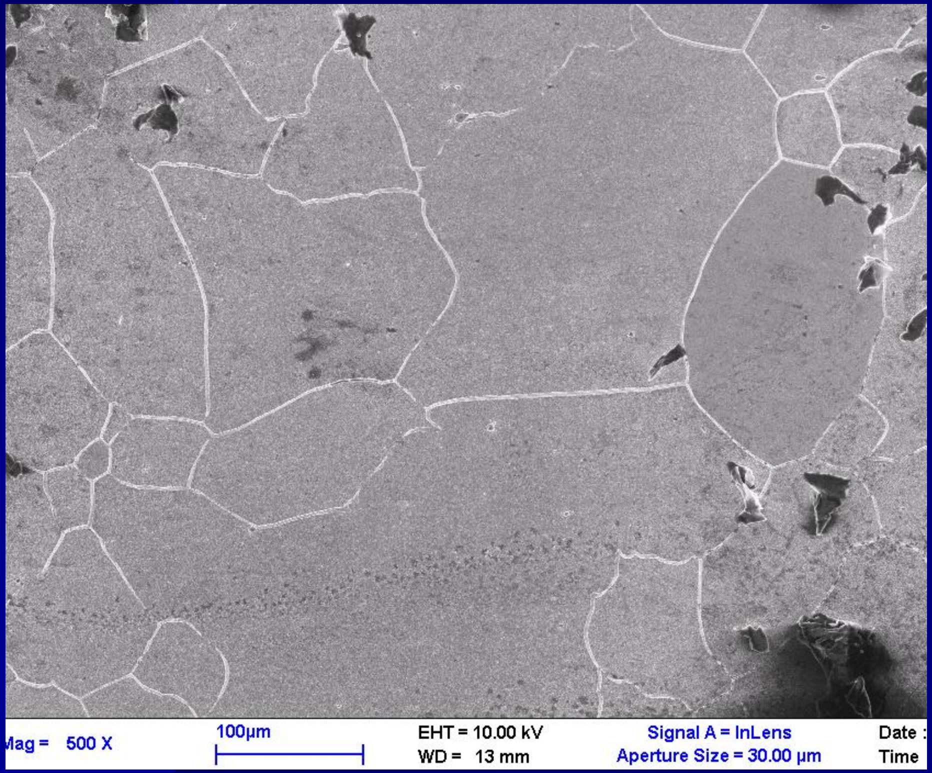


Contaminants Effects

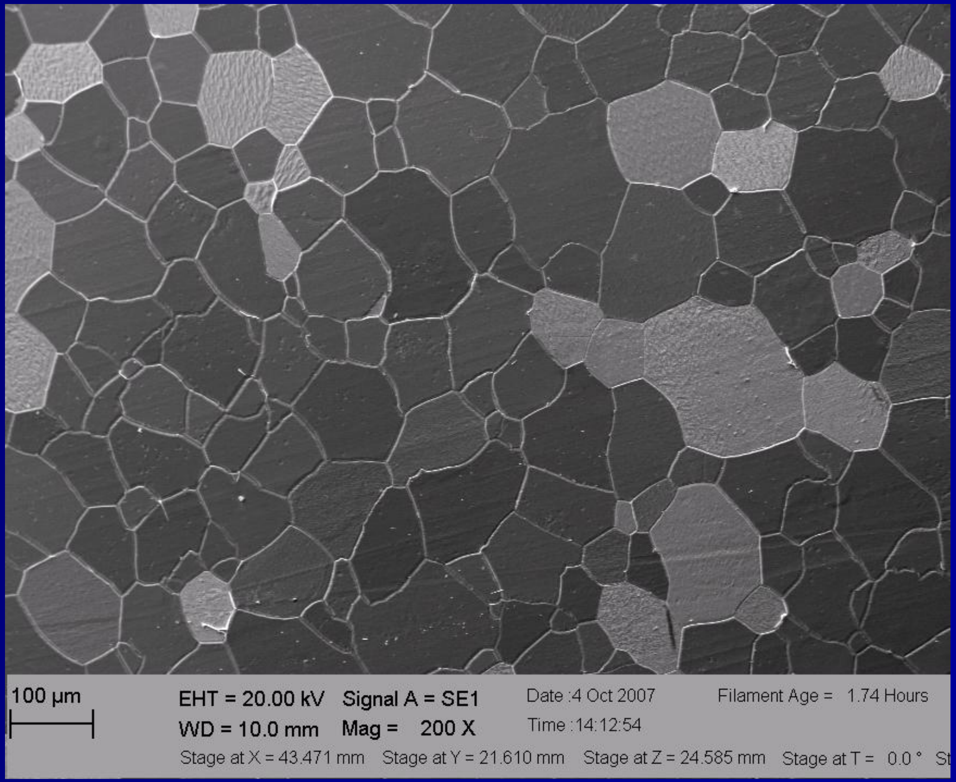
Contaminants may act on:

- Grain size
- Chrystal orientation
- Grain boundary

Same treatments



Lot 1



Lot 2

Crystal Orientation (NRL Study)

X Ray Diffraction :Crystals orientation after metallurgical treatment

a) LOT 1 *is well aligned <100>, little or no <110>*

b) ***LOT 2*** *samples is a mix of <100> and <110>* (Please see also S1_04)

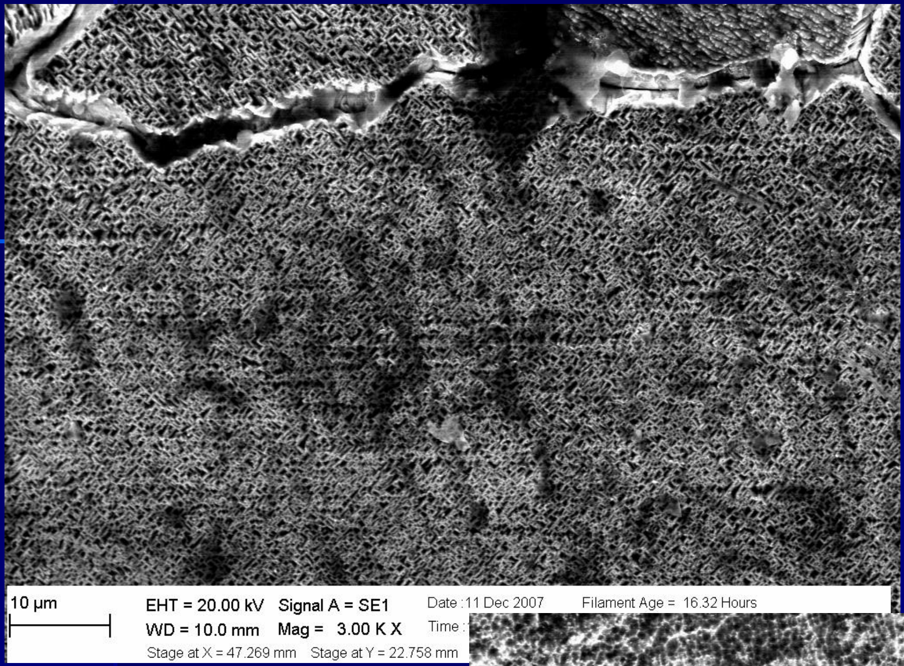
c) A third lot giving a different spectrum of contaminants undergone to the same treatment revealed mostly <110> very little <100>

No excess was produced by testing cathodes realized with this third lot.

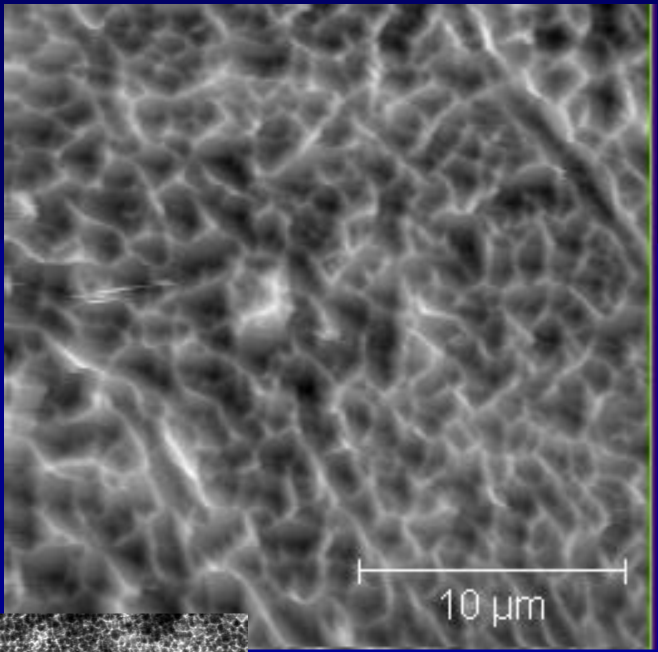
Crystal orientation and surface morphology are further conditions For having the excess

Power spectral density has been selected as merit figure to identify the status of the surface (please see S10_O1):

Typical Surface Morphology (after Etching) giving Excess of Heat



#64

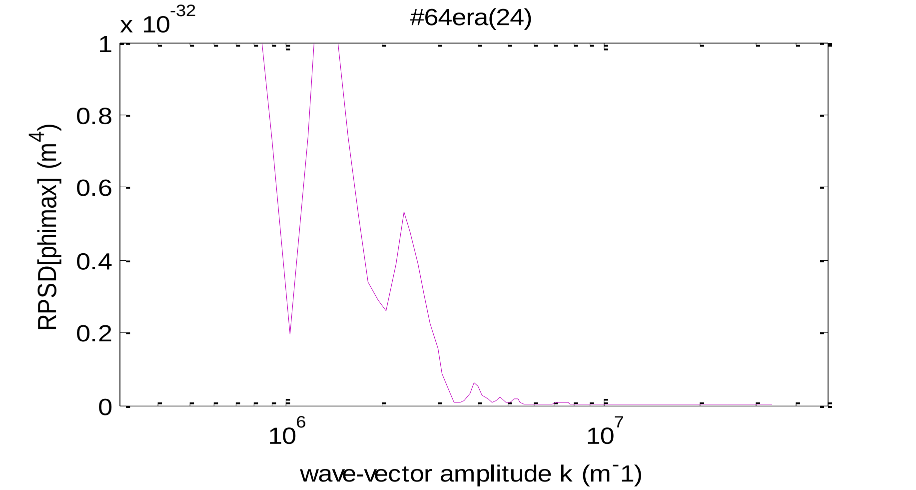


L25

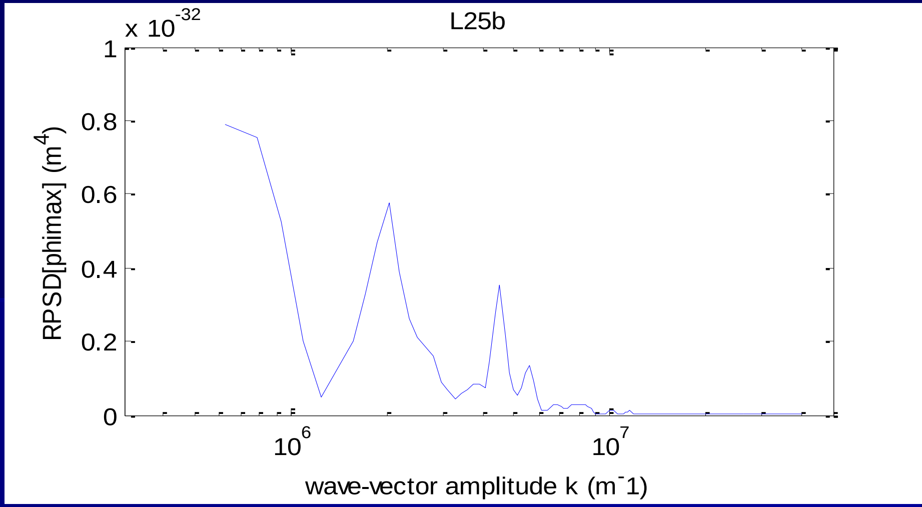
(Please see also P_41)

ET-UTS-05

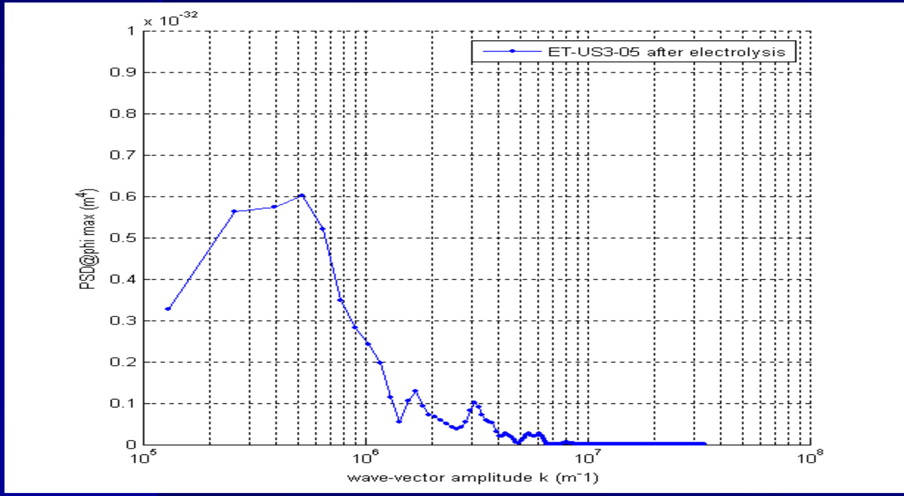
PSDF



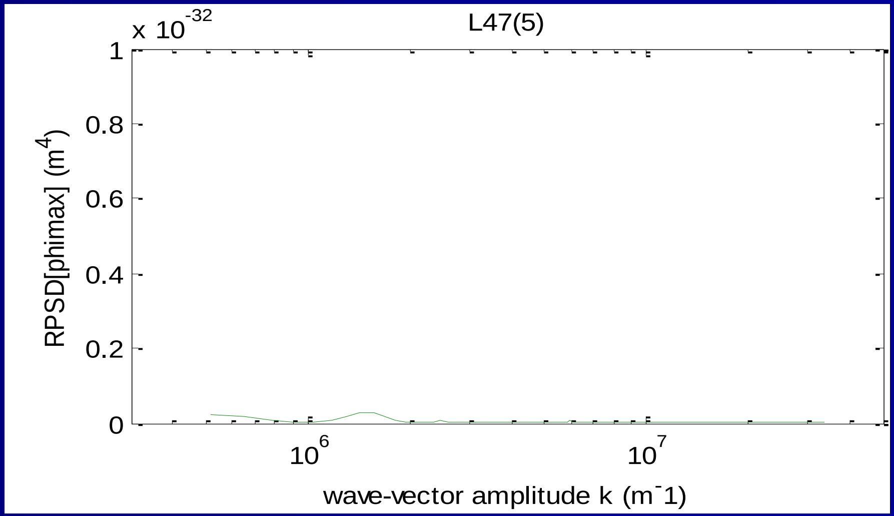
PSDF of sample #64 producing 3500% excess of heat.



PSDF of sample L25 producing up to 250% excess of heat.



PSDF of sample ET-UTS-05 producing 25% excess of heat under electrolysis.



PSDF of a sample not producing excess of heat

Surface morphology results to be a third condition

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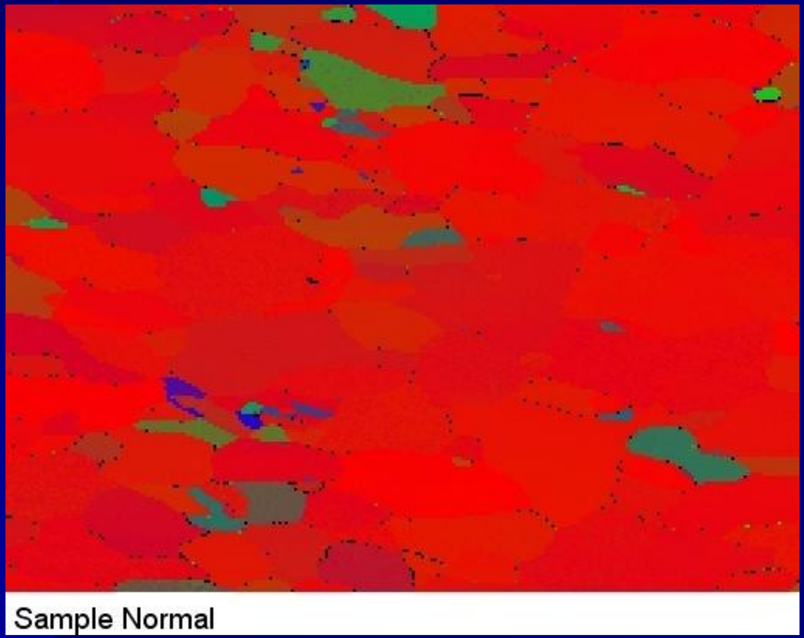
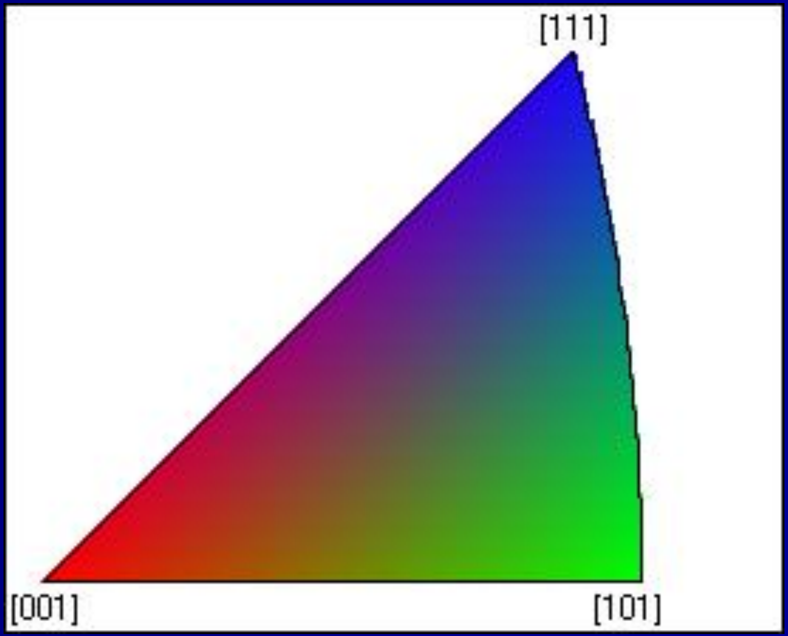
A Designed Material

The experimental evidences leaded to produce a material having characteristics close to the ones described

A lot of Pd having a spectrum of contaminants approaching the lot 1 one was undergone to the treatment leading to: dominant <100> orientation and an appropriate metallurgy.

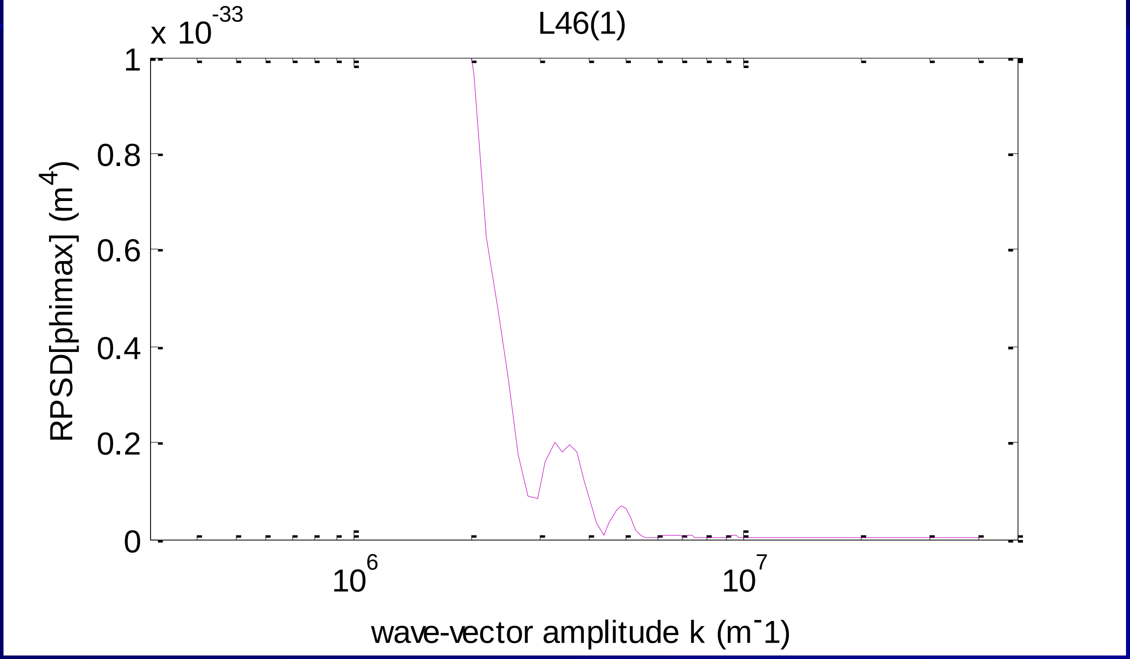




L46 EBDS Results

PSDF of Sample L46

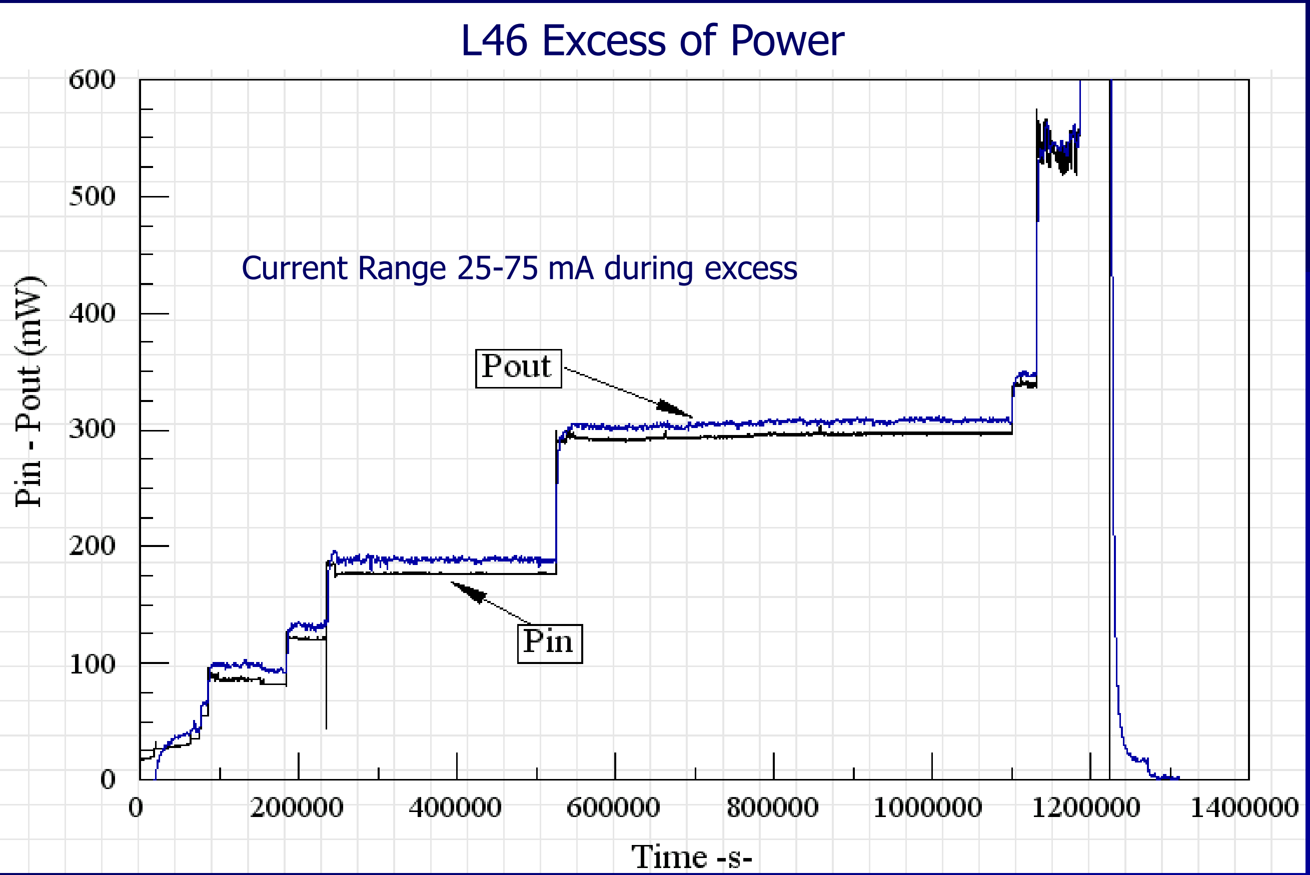
After performing chemical etching the surface achieved a status identified by the PSDF calculated from the surface image given by the Atomic Force Microscopy.



PSDF of sample L46

Even if of reduced amplitudes the peaks structure belonging to samples producing excess of heat is clearly recognized. A small excess is expected

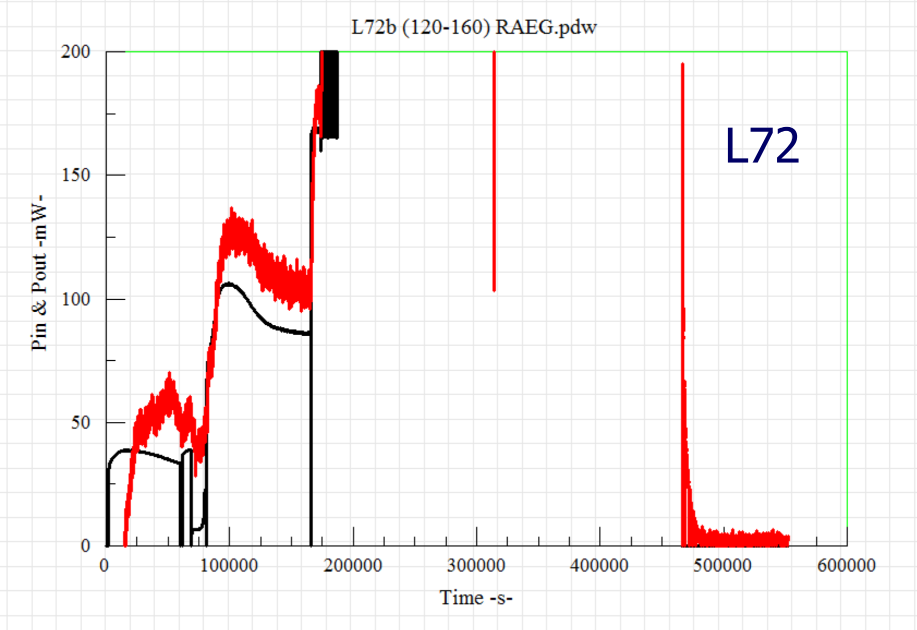
Calorimetric Results

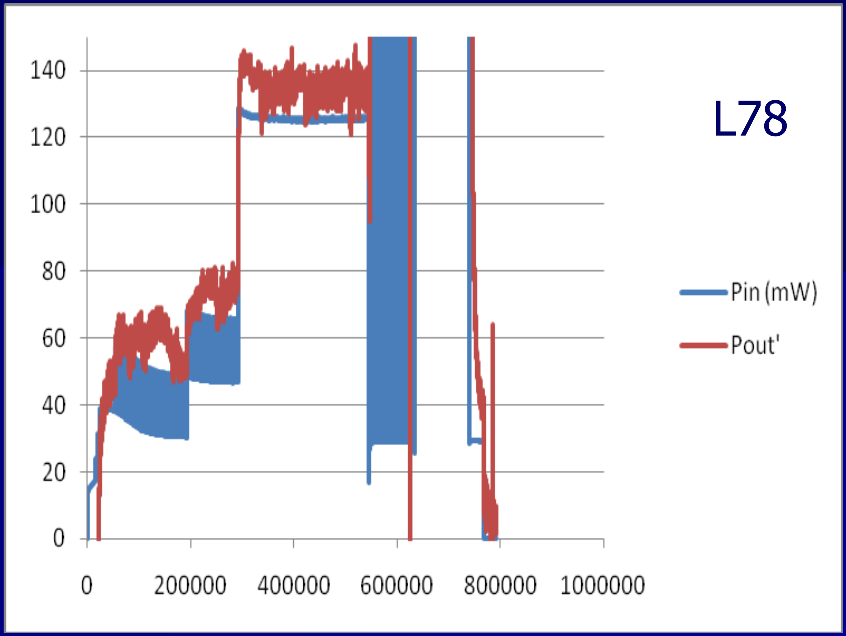


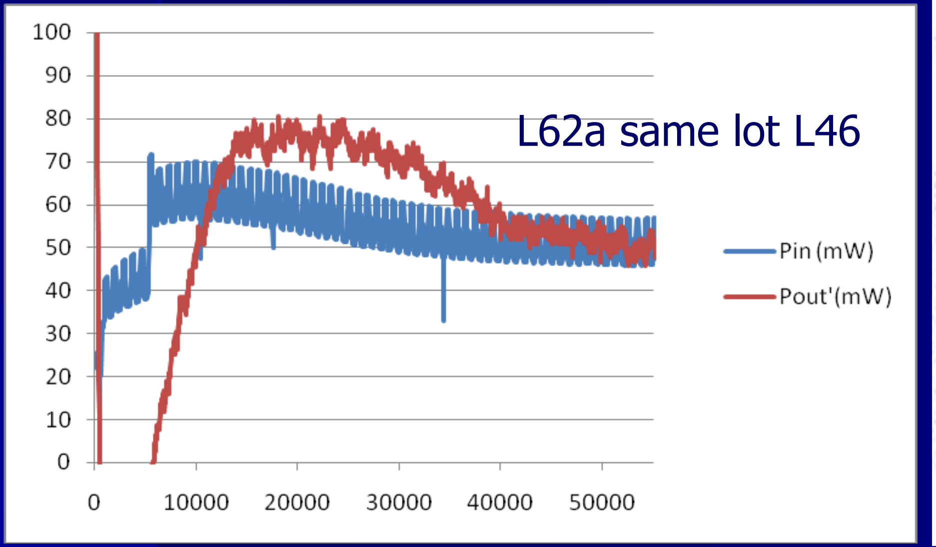
Evolution of the input and output power during experiment L-46:
Excess up to 12% was observed and the amplitude is again proportional to the PSDF peaks amplitude.

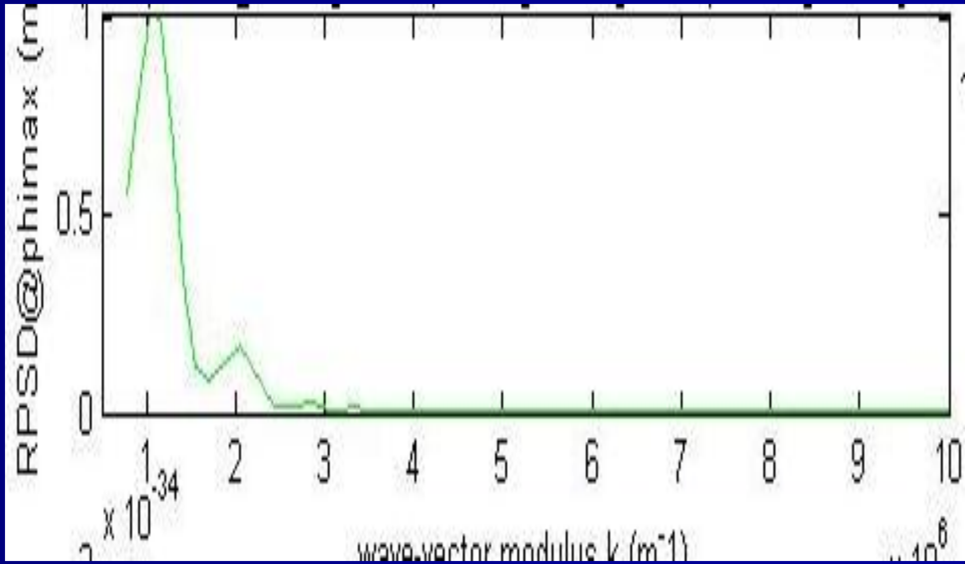
This is giving an additional evidence that a proper surface morphology is a third condition for having the excess of power.

Some Recent Results with "Designed Materials"









(Please see also S1_05)

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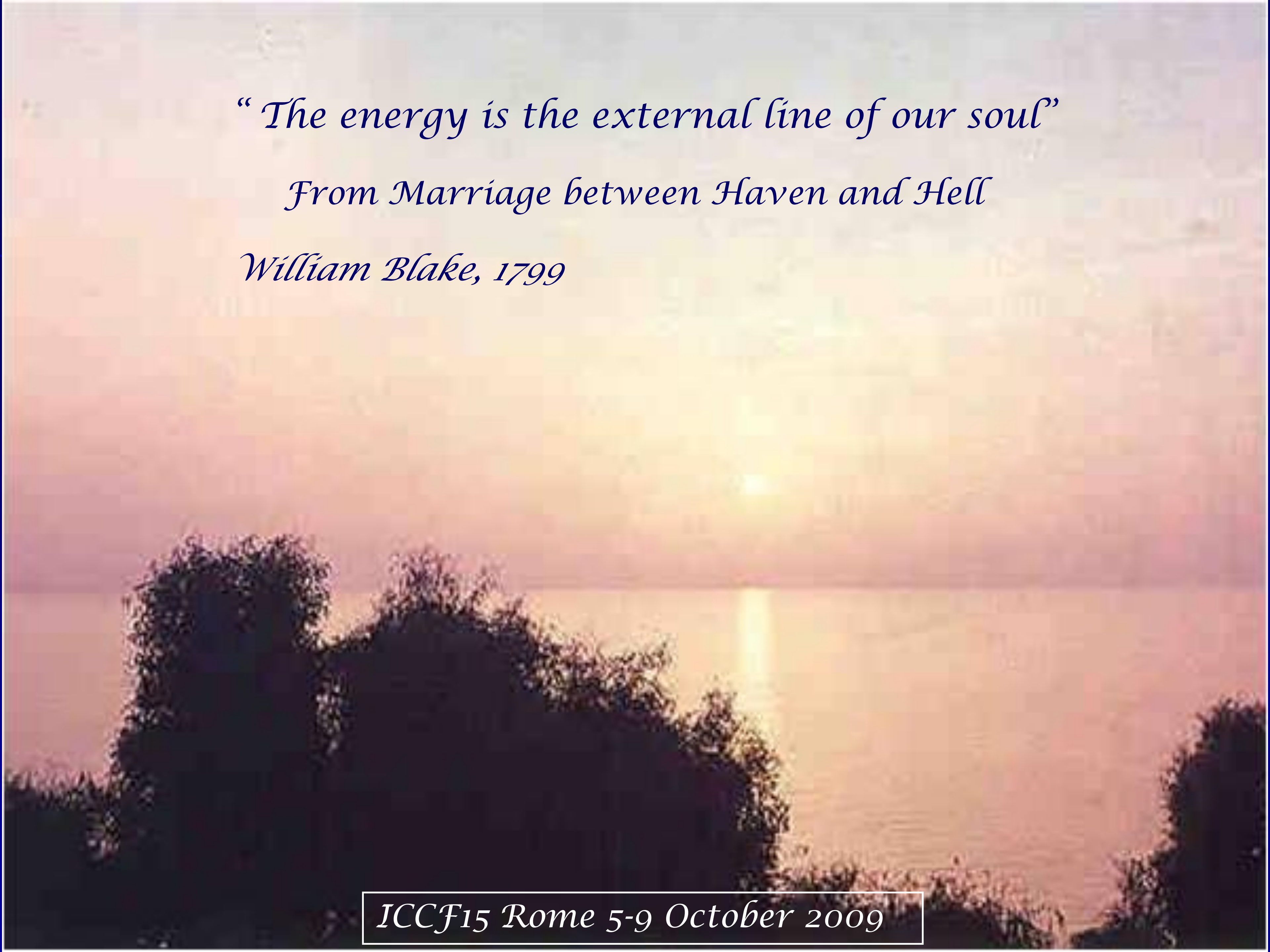
Conclusions

- Results from designed and rebuilt materials
- Important result for understanding the effect , even if the amplitude of the signals was not extraordinary
- Amplitude and shape of the PSDF peaks is proportional to the amplitude of the observed thermal signals
- The ability to produce a sample giving the excess is only at the early stage but the walk has been initiated
- Energy gains above 10^1 eV/atom have been observed in the experiments
- A large amount of produced energy per atom it's difficult to be interpreted as chemical effect
- A big challenge for material science and a great interdisciplinary task


" The energy is the external line of our soul"
From Marriage between Haven and Hell
William Blake, 1799
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