Low Energy Nuclear Reactions in Condensed Matter: The study of the Fleischman & Pons Effect through Materials Science Development

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Research Frame

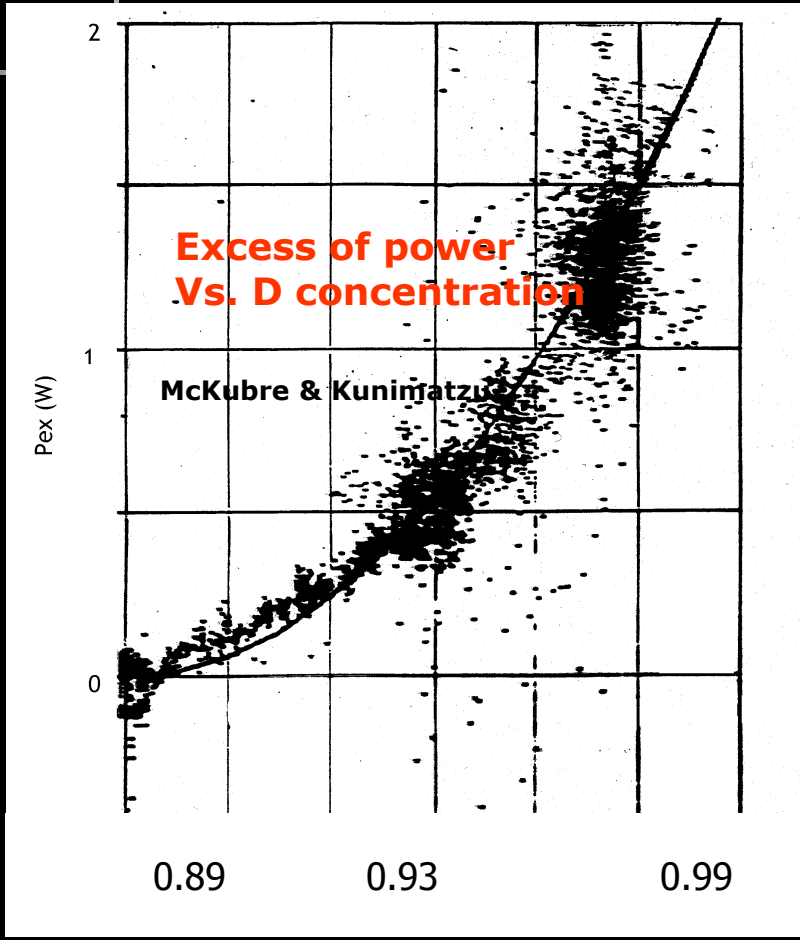
Material status, is considered to be foundamental

1) Material science study to increase both reproducibility and signals

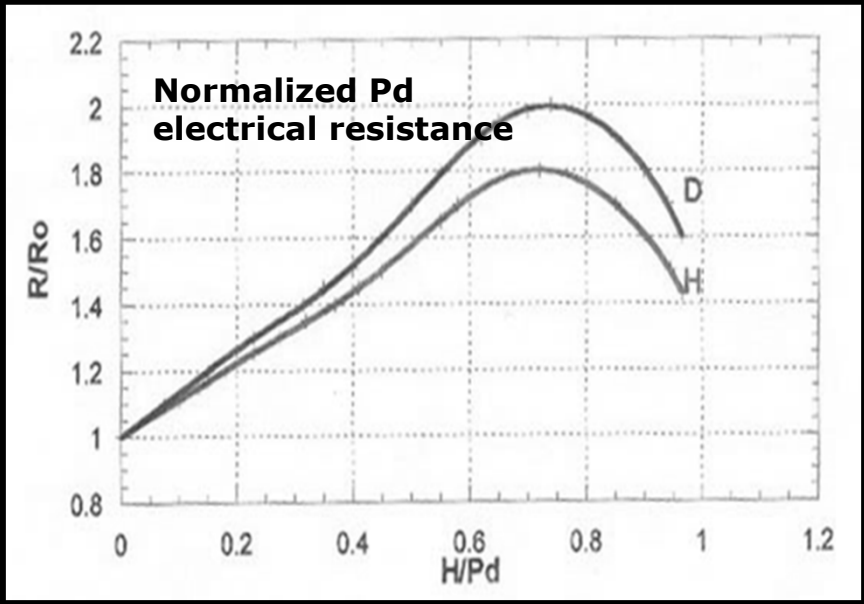
2) Calorimetric experiments conceived to have an appropriate signal/noise ratio

3) Theoretical work to identify methods to trigger the effect

Deuterium Loading Threshold Effect : Reproducibility of Loading and Excess of Power as a Material Science Problem



Excess of power vs D/Pd



Normalized Pd-H(D) resistance as function of loading (McKubre SRI).

Material Science on Metallurgy

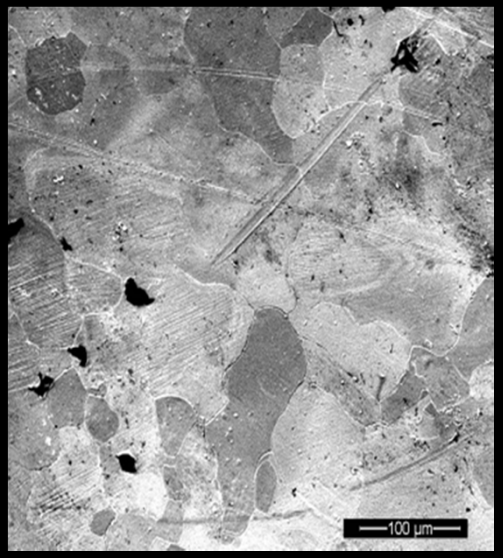
H or D entering Pd lattice produces an elongation of the lattice parameter

Loading is not homogeneous and concentration gradients produce a stress field

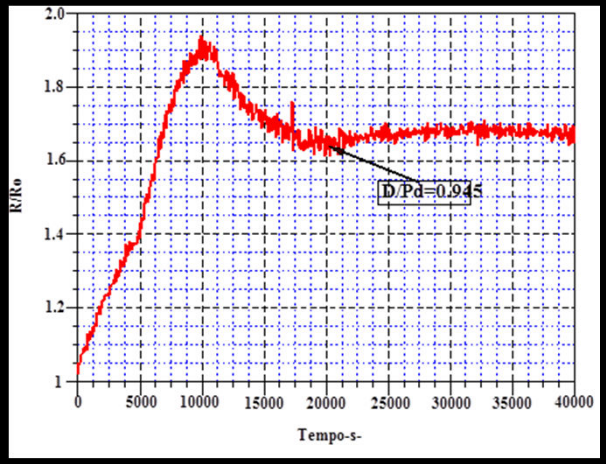
The stress field modify the chemical potential of hydrogen dissolving into the lattice and the flux equation becomes:

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

A metallurgy process able to minimize the concentration gradients and stress is required to enhance mass transfer and loading



Cold rolled and annealed
At 850°C



Normalized resistance

Observed Behaviors

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.

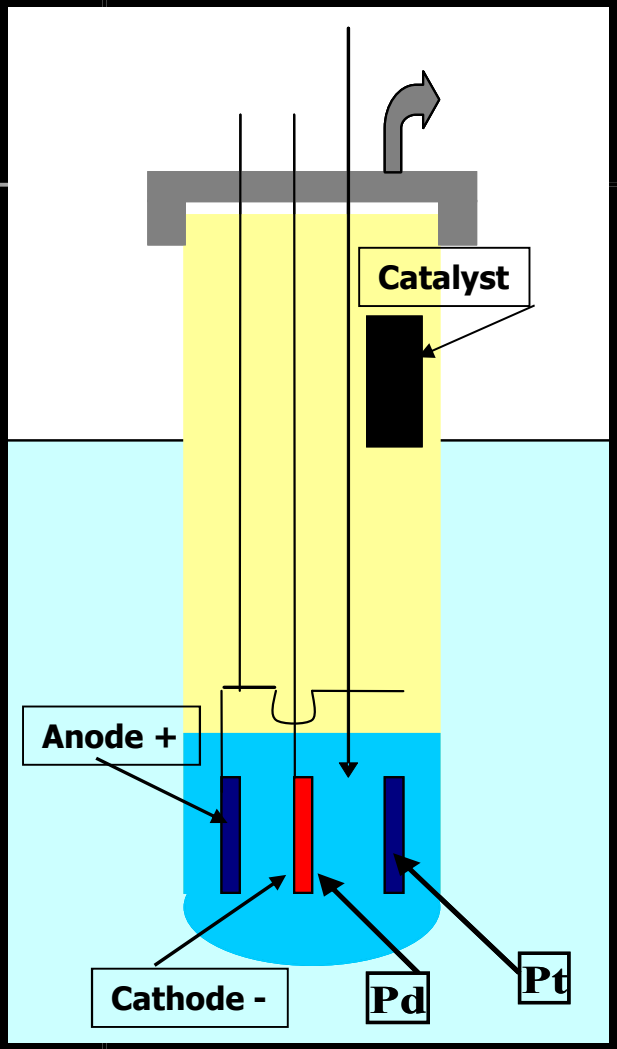
Energy densities measured during excess of power are tens, hundreds, and even thousands times larger than the maximum energy associated to any known chemical process

The effect takes place only with Deuterium in Pd and not with Hydrogen

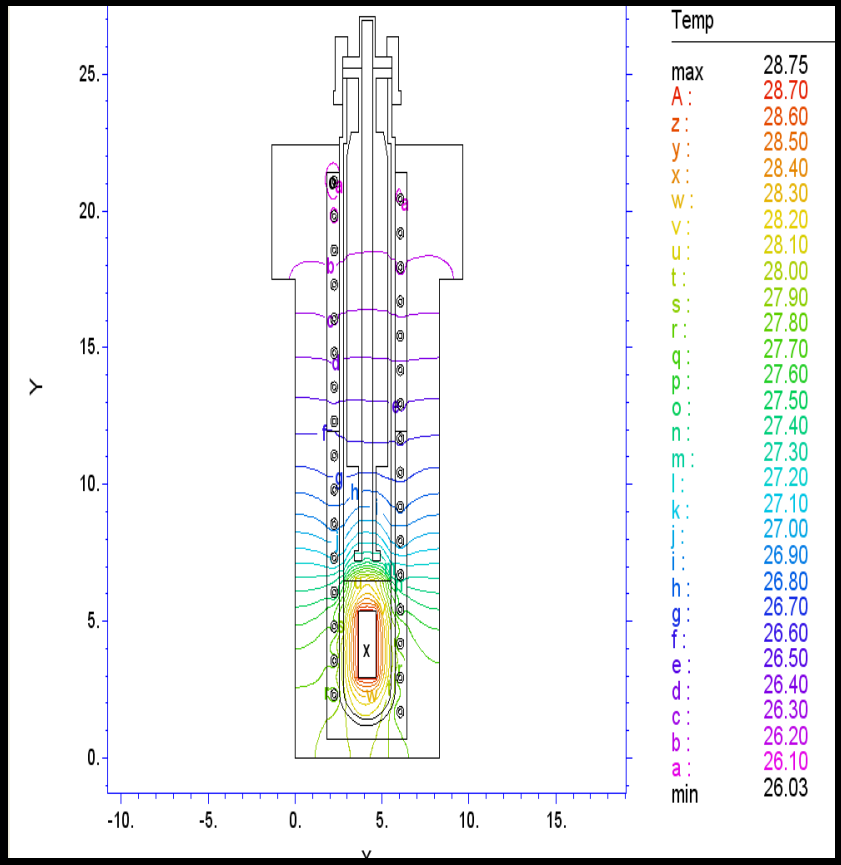
Mass Flow Calorimetry and Closed Cells

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

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



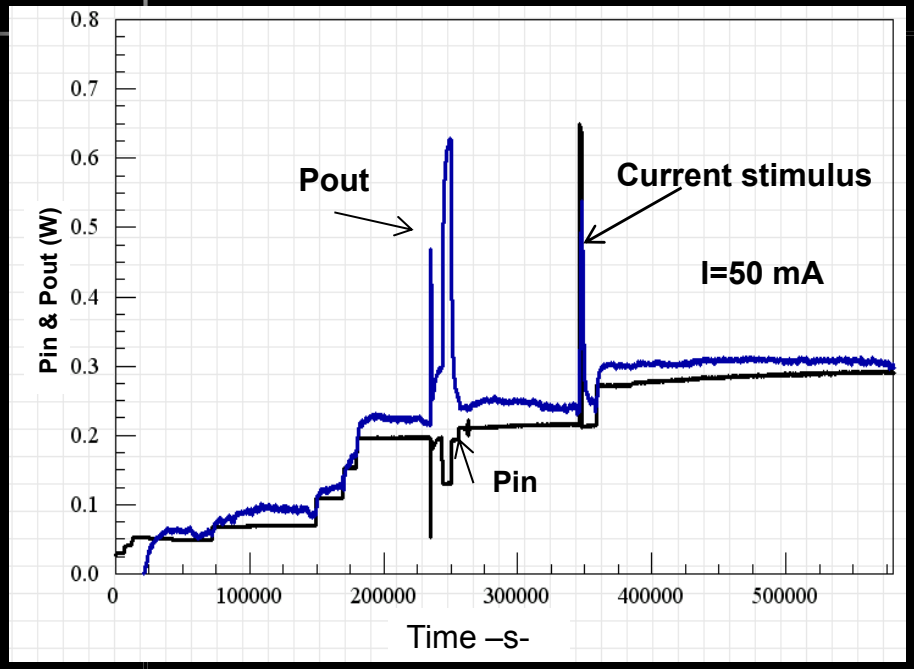
Cell scheme



FEM Modelling

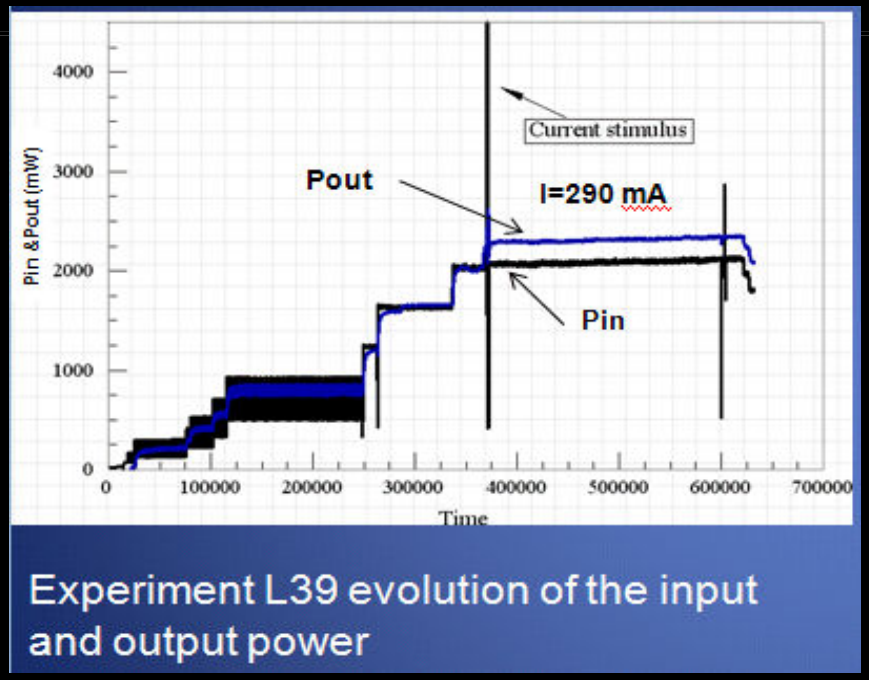
Palladium Lot 1 and Lot 2 from the Same Producer

LOT 1 : excess of power > 100%



Experiment L17 evolution of the input and output power : Excess 500%.

LOT 2: excess of power less than 20%



Experiment L39 evolution of the input and output power

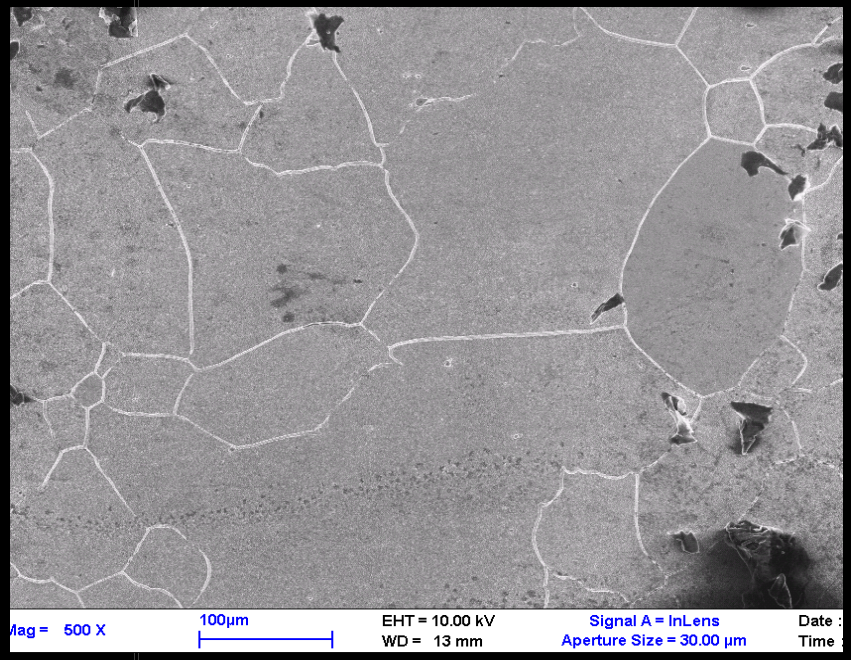
Loading at high current, lower reproducibility (< 20%)

Contaminants Effects

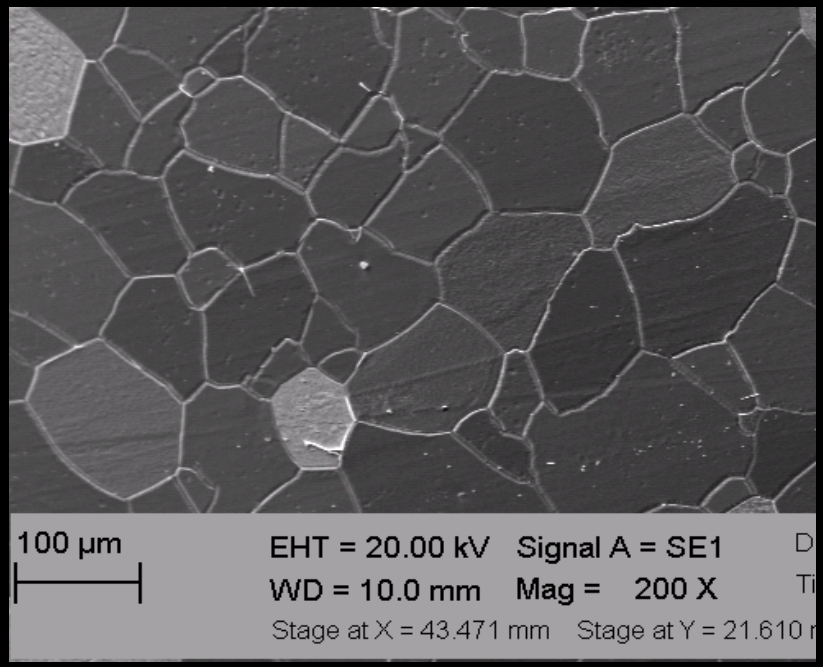
Contaminants may act on:

- Grain size → Controls Stress and Mass Transfer
- Crystal orientation → Controls Kinetics and DL Capacitance
- Grain boundary → Controls Stress and Mass Transfer
- Etching → Surface Morphology → Acts on Kinetics and DL Capacitance

Same treatments



Lot 1



Lot 2

X Ray Diffraction :Crystals orientation after metallurgical treatment

LOT 1 *is well aligned <100>, very sharp X-ray spectra with little or no <110>.*

LOT 2 *samples is a mix of <100> and <110>. The spectra is not as sharp as LOT I .*

Crystal orientation results to be a second condition

Surface Morphology

- Crystal orientation and specific contaminants modify the effect of the chemical etching leading a different surface status.

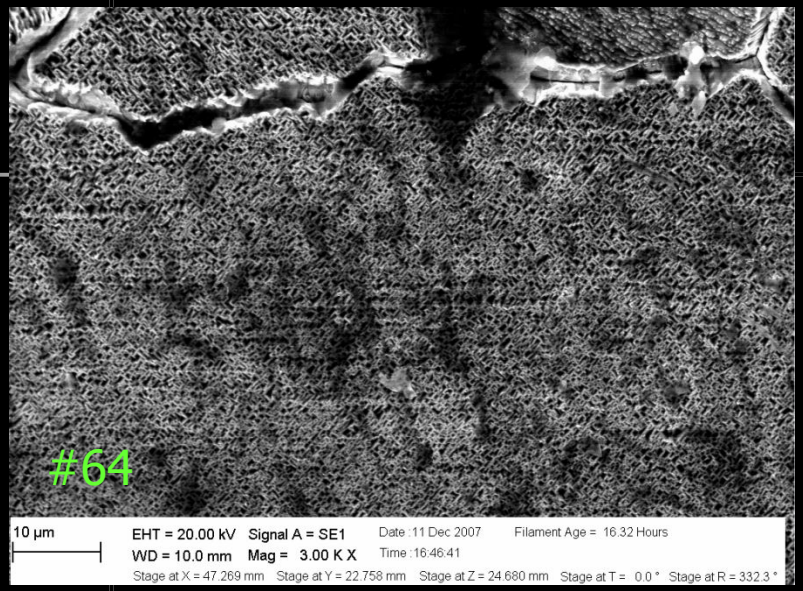
- The surface morphology modifies the operating conditions in the electrochemical process.

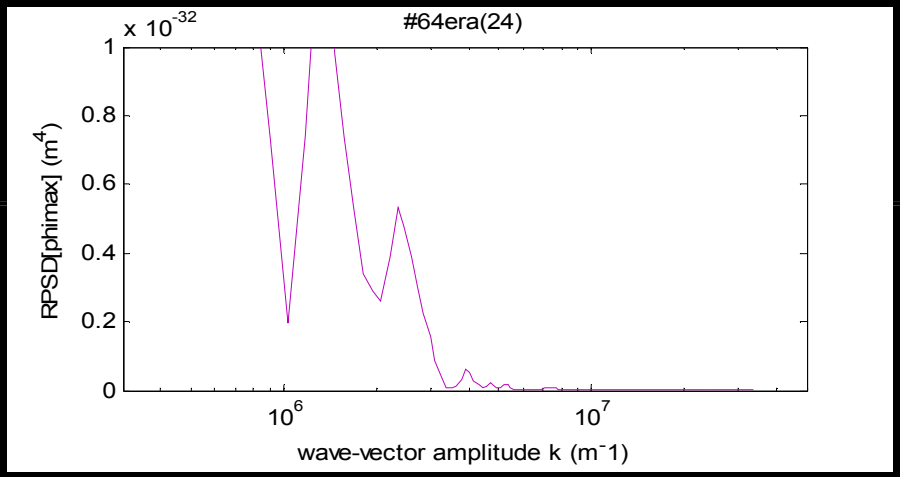
- The status of the surface is supposed to be an other condition to have the excess of heat

A merit figure has been chosen to identify such a status of the surface:

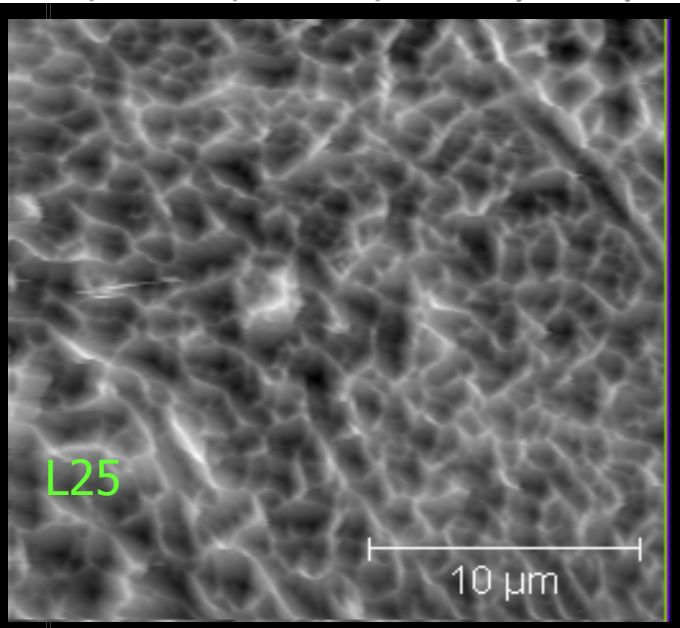
The Power Spectral Density Function defined as the Fourier Transform of the surface roughness correlation function.

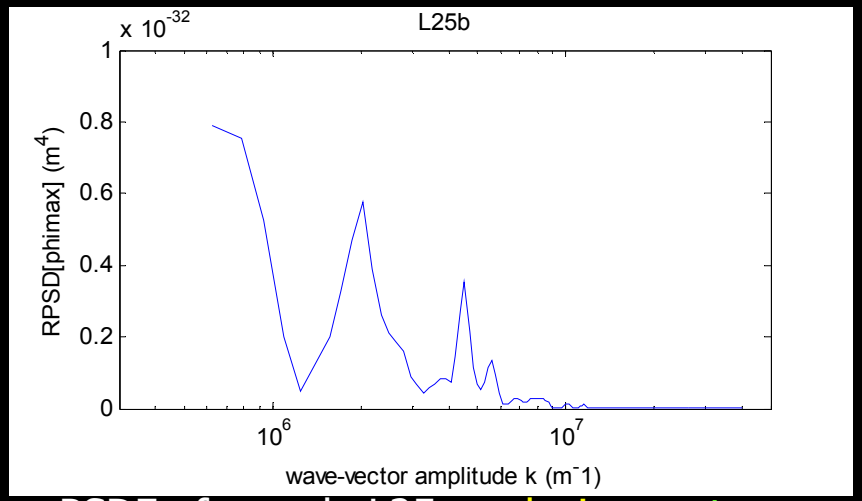
Typical Surface Morphology (after Etching) giving Excess of Heat: the larger the PSD signal the larger the excess. Surface status results to be another condition.





PSDF of sample #64 producing > 1000% excess of heat.



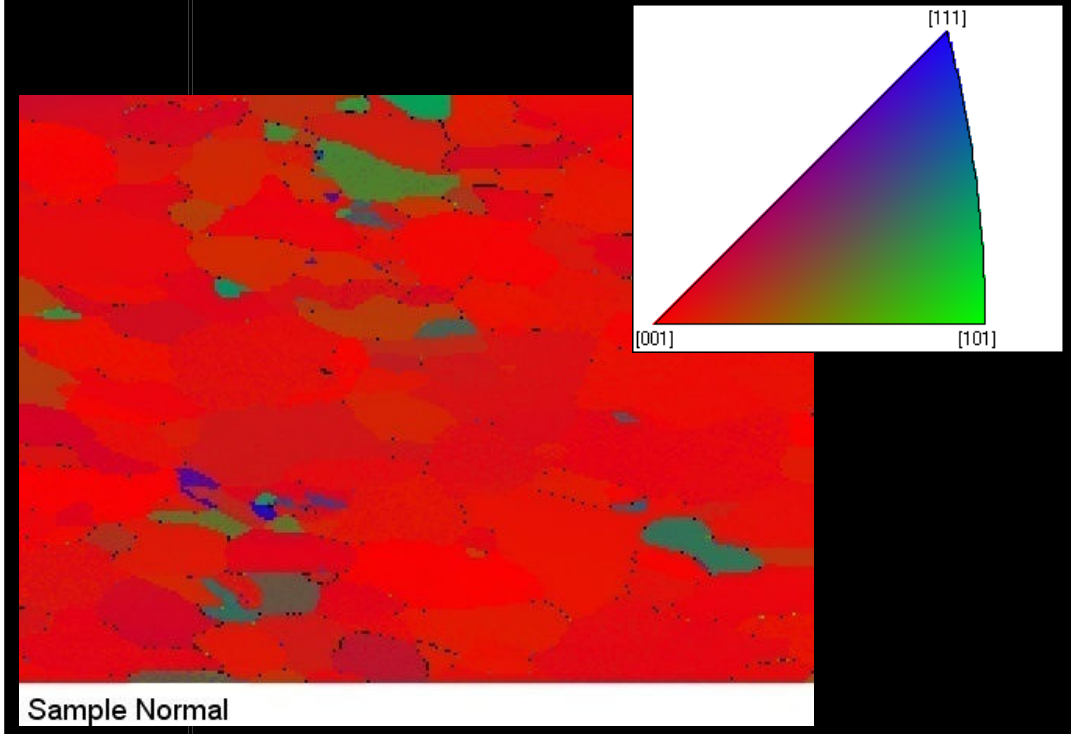


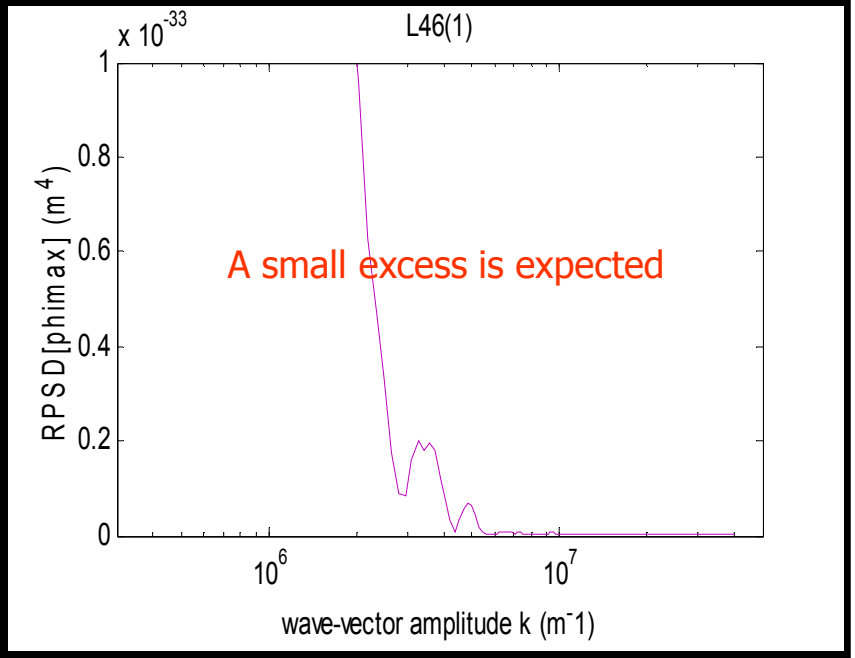
PSDF of sample L25 producing up to 250% excess of heat.

A Designed Material

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

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.

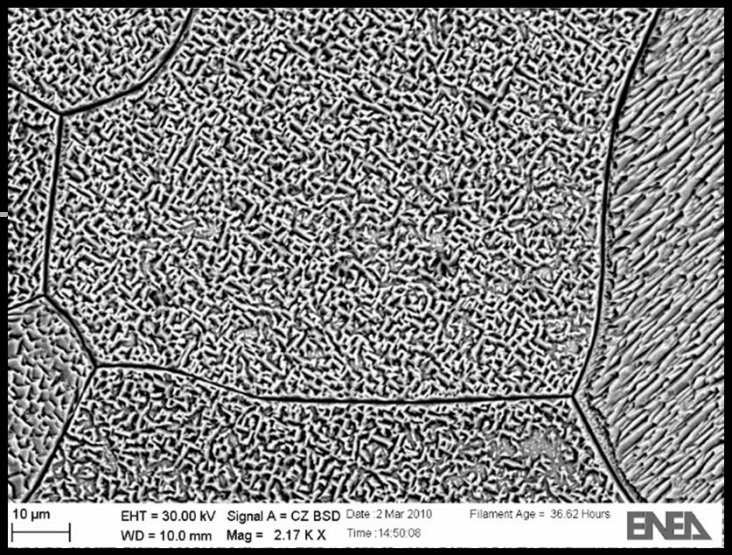


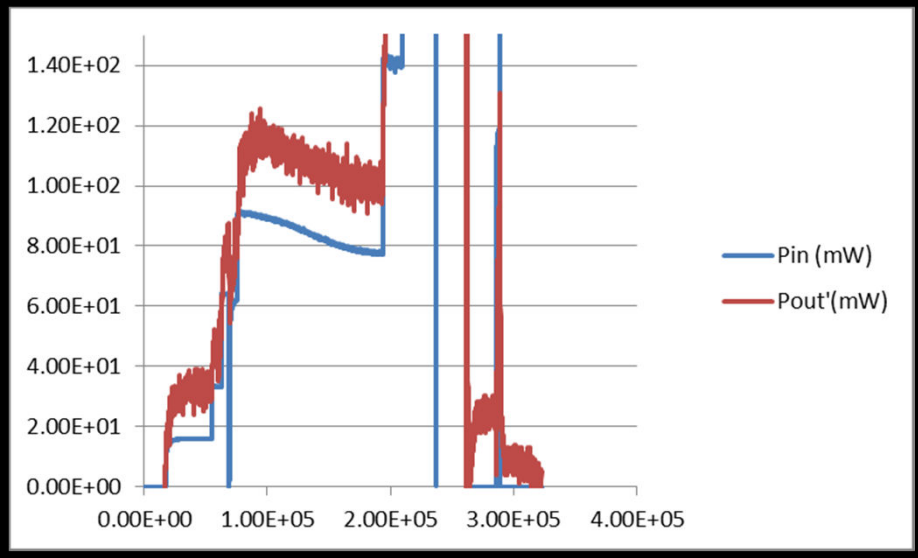


L46 ESBD Results

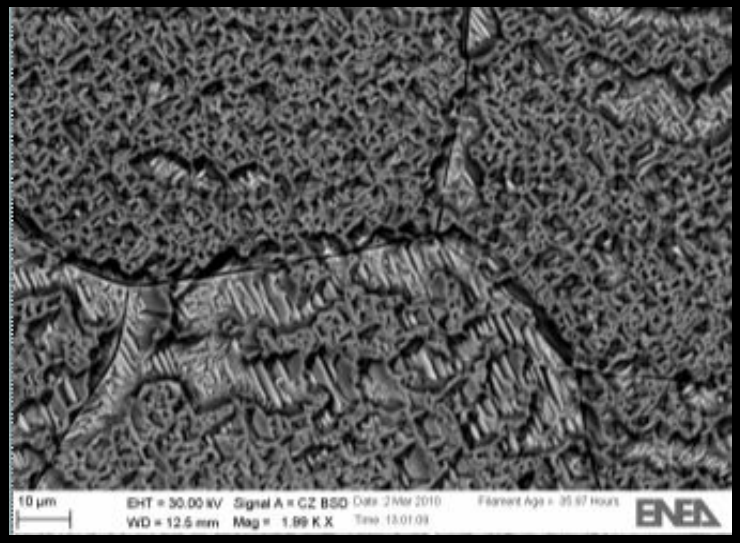
Designed Samples with 'DOPED' Pd

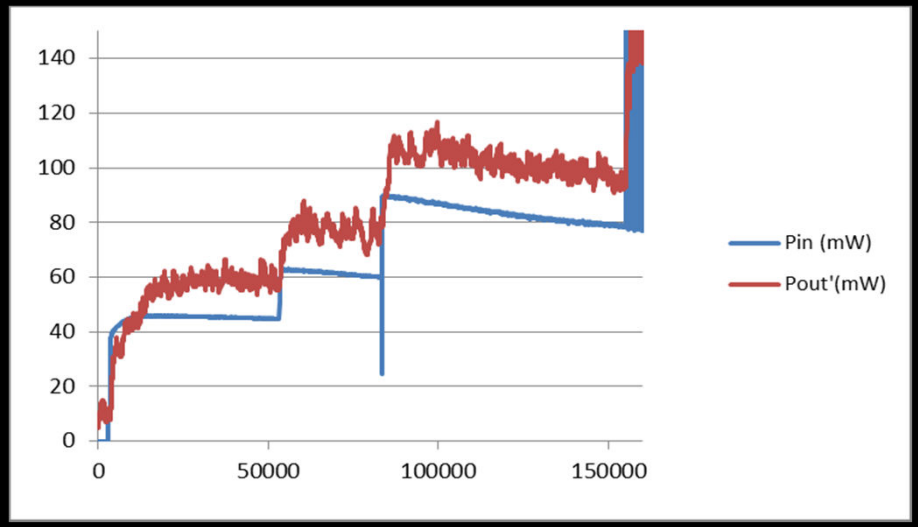
L66 (120-160) RTAEG





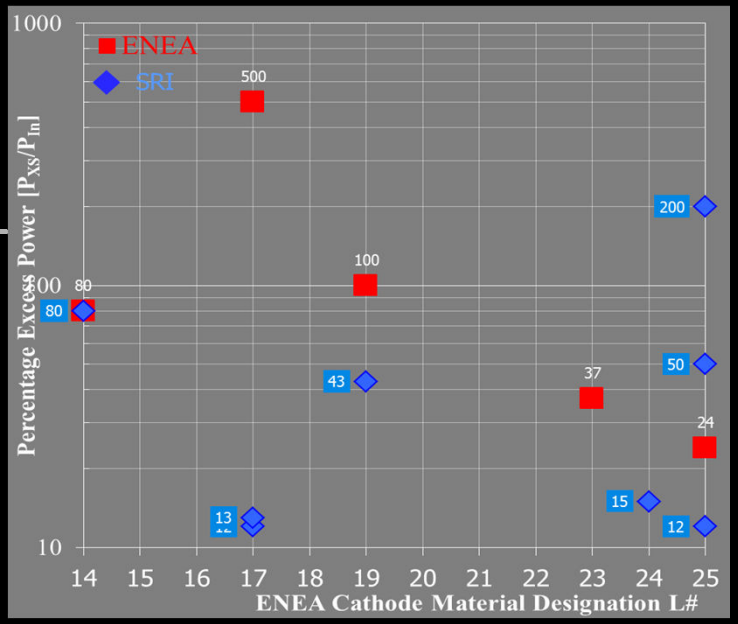
L66 (160-200) RTAEN



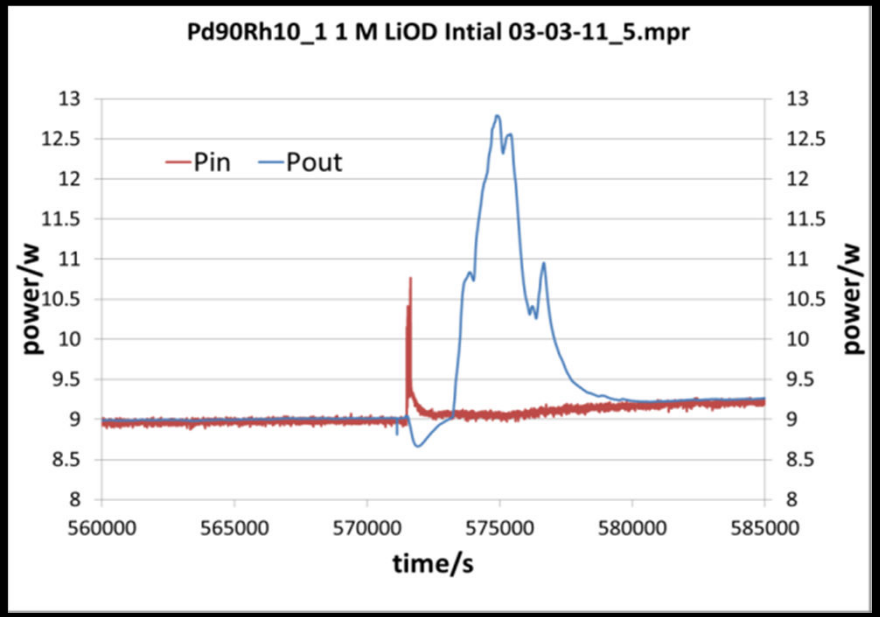


Surface morphology is an additional condition for having the excess of power

Cross Check between Scientific Institutions within the Frame of Review Projects Supported by Government Founding

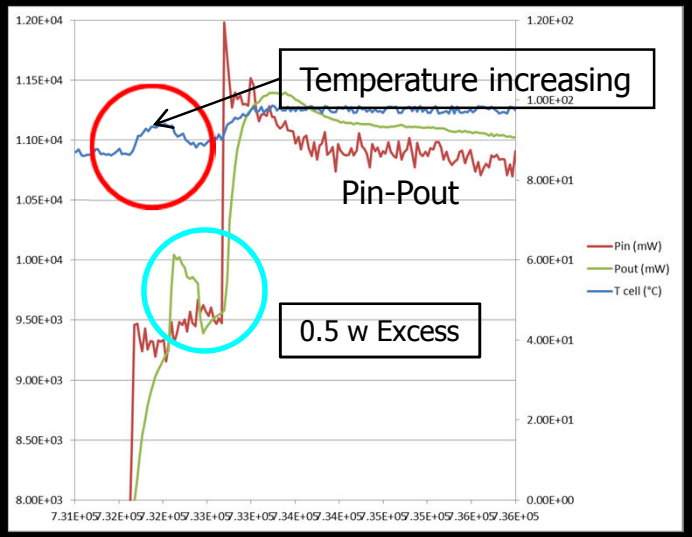


Excesses of power at SRI and ENEA by using the same palladium lots from ENEA



Excesses of power at NRL

Excess of power at ENEA following NRL procedure with a selected palladium cathode



Concluding Remarks

The existance of the effect is not questionable any more and future work have to be oriented to the definition of the effect rather than to demonstrate its existance.

Progress in the field requires well conceived research Projects involving instrumentation and expertise at the 'status of the art' .

Material science is the key for understanding since some material characteristics are supporting some processes and not others.

Results show that processes at the cathode/electrolyte interface have a foundamental role for the occurrence of the effect.

In order to define the phenomenon:
Cristalline status, surface characteristics , surface morphology and the resulting electrochemical interface structure before during and after the occurrence of the effect have to be completely identified also at local level.

Since the effect takes place only with D in Pd search for ashes (mainly He and Tritium) have to be included into the research program, as further task , for defining the effect.

Research Projects on this field are required to determine the origin of such an extraordinary process, with a sound materials science approach and with no preconceived conceptions as to the mechanism.

` *The nearly unanimous opinion of the reviewer was that founding Agencies Should entertain individual, well-designed proposal for experiments*'

Panel DoE Washington DC August 2004 (Comment of the Reviewers)

Thank you All