Electro-deposited alloys for backscattering-mode positron moderators

Robert I. Grynszpan

LCMTR-CNRS UPR 209, ISCSA, Thiais

&

DGA-DCE-CTA-LOT- Arcueil France

Study performed in collaboration with:

- **Paul Coleman**, Univ. Bath, UK

(Measur. Sci. & Techno., 12 (2001) 163)

a continuation of the work of

- Valérie Fradin, (PhD Thesis, 1997, ENSAM-Paris)

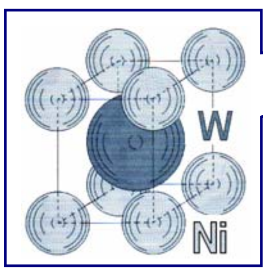
- and of several Master theses prepared at Ecole Nationale Supérieure d'Arts & Métiers-Paris.

- **PURPOSE : search for**

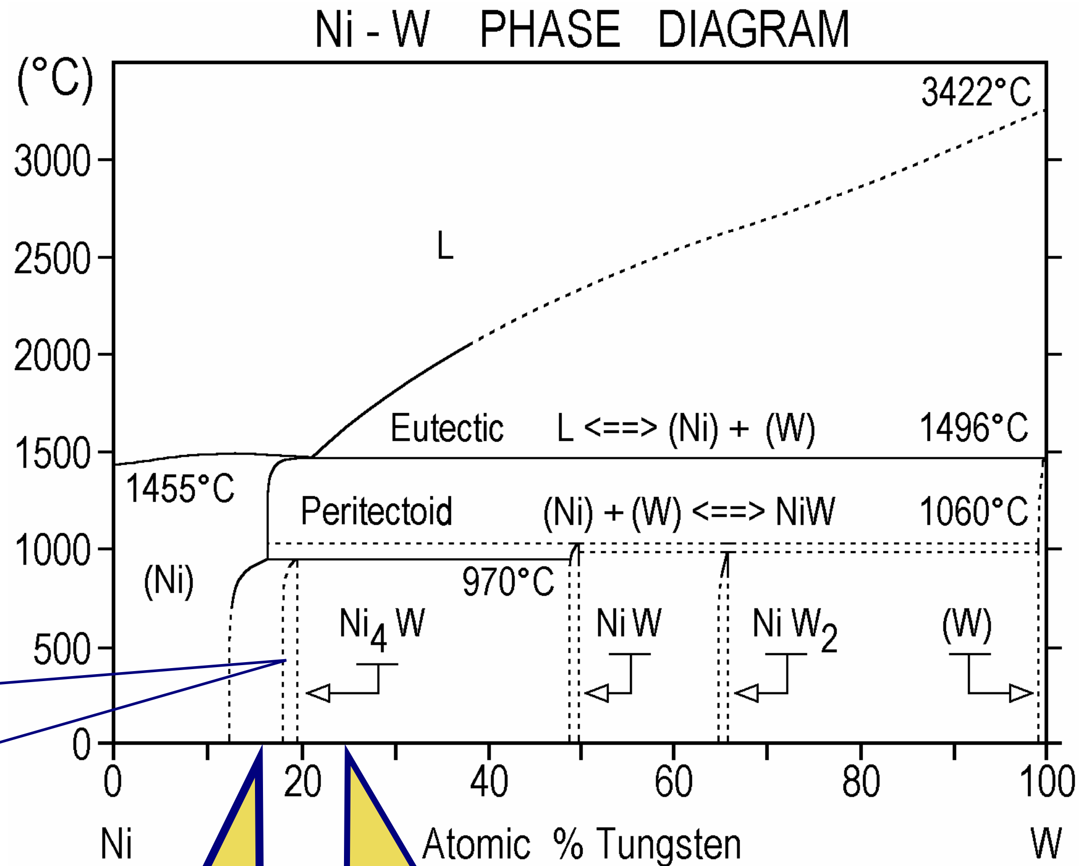
- a moderator material, solid at room T. and with lower annealing temperature than that needed for W (~2000°C) but with similar re-emission characteristics
- a material that can be "painted" (electro-deposited) on special focussing shapes or on pieces which are difficult to access (e.g.:high radioactive environment)

Composition & crystal structure

Electro-deposition of W in aqueous solution can only be achieved by co-deposition with a transition metal. The Ni-W system was chosen since both elements have suitable re-emission characteristics.



Tetragonal



Amorphous alloy

15 - 25 % W

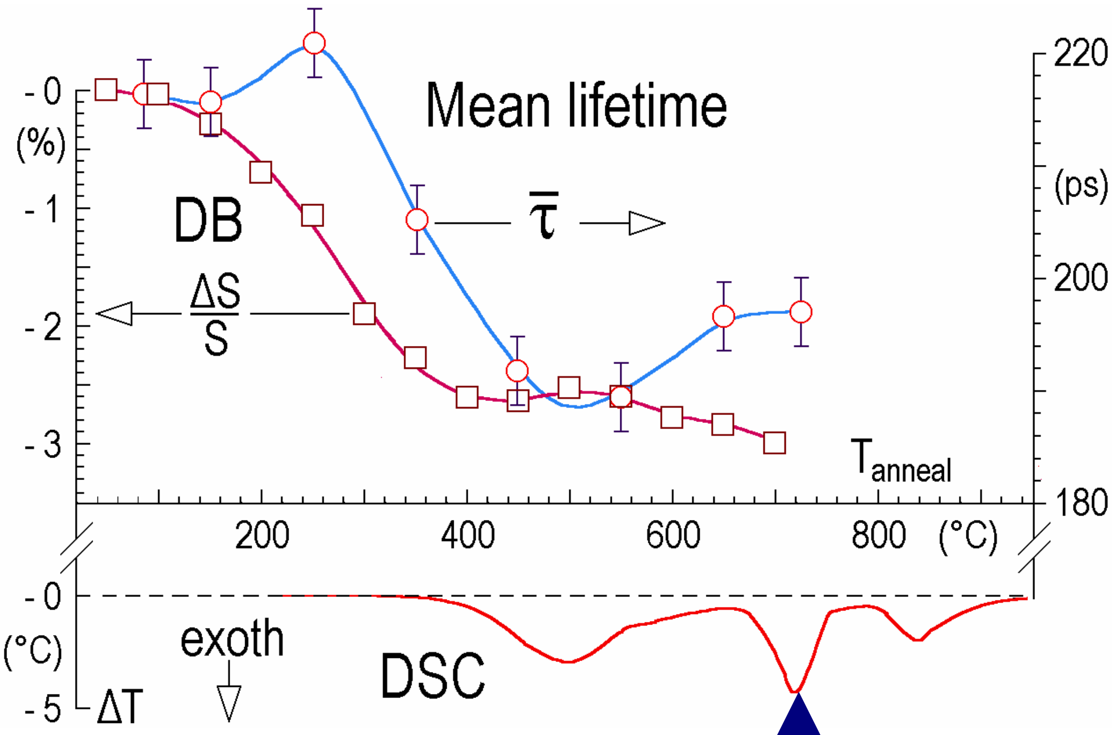
The highest concentation achievable is about 25 at % and, in the 15-25% range, chances are that the alloy is in the amorphous state.

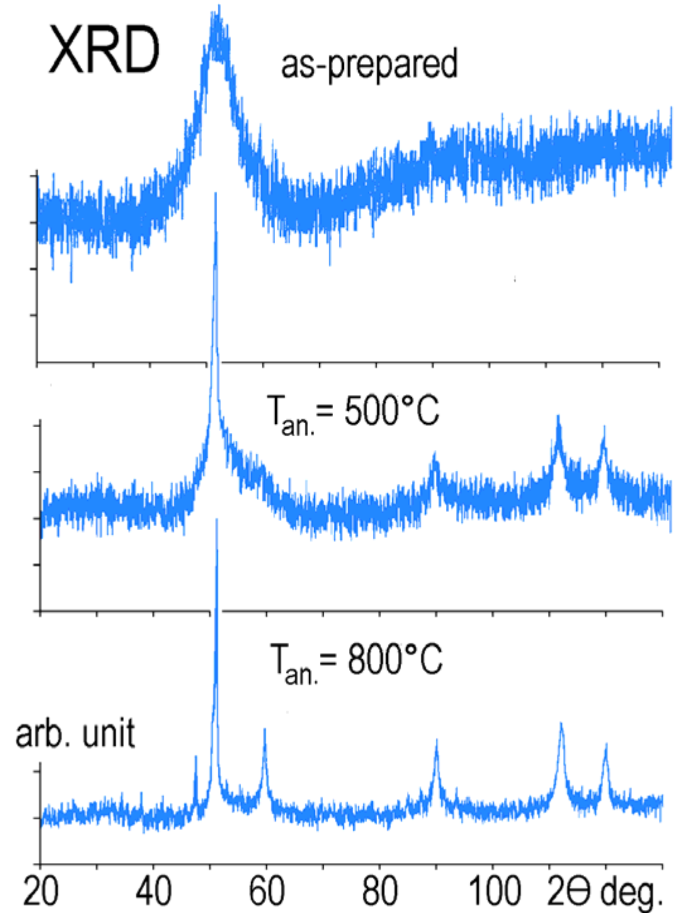
During temperature annealing, these alloy will tend to crystallized into the Ni_4W compound.

1500°C can be considered a their melting point limit.

Structural Relaxation & Crystallization

Amorphous $Ni_{80}W_{20}$



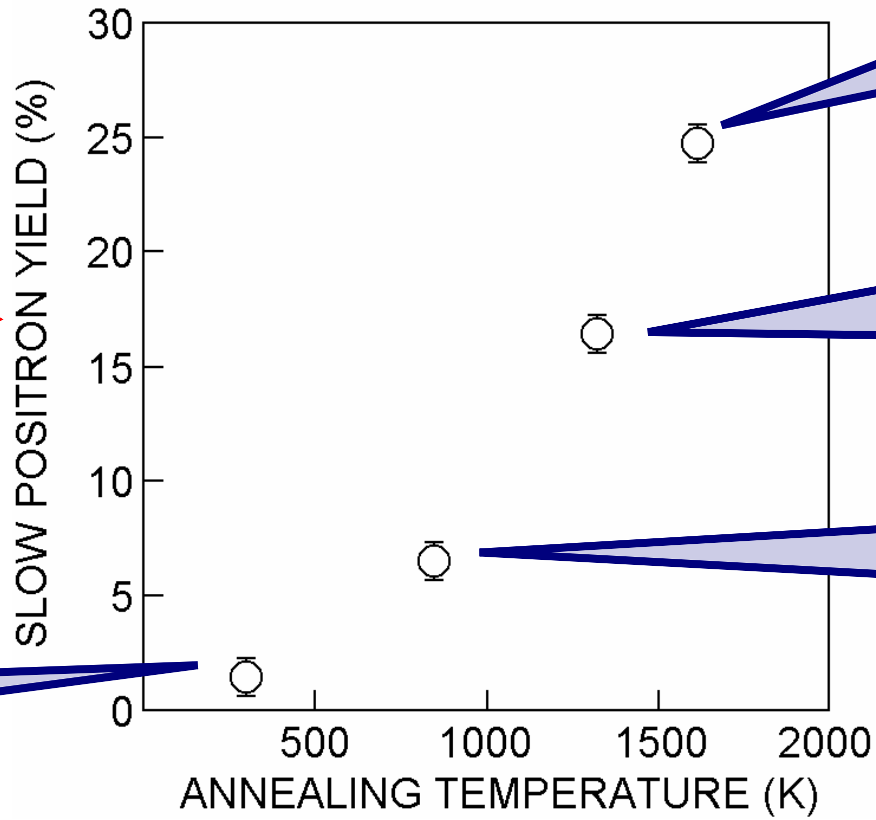


Defect recovery not yet completed at crystallization temperature (~720°C) since lifetime still shows a long component attributed to small bubbles possibly filled with hydrogen (generated by electrodeposition)

Slow Positron re-emission Yield versus annealing temperature

$Ni_{80}W_{20}$

e+ Incident energy: 1keV



1350°C

After crystallization

Amorphous state

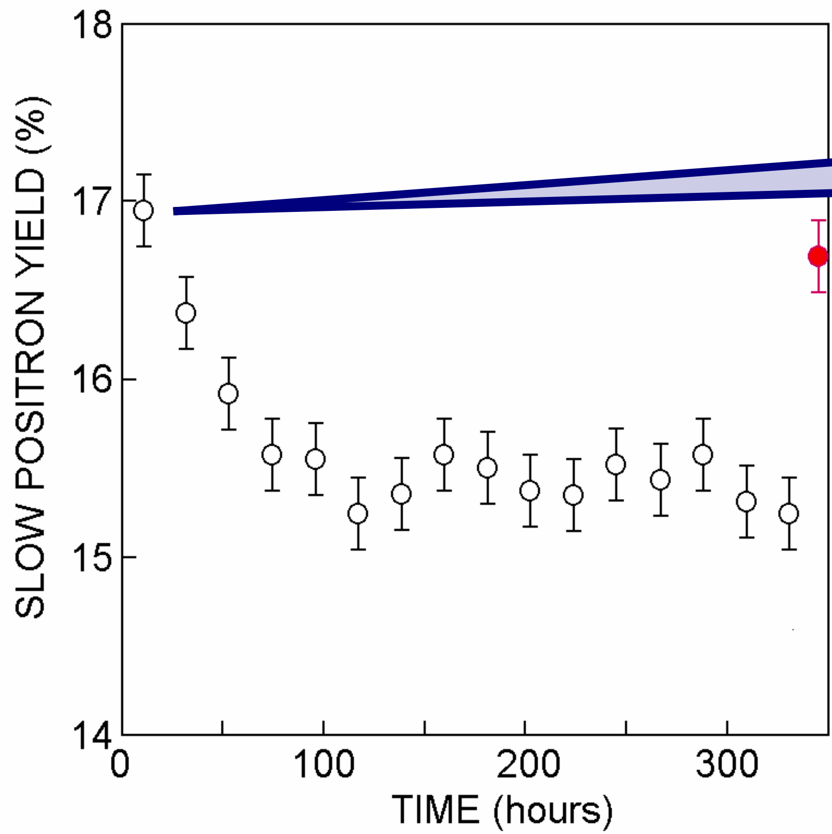
As-pre-pared

Highest yield similar to that of pure W but no need to anneal above 1350 °C (close to melting point)

Slow Positron re-emission Yield versus Time (short term stability)

$Ni_{80}W_{20}$

e+ Incident energy: 2keV



As-annealed at 1350°C

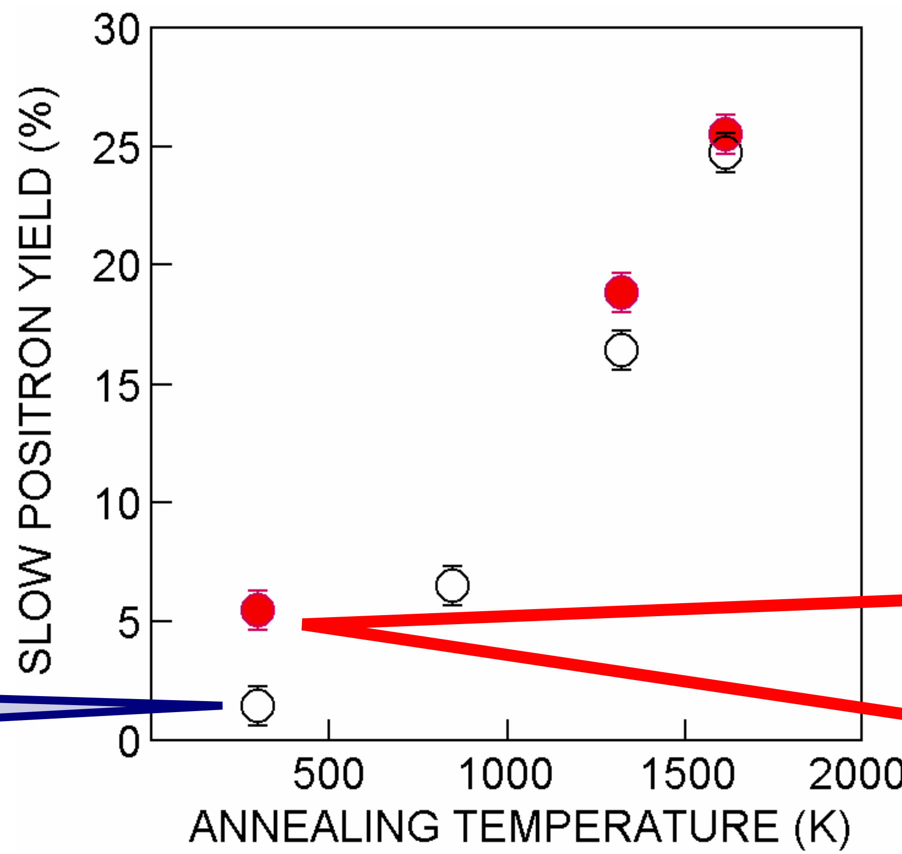
Recovery after 1250°C re-annealing

~10% “prompt” decrease then stabilization. Re-annealing restores original value. Behavior similar to W

Slow Positron re-emission Yield vs. sample age (Long term stability : storage)

$Ni_{80}W_{20}$

e+ Incident energy: 1keV



As-prepared

Sample annealed at 1350°C and left 6 months in air

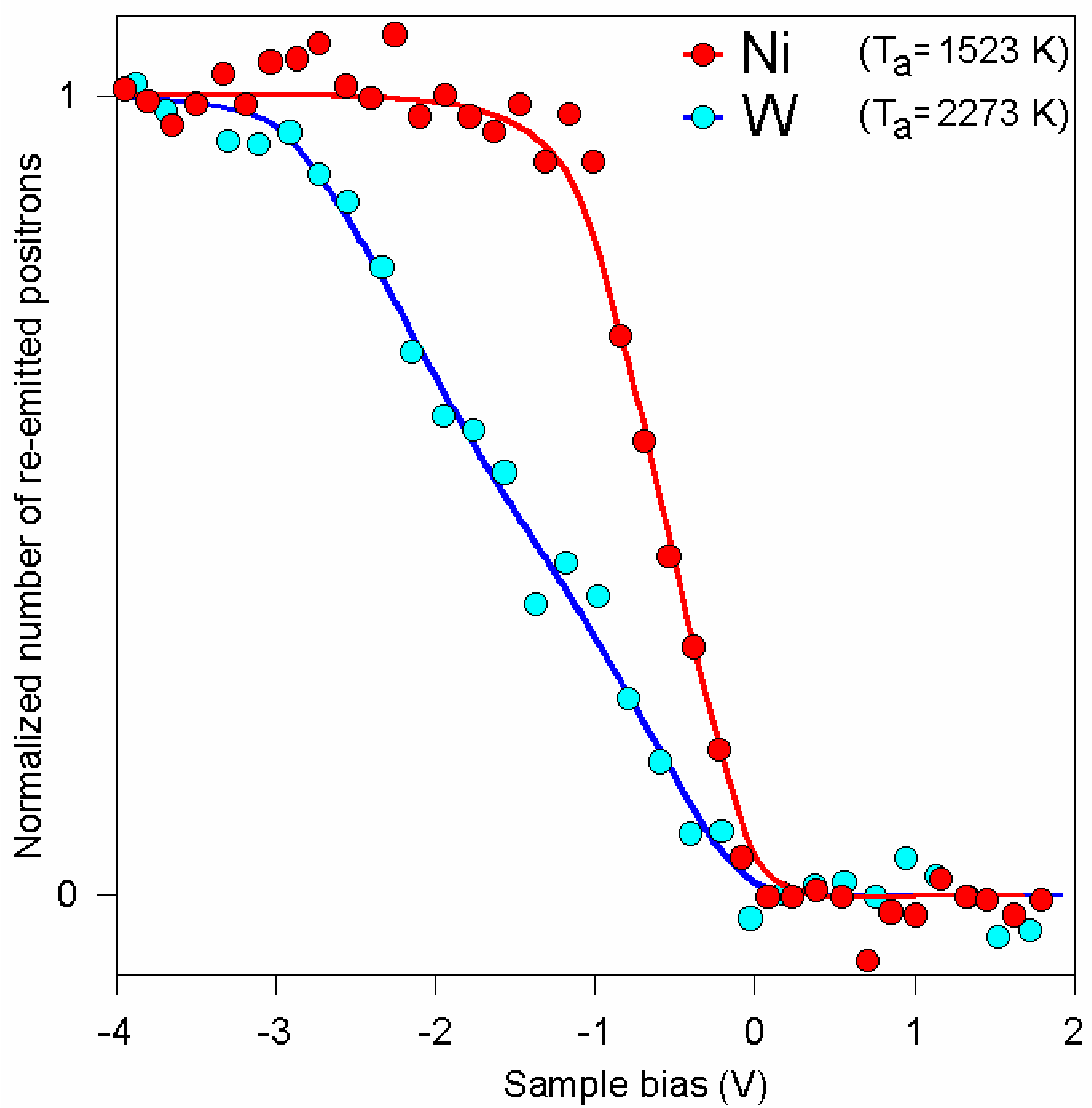
Checking the work function

- Measure of the gamma counts dependence on the sample bias. **Range: [- 5, + 5] volts**
  Incident beam energy: 2keV (to avoid epithermal e+)
- References:
  - **Ni annealed *in situ* at 1250°C**
  - **W annealed *ex situ* at 2000°C**
- Samples:
  - **$Ni_{80}W_{20}$ annealed *in situ* at 1050°C**
  - **$Ni_{80}W_{20}$ annealed *in situ* at 1350°C**

Sample Bias dependence of re-emitted Positrons

Reference samples

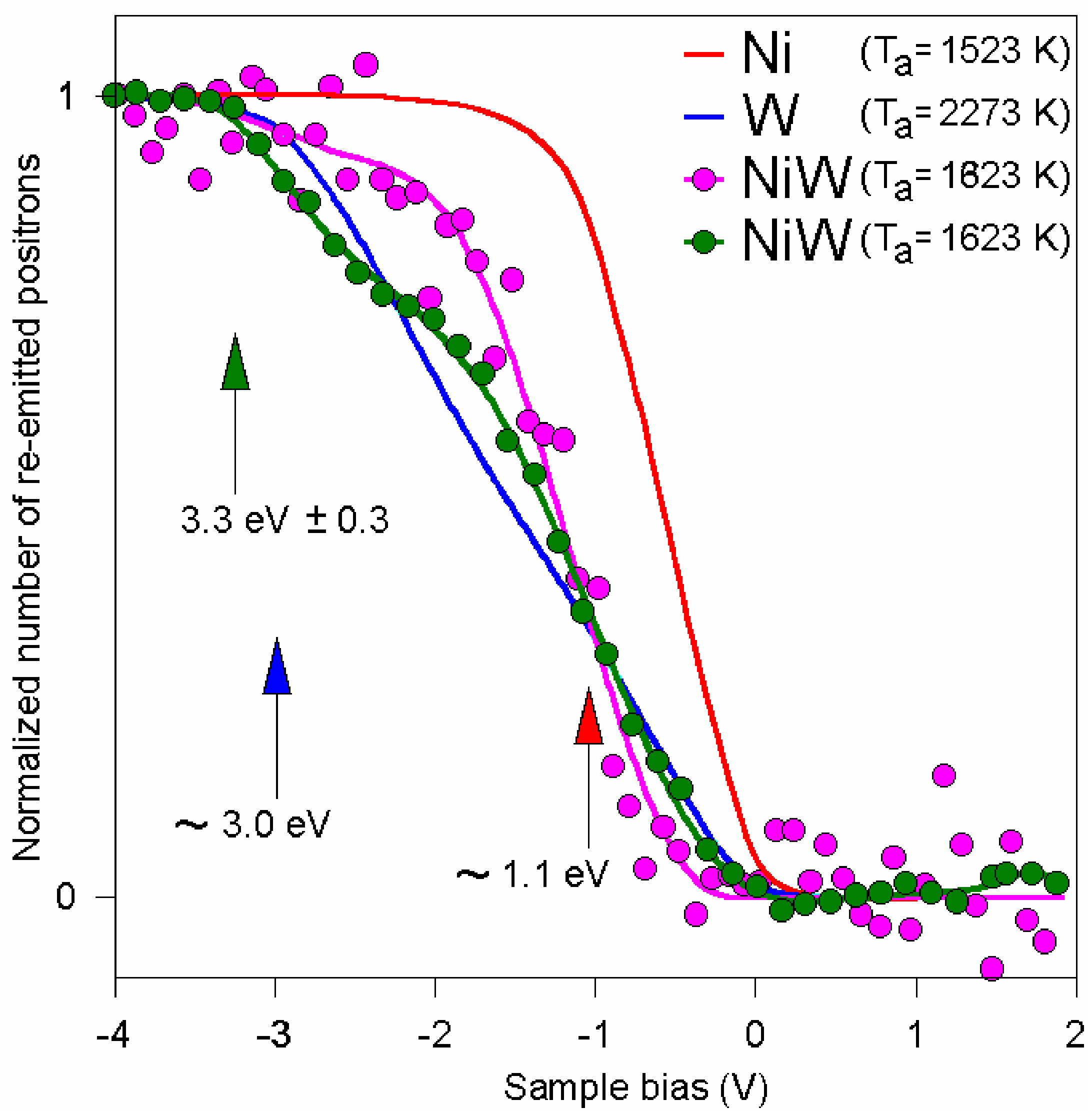
e+
Incident
energy:
2keV



Sample Bias dependence an maximum Energy of re-emitted Positrons: work function $\phi+$

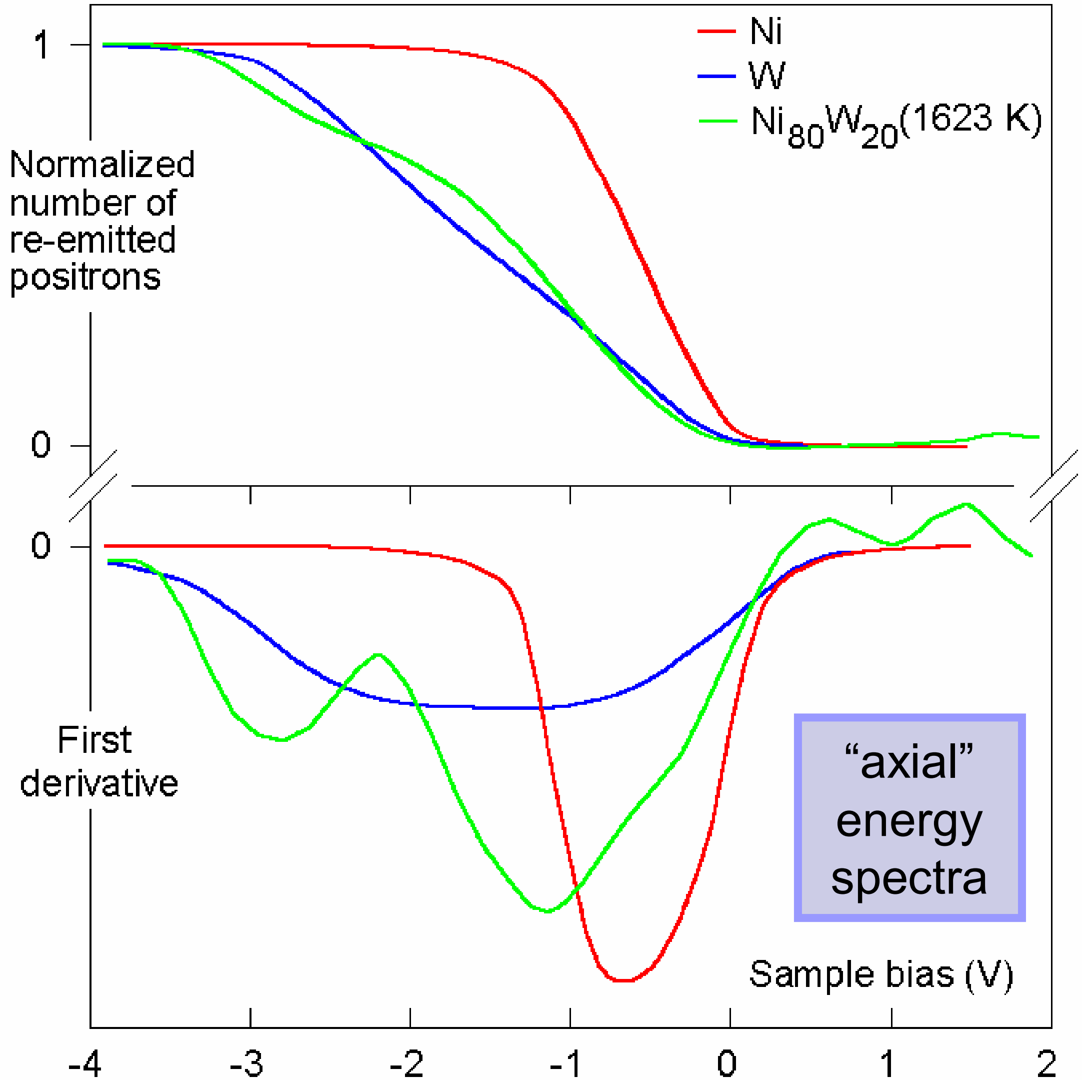
$Ni_{80}W_{20}$ Alloy after annealing at T_a

e+ Incident energy: 2keV

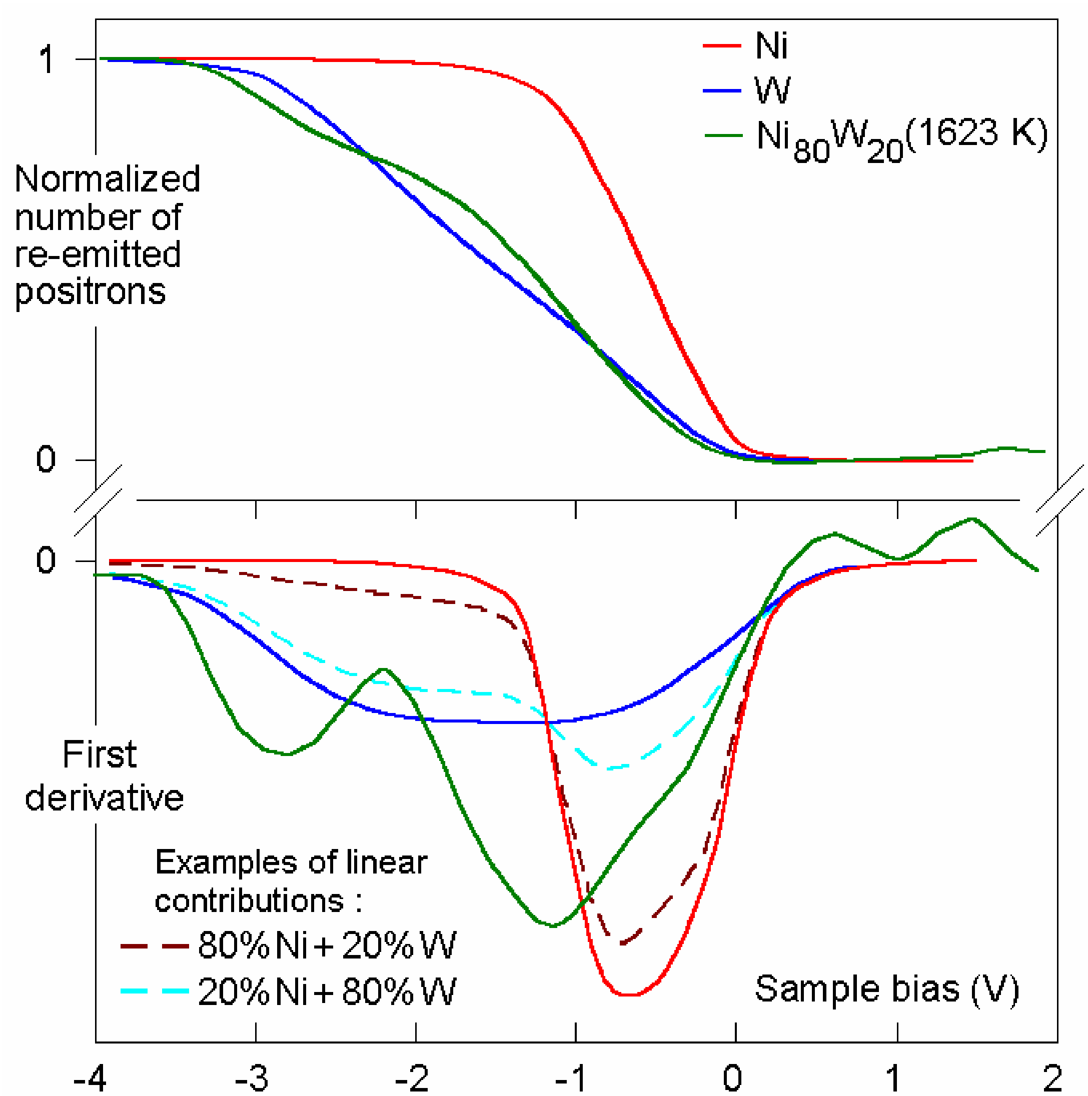


High-T anneal NiW alloy similar to W but substructure recalls Ni spectrum

“Axial” energy spectra



Comparison of “Axial” energy spectra



Linear combination of Ni and W contributions does not fully account for $Ni_{80}W_{20}$ alloy effect

Surface segregation of atoms W : W area growing at the expense of Ni area: **possible effect but not exclusive**

Additional correlation effect between Ni and W seems to occur

Conclusion

- New metallic moderator : Ni - 20 % W
  - re-emission yield at 1 keV : more than 25 %
  - estimated primary (overall) moderation efficiency ~10^{-3}
- Annealing Temp. much lower than Tungsten (~half !)
- Stable short term stability: re-emission yield remains constant after prompt slight decrease (similar to W); initial value restored after annealing at 1250°C
- Long term stability: re-emission recovered after 1350°C anneal
- Work function closer to W (~3 eV) than to Ni
  - Suggests surface segregation of W atoms
  - Substructure on the “axial energy” spectrum ==> simple linear contribution Ni and W does not fully account for Ni-W alloy behavior ==> possible interactions.of e+ with Ni and W atom
- Electro-deposition ==> possibility of making special shapes for backscattering moderators