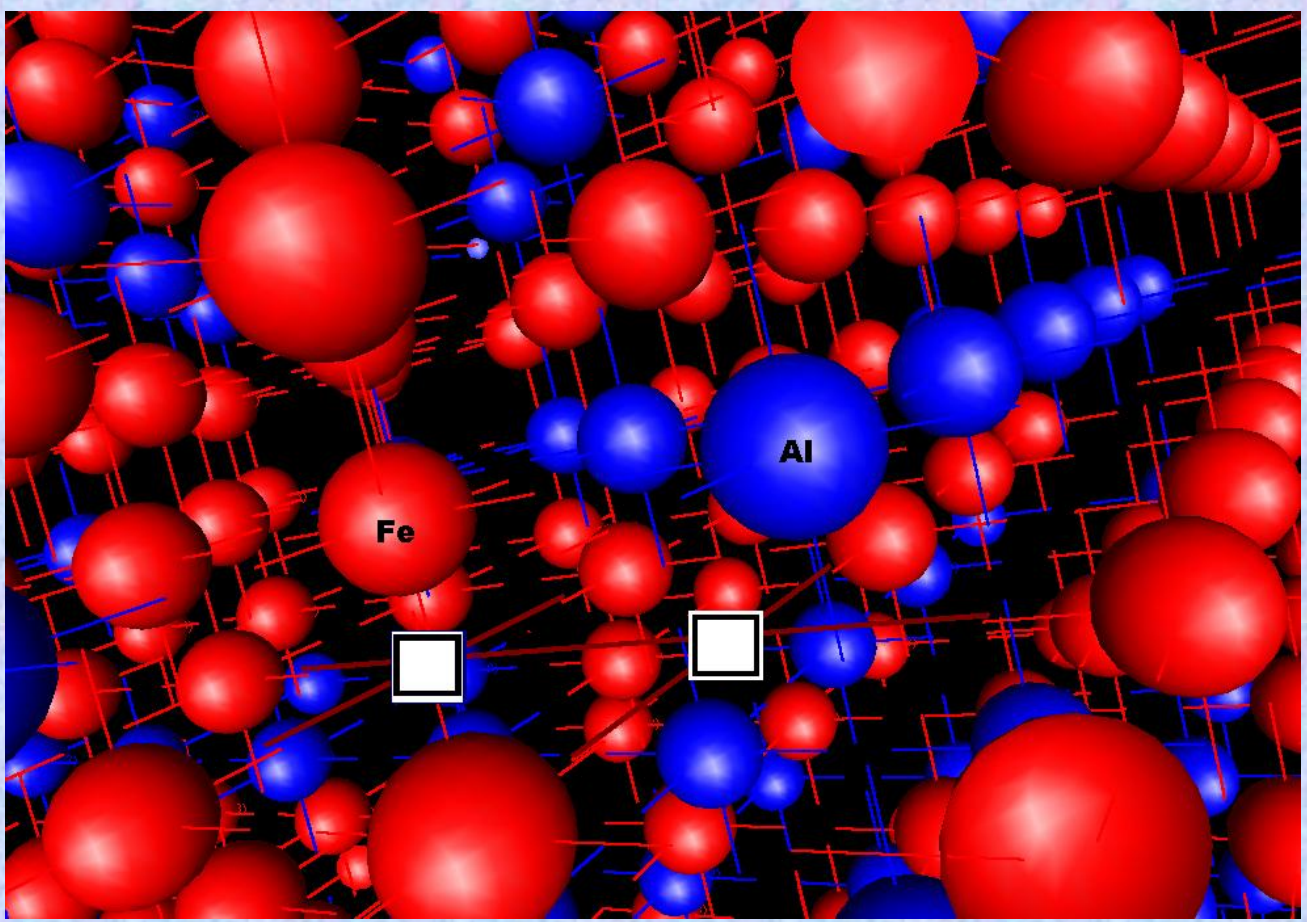
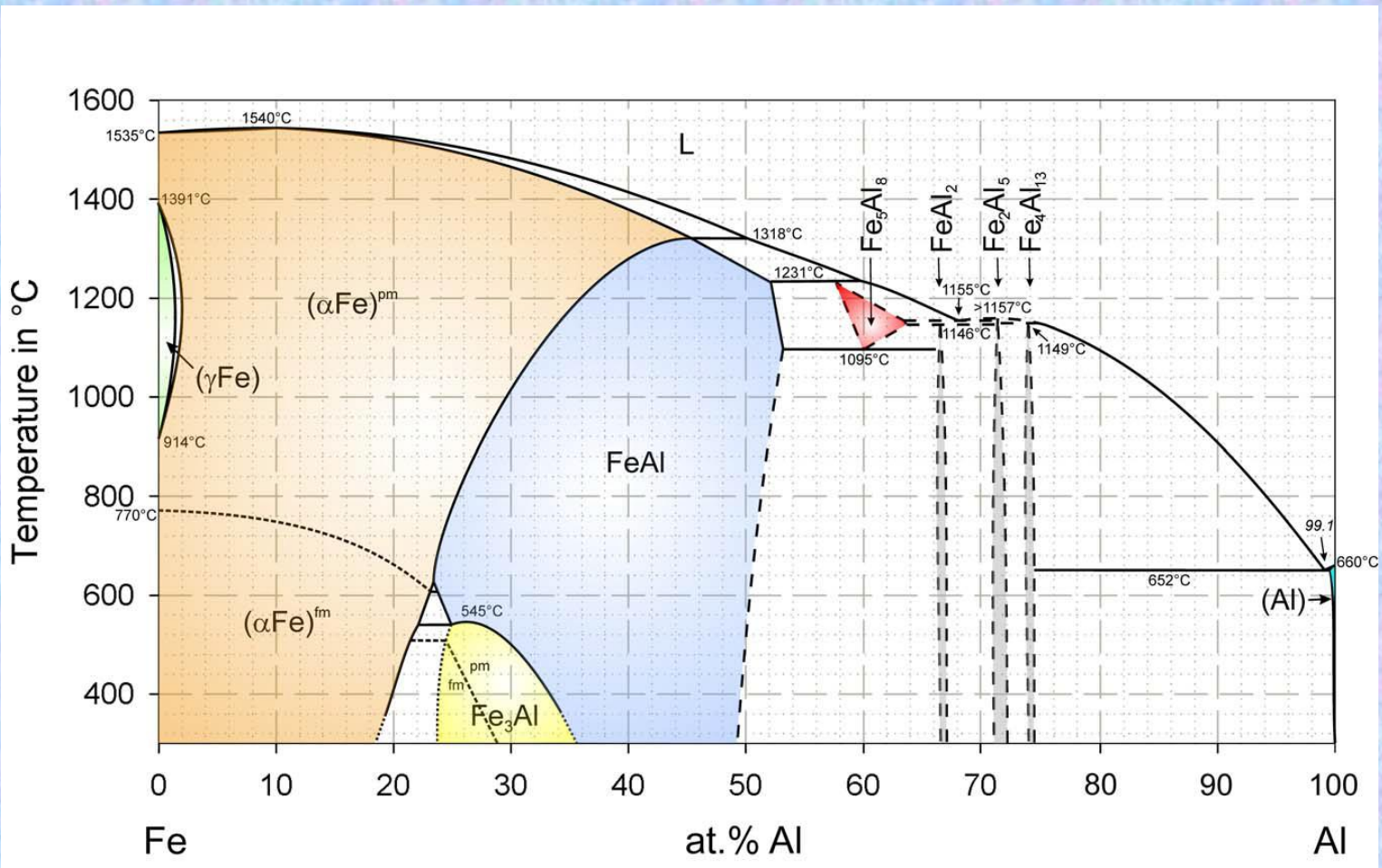
Vacancy-induced hardening in Fe-Al alloys



František Lukáč, Charles University in Prague

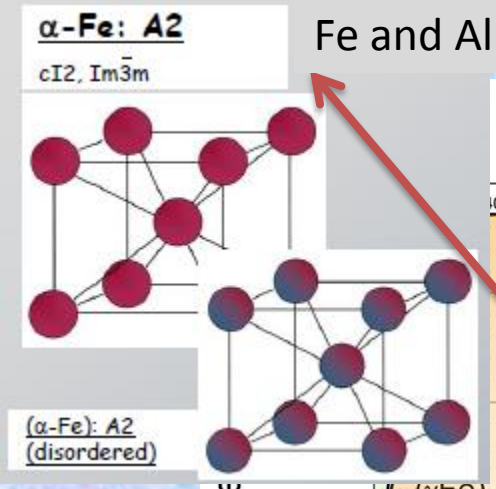
Fe – Al phase diagram



Kubaschewski, O.: Springer Verlag, Berlin, (1982)

Studied Fe – Al intermetallics

Fe and Al solid solution

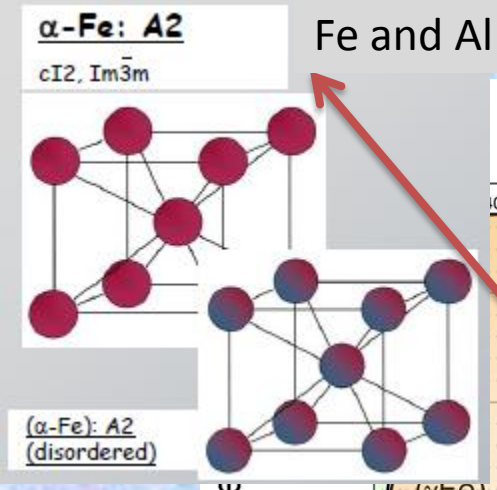


Fe

Al

Studied Fe – Al intermetallics

Fe and Al solid solution



Fe

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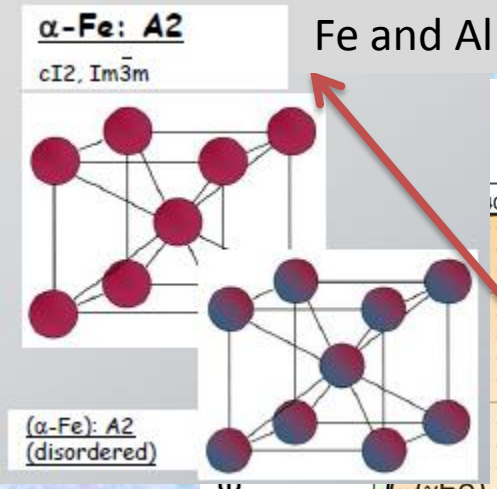
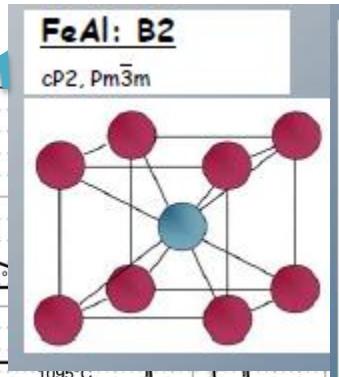
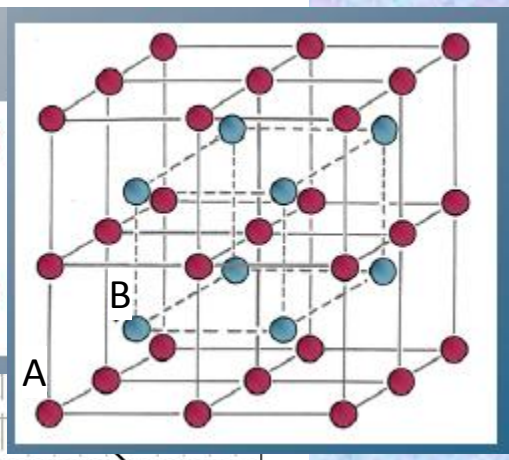
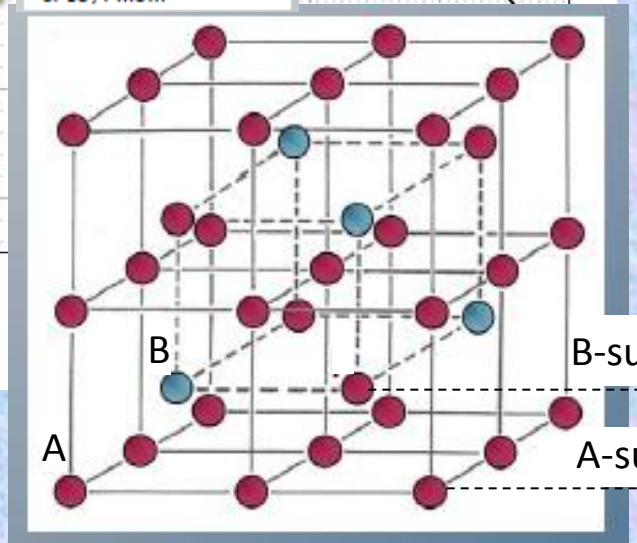
Studied Fe – Al intermetallics

Fe and Al solid solution





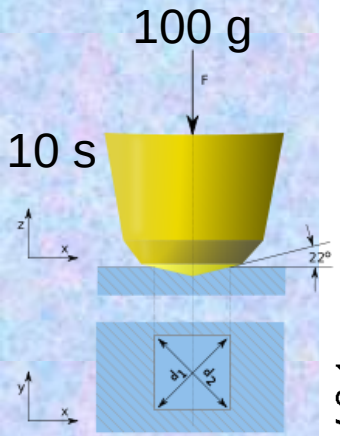


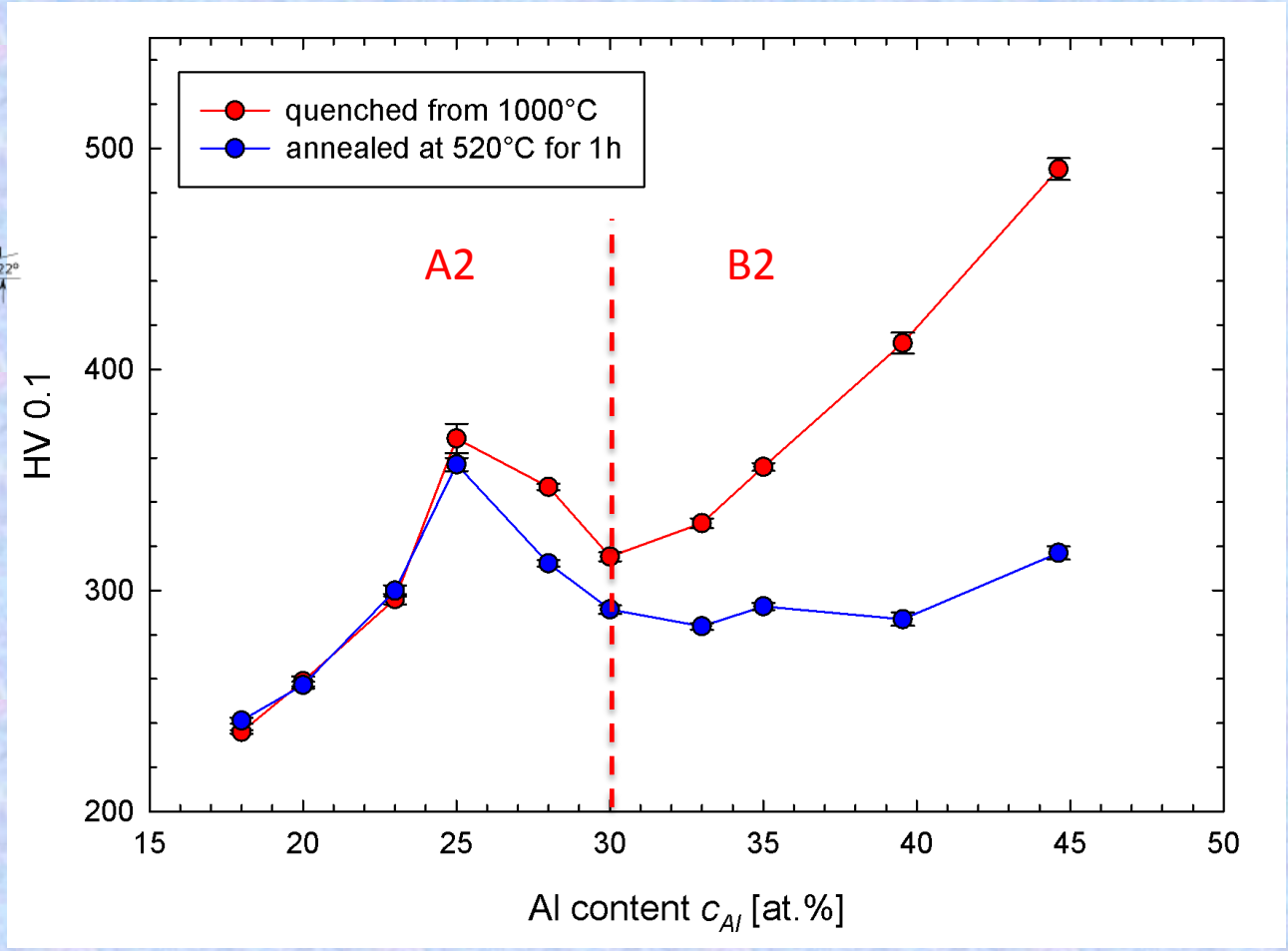


Fe

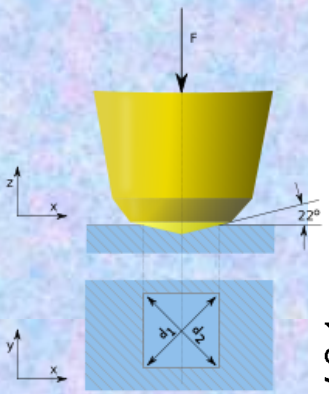
Al

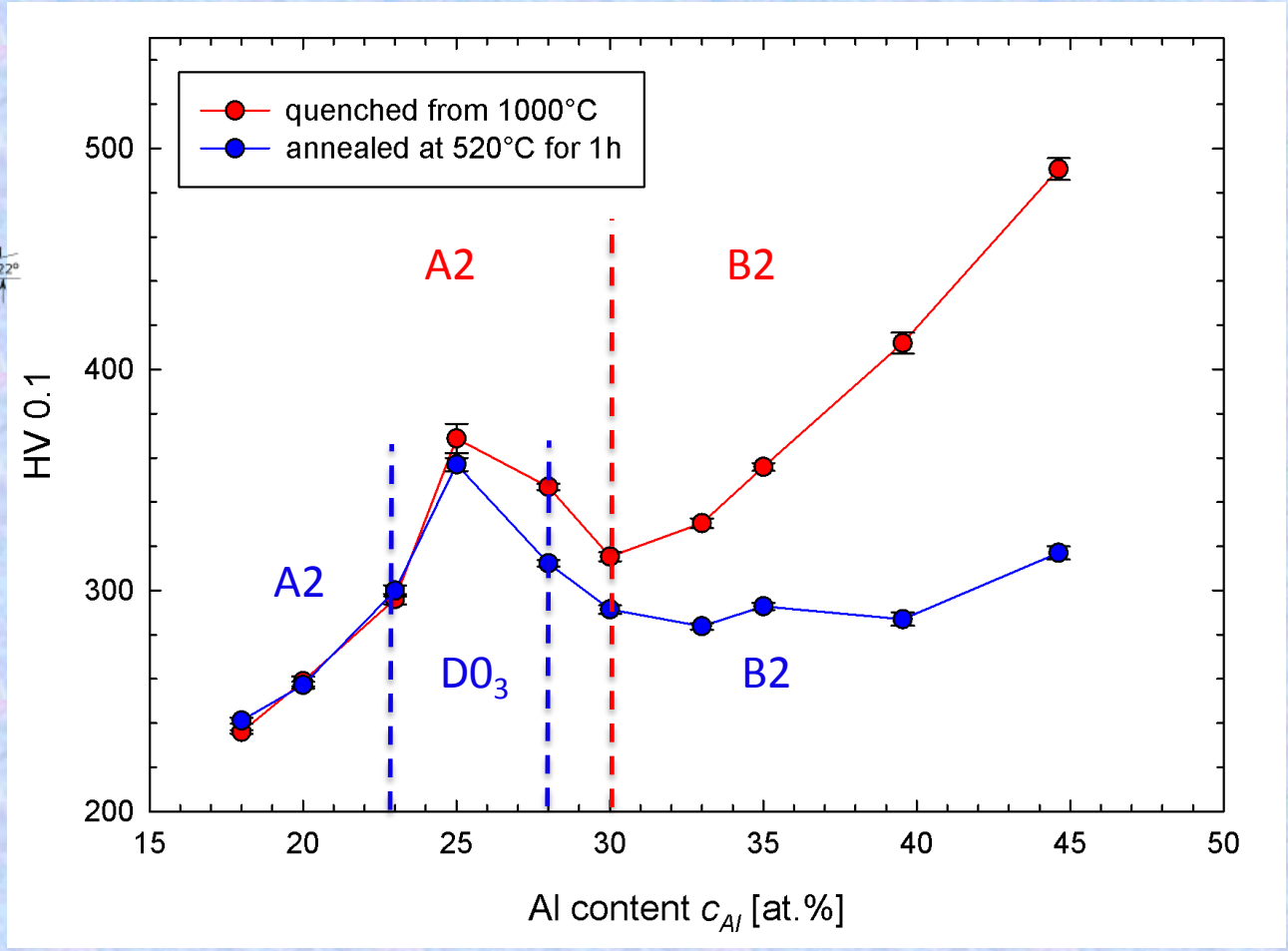
Vickers microhardness of Fe-Al alloys





Vickers microhardness of Fe-Al alloys

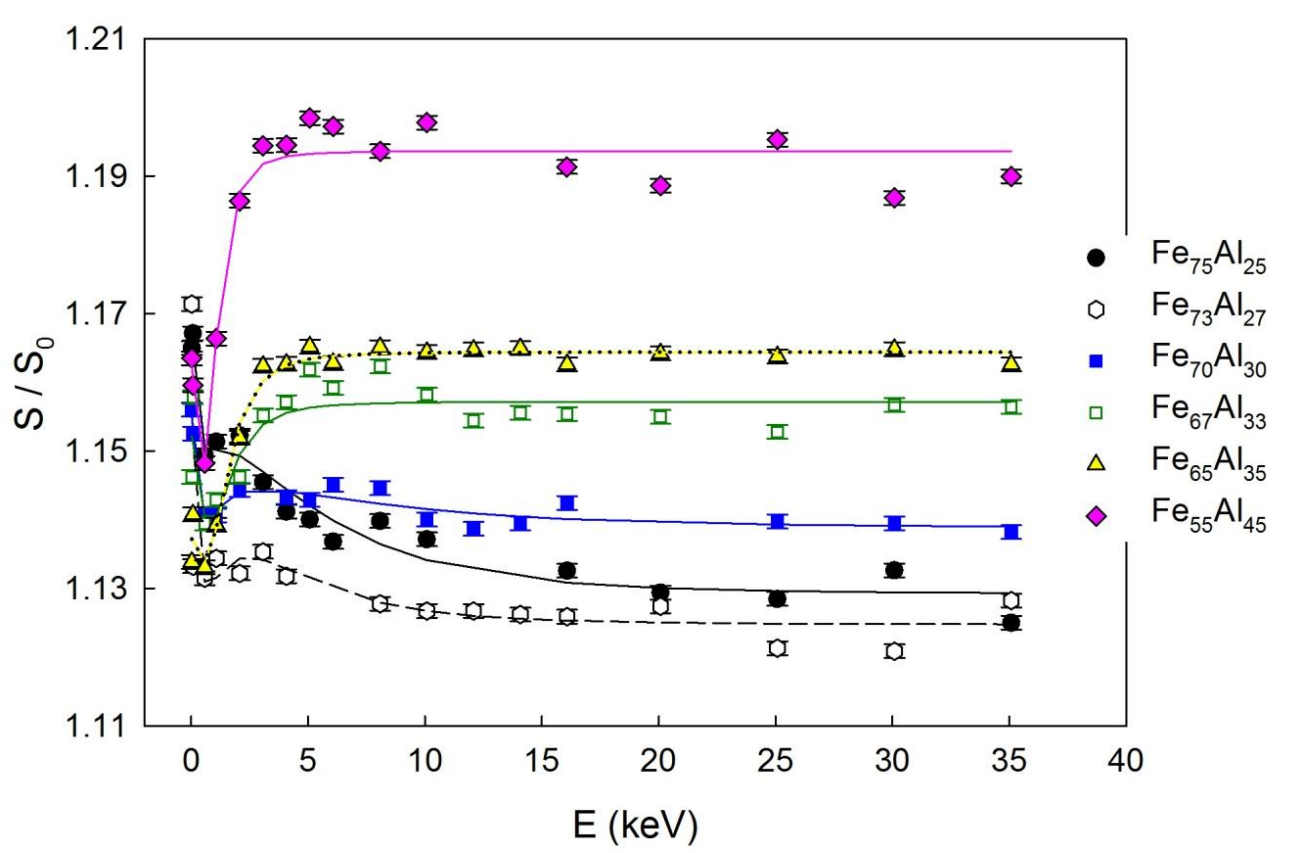




Measurable effect of vacancy hardening starts from $c_{Al} > 25$ %

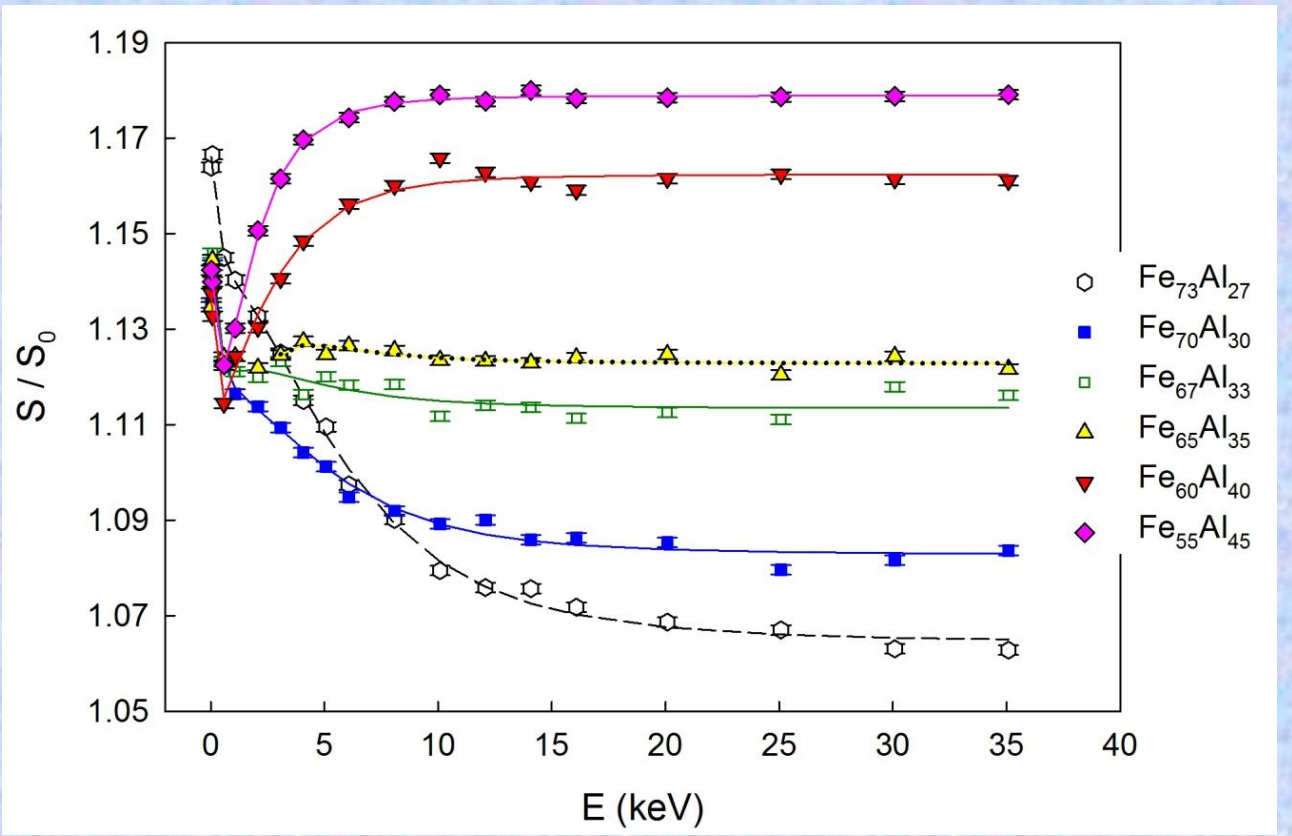
Slow positron implantation spectroscopy (SPIS)

- Fe-Al alloys quenched from 1000 °C



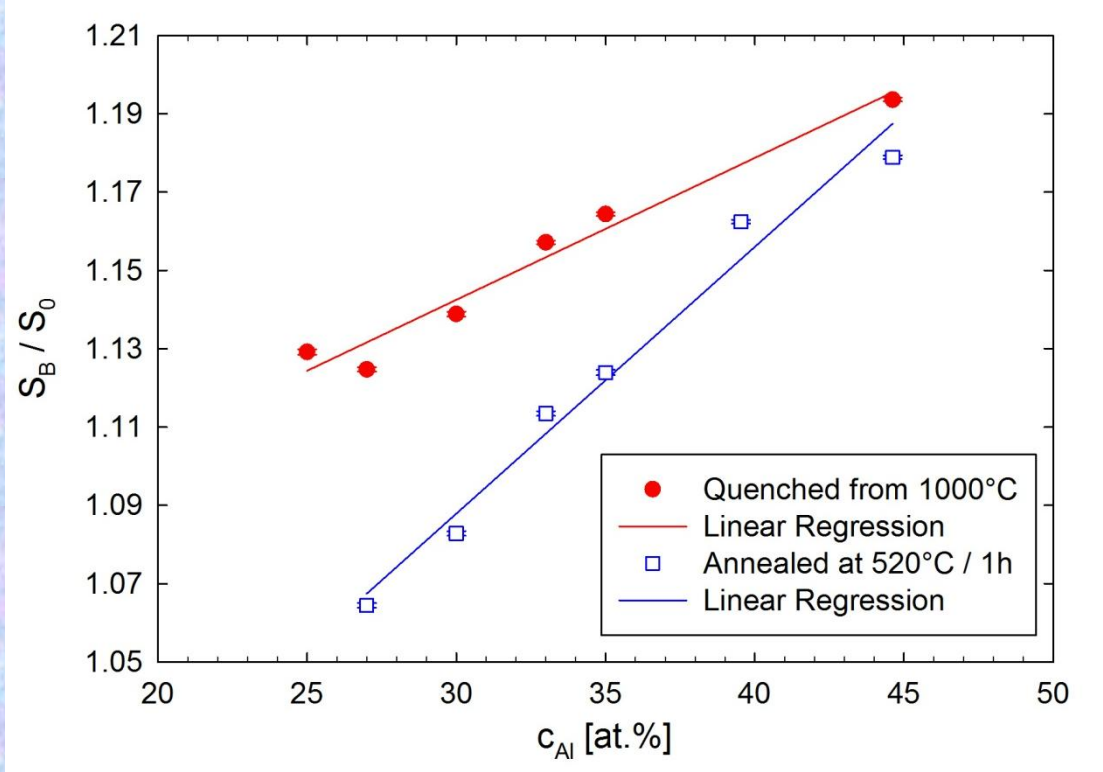
Slow positron implantation spectroscopy (SPIS)

- Fe-Al alloys subsequently annealed at 520 °C



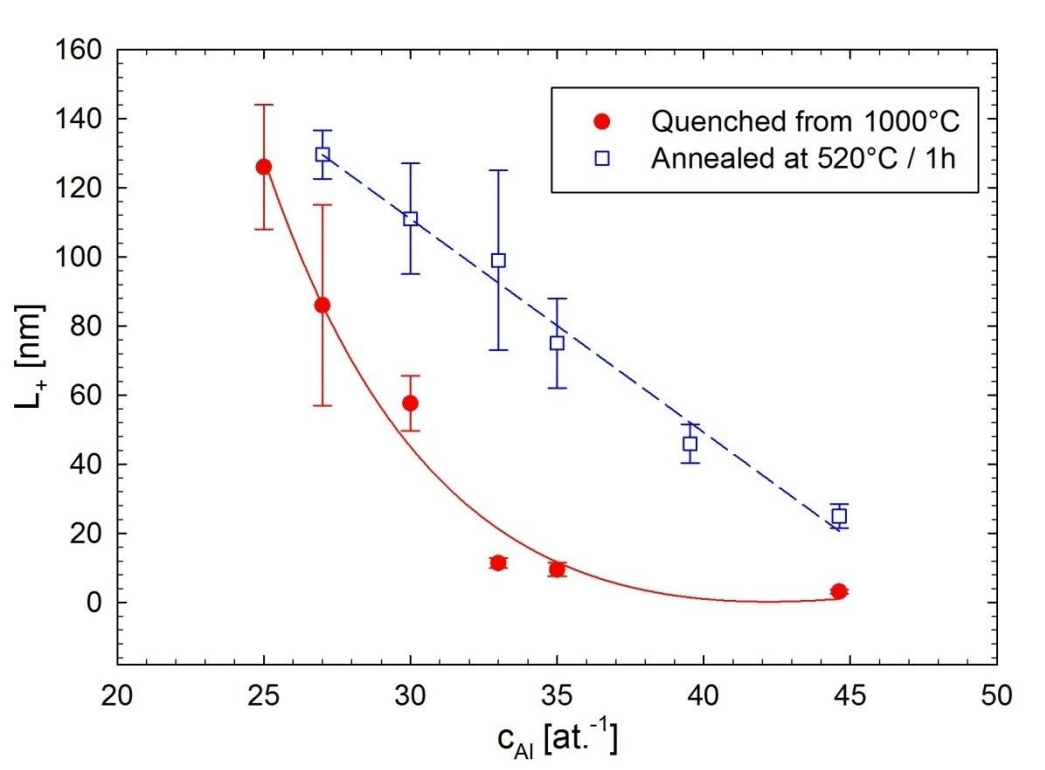
Slow positron implantation spectroscopy (SPIS)

- bulk *S*-parameter fitted from *S(E)* curves shows increase with c_{Al}



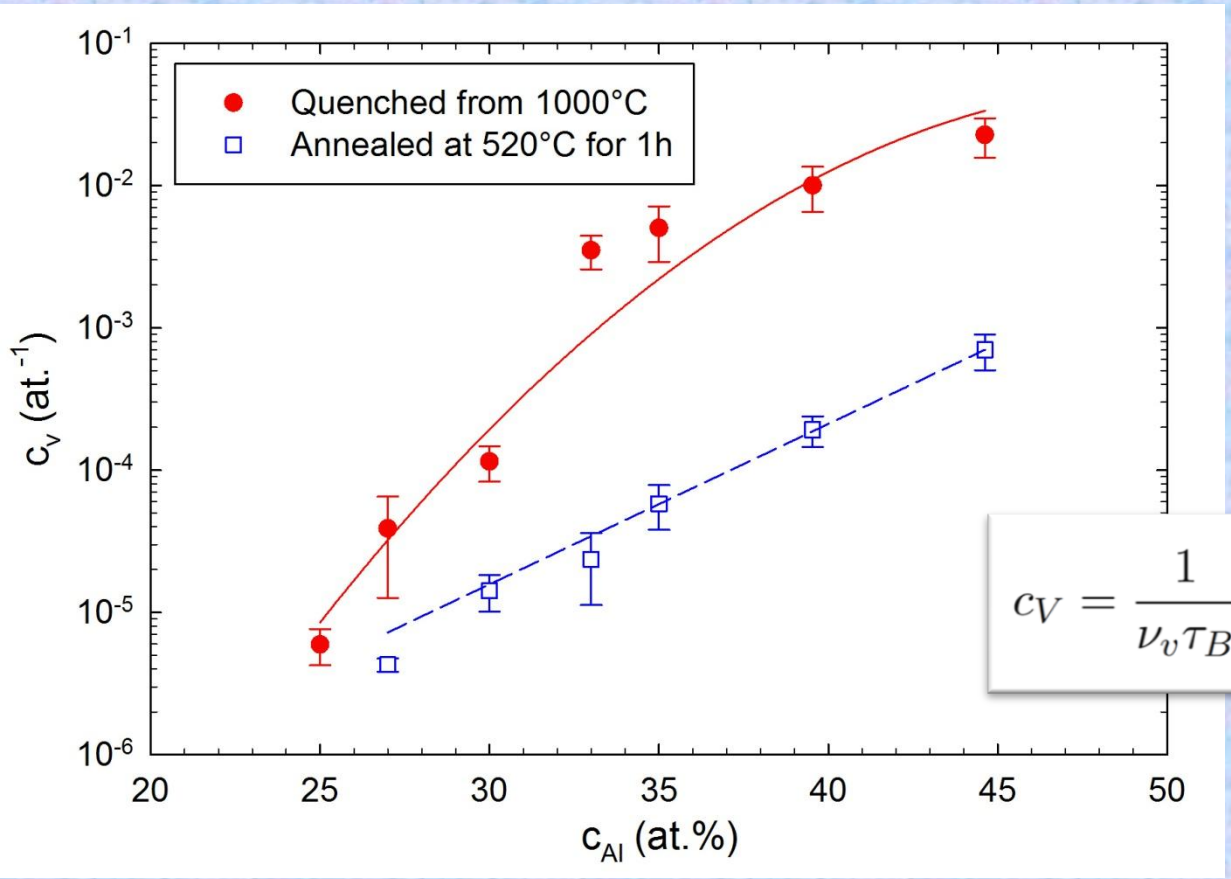
Slow positron implantation spectroscopy (SPIS)

- L_+ positron diffusion length fitted from *S(E)* curves



Slow positron implantation spectroscopy (SPIS)

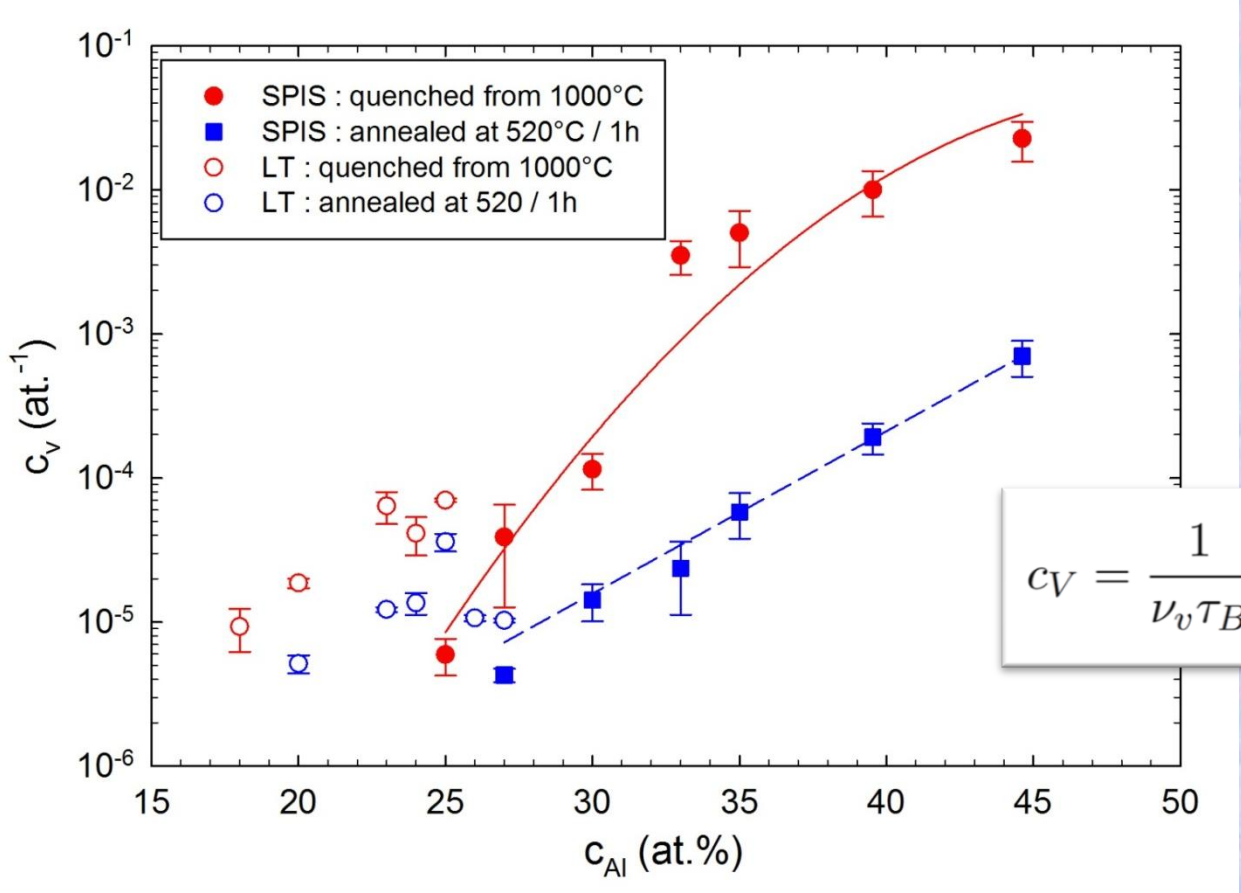
- Vacancy concentration calculated from L_+ shows a drop after the annealing



Quenched-in vacancies anneal out

Vacancy concentration of Fe-Al alloys

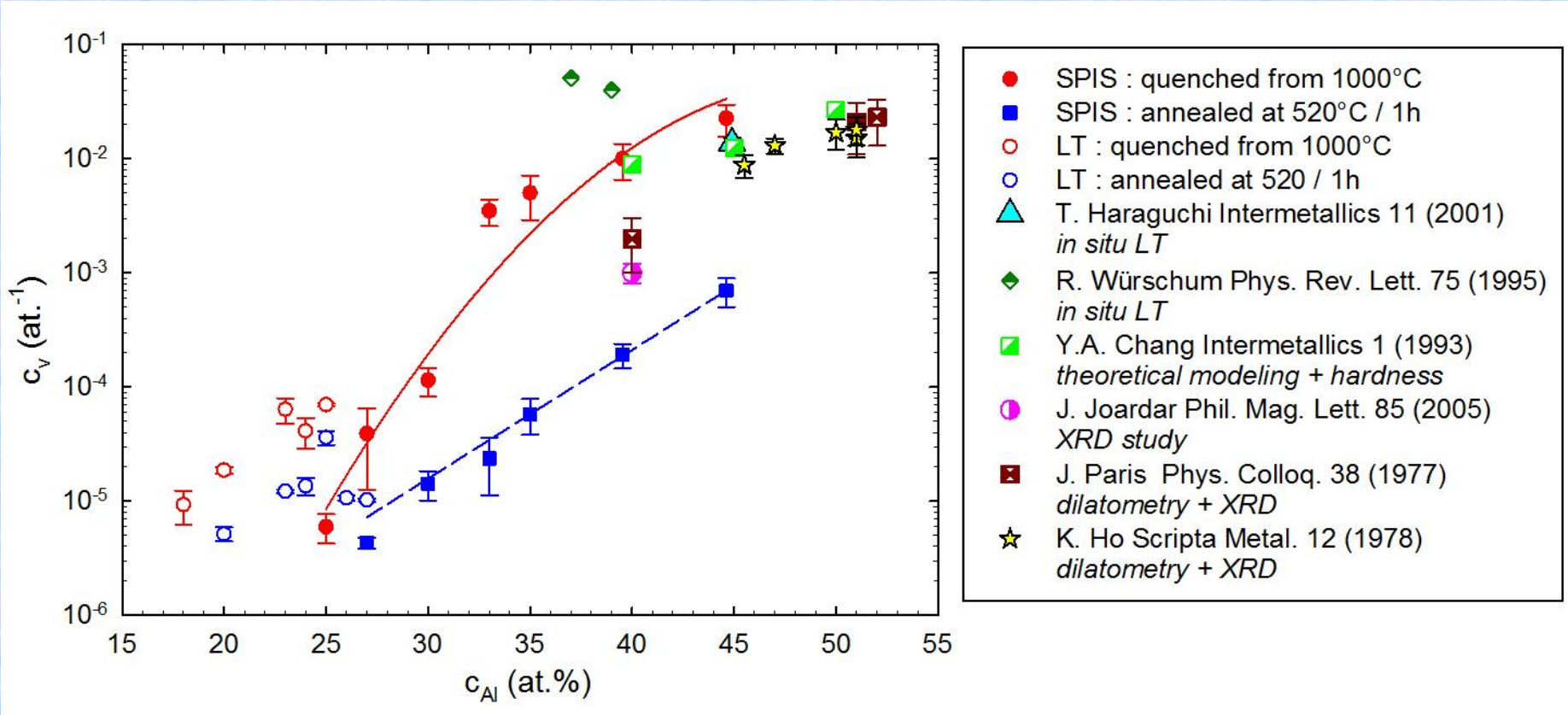
- Comparison with LT results



$$c_V = \frac{1}{\nu_v \tau_B}\left(\frac{L_{+,B}^2}{L_+^2} - 1\right)$$

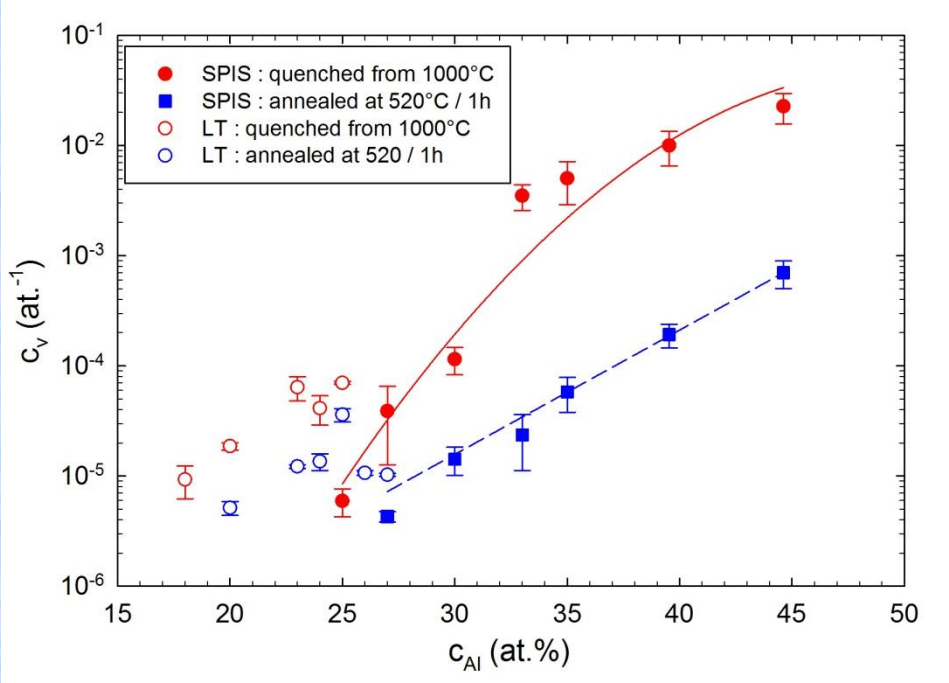
Vacancy concentration of Fe-Al alloys

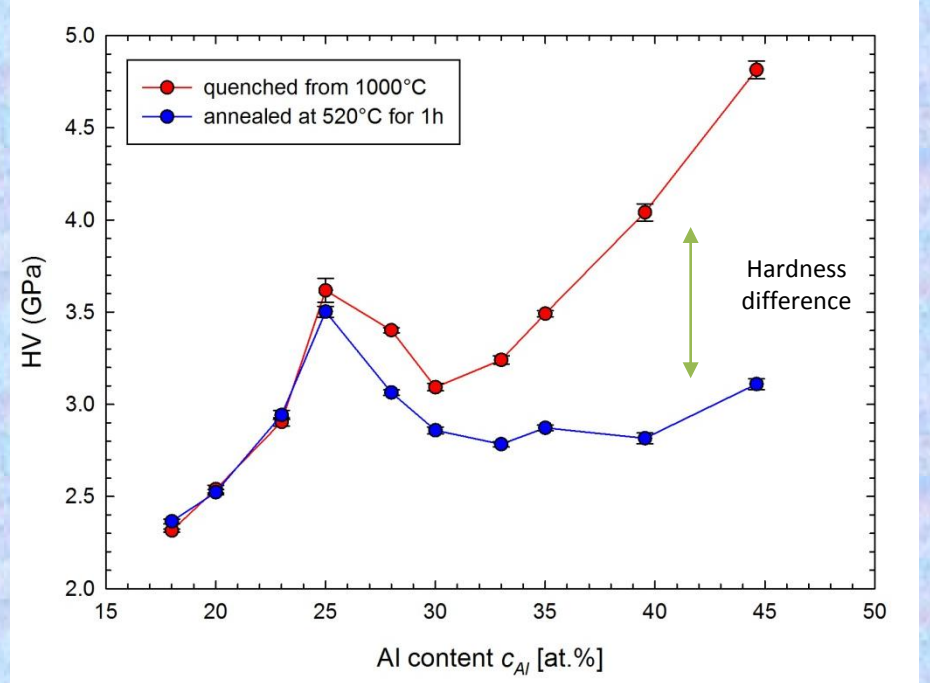
- Comparison with the results of various methods found in the literature



Correlation of hardness with vacancy concentration

Comparison of HV and c_v dependencies shows clear correlation



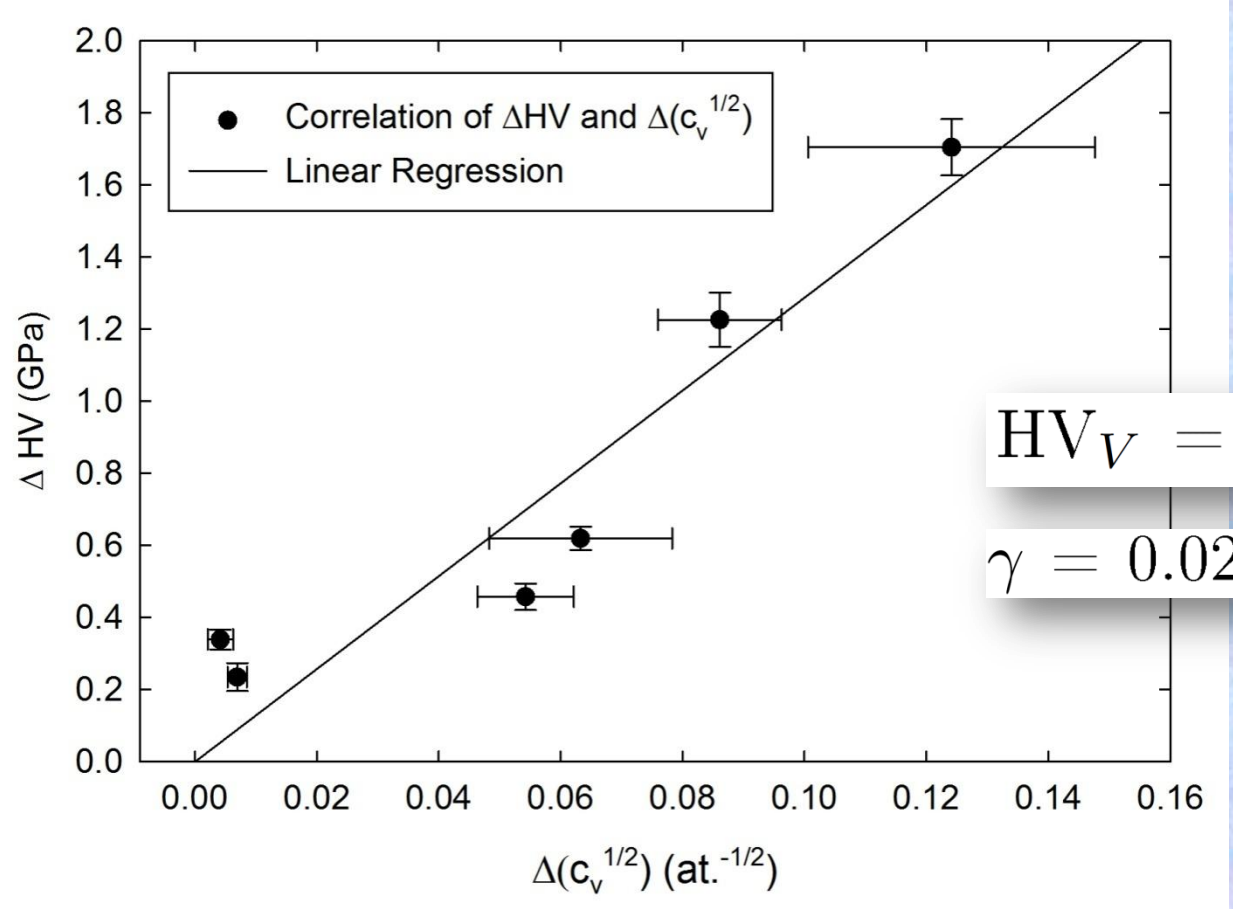


Vacancy hardening occurs when the concentration c_v exceeds ≈10^{-4} at.$^{-1}$

$$\mathrm{HV} = \mathrm{HV}_V(c_V) + \mathrm{HV}_c(c_{Al})$$

Vacancy hardening

- Chang et al.* proposed square root dependence of hardness on vacancy concentration
- Difference of hardness between quenched and annealed alloys gives vacancy hardening comming from solid solution hardening of high concentration of vacancies



$$\mathrm{HV}_V = 6\gamma\mu\sqrt{c_V}$$

$$\gamma = 0.020 \pm 0.005$$

* Chang et al. 1993 Intermetallics 1

Conclusions

- SPIS measurements enable determination of high concentration of vacancies in Fe-Al alloys
- Vacancy concentration is consistent with other methods
- Hardening of the alloys fullfils the proposed square root dependence of hardness on c_v
- Hardening coefficient γ is in the order of magnitude of previous result.