Effects of Aging on Microstructure and Tensile Properties of AFA steel

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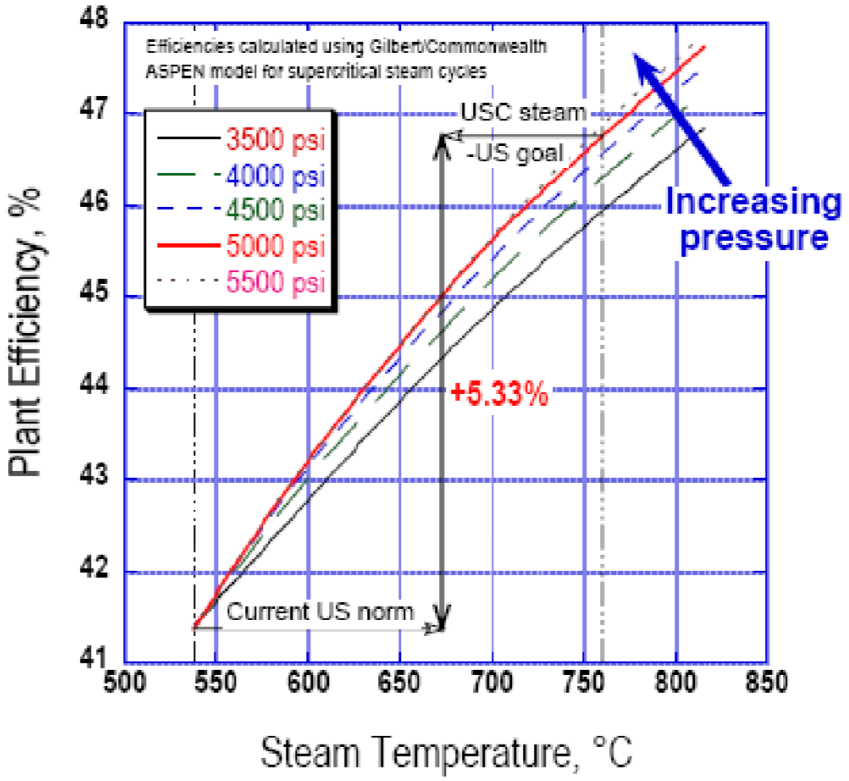
Outline

1. **Introduction**
2. Experimental
3. Microstructural Stability during Aging
4. Evolution of Tensile Properties
5. Conclusions

1. Introduction



650-700℃; 35MPa

◆Structural materials for superheater/ reheater

◆ Stability during long term serving

Alumina-Forming Austenitic (AFA) Steels

oxidation resistance and creep resistance

[1] R. Viswanathan et al. JMEPEG. 2001, 10 (1): 81-95

1.1 Development of AFA steel

HT-UPS

high-temperature ultrafine precipitate strengthening steel

↓

addition of Al (Al_2O_3 scale)

↓

AFA steel

alumina-**f**orming **a**ustenitic stainless steel

Note: Al is a ferrite stabilizer; alloy design to maintain austenite

1.2 AFA steel- oxidation resistance

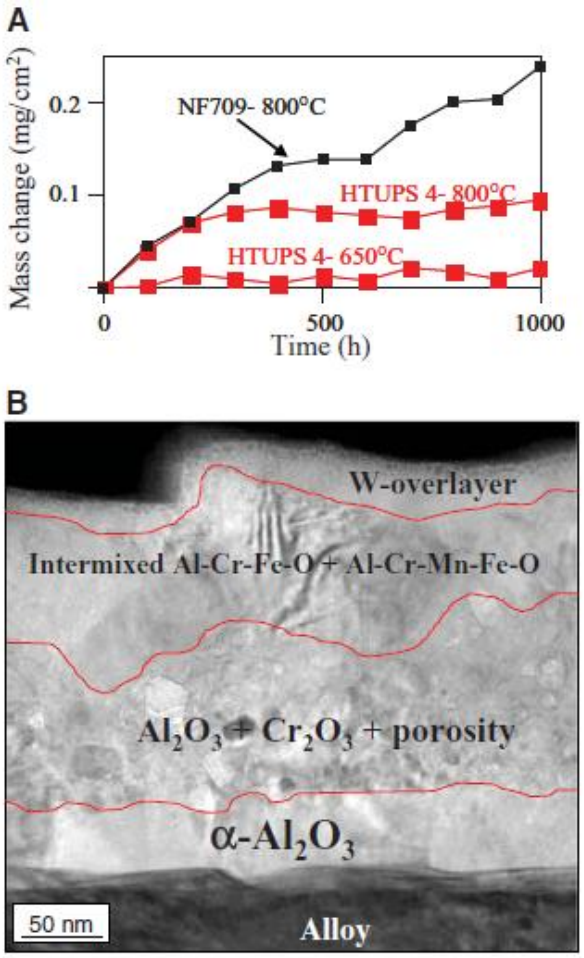
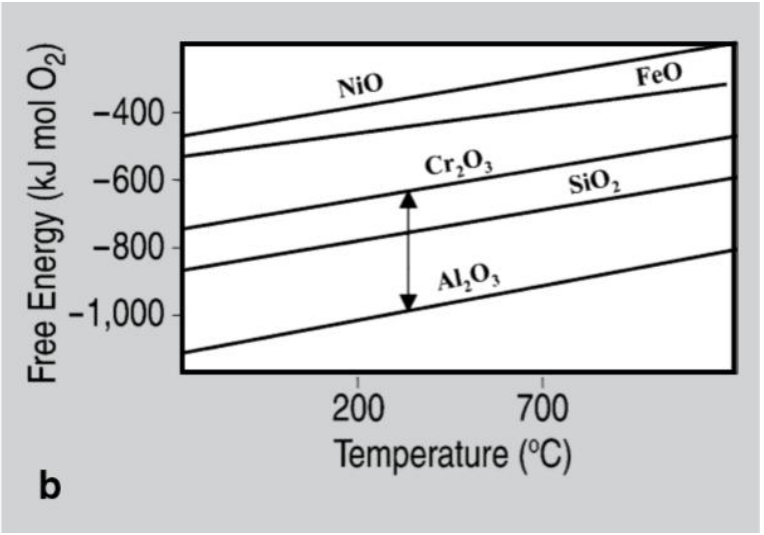


Fig. 3. (**A**) Oxidation kinetics in air with 10% water vapor (10 to 100 hours cycles) [NF709 data from (*22*, *23*)]. (**B**) TEM bright-field cross section of scale formed on HTUPS 4 after 1000 hours at 800°C in air with 10% water vapor.



good oxidation resistance of Al_2O_3 scale

problem of IOTT at 800℃
(internal oxidation transition temp.)

1.3 AFA steels- strengthening

MX; B2-NiAl; Laves-Fe2Nb; γ‘-Ni3(Al,Ti)

① MX: NbC, TiC, VC
- significant strengthening effect

② B2-NiAl:
- DBTT(500-800℃); lose strengthening at high-temp

③ γ‘-Ni3(Al,Ti)
- AFA steels with high content of Ni → **high cost**

Laves-Fe2Nb: different opinions

Objective

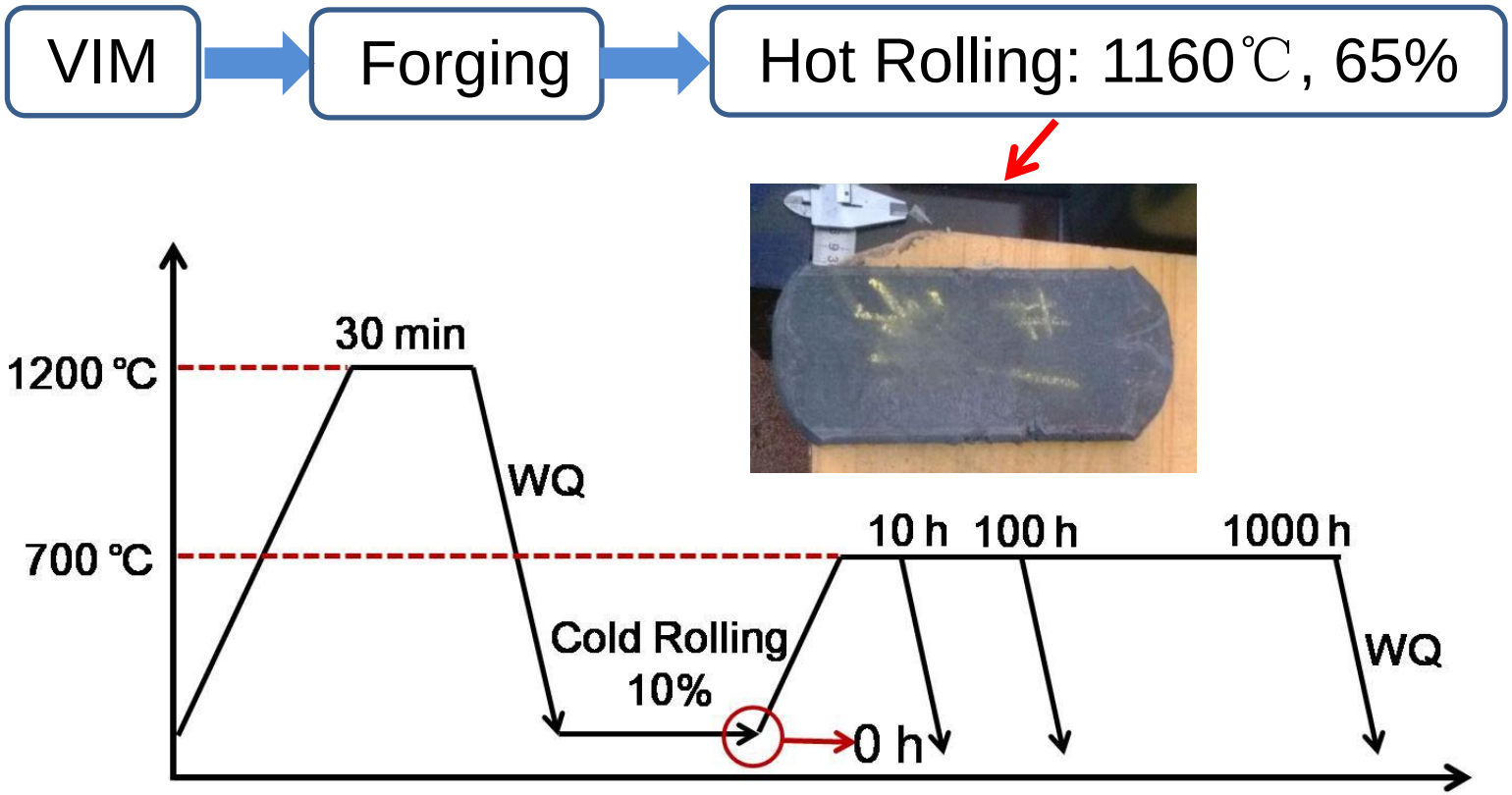
Laves-Fe2Nb

- good stability at high temperature
  - GBPS (grain boundary precipitate strengthening)
  - increase creep resistance
- TCP phase → deterioration of ductility
- relationship between NbC and Laves phase

- investigation the strengthening roles of intermetallic compounds
- evaluation of mircostructural stability
- decrease the contents of Ni and Cr

2. Experimental

element	Fe	Ni	Cr	Mo	Si	Mn	Y	Al	Nb	C	O	N
wt.%	Bal.	19.2	12.7	2.18	0.38	0.03	30ppm	**2.28**	**0.78**	**0.019**	0.006	0.008



aging process

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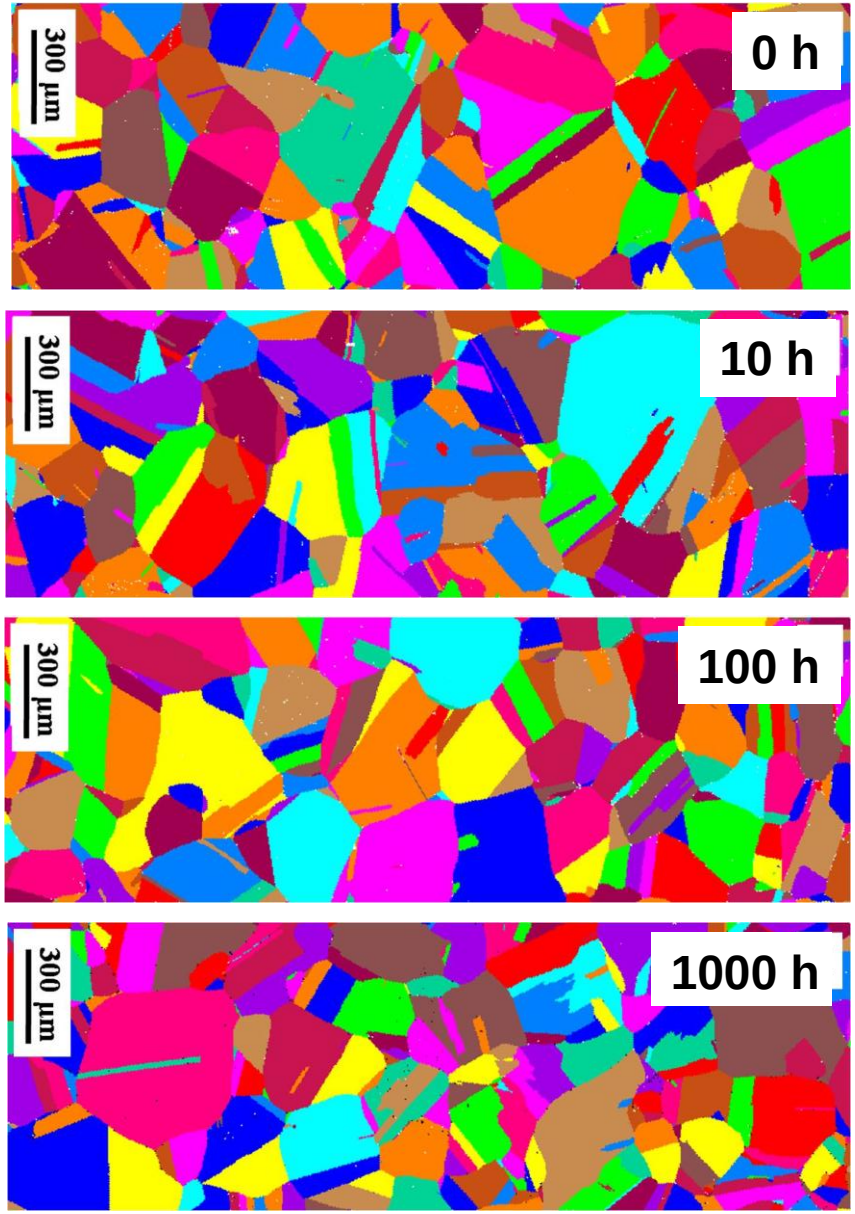
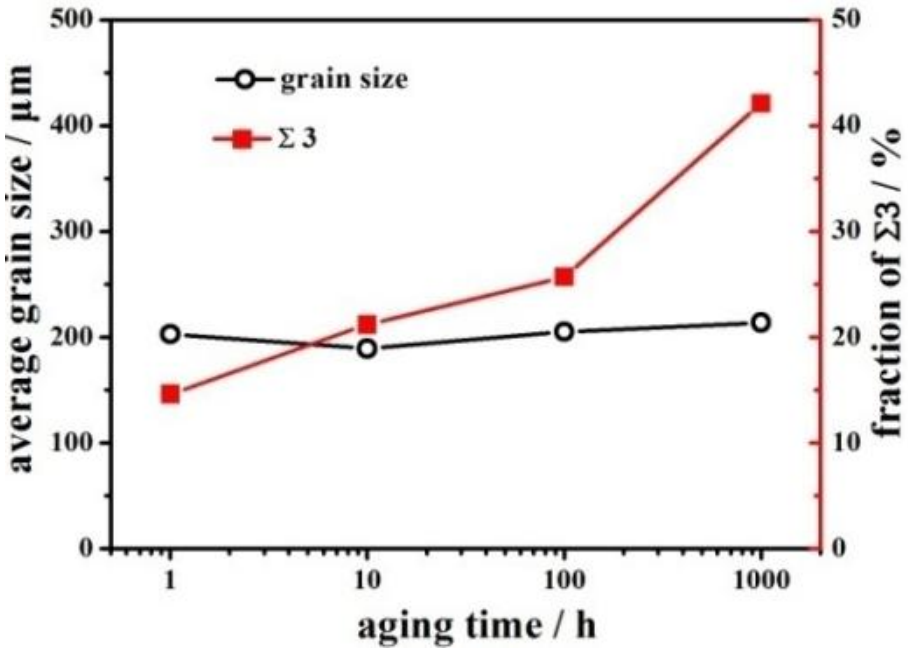
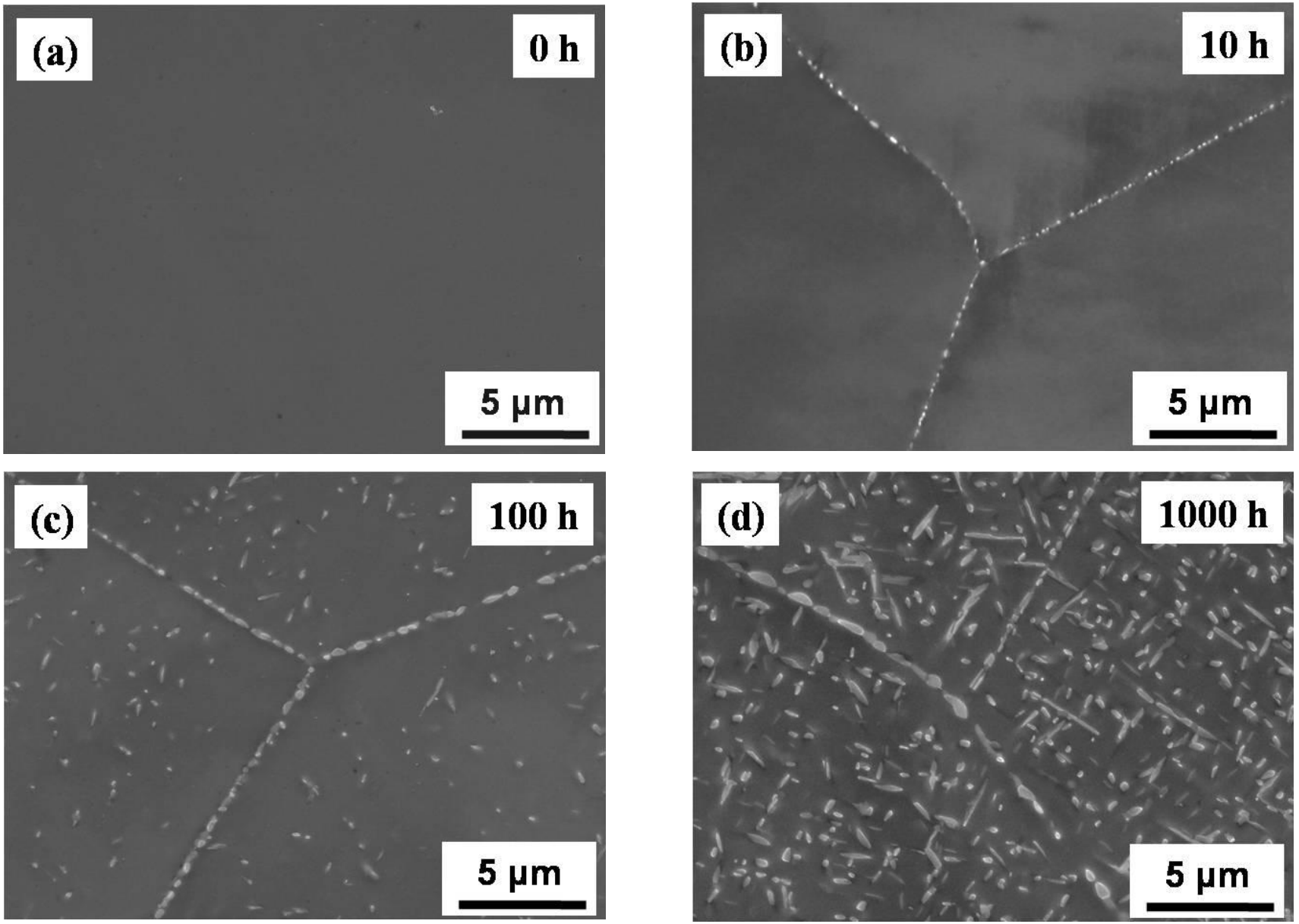
3.1 Microstructural Evolution



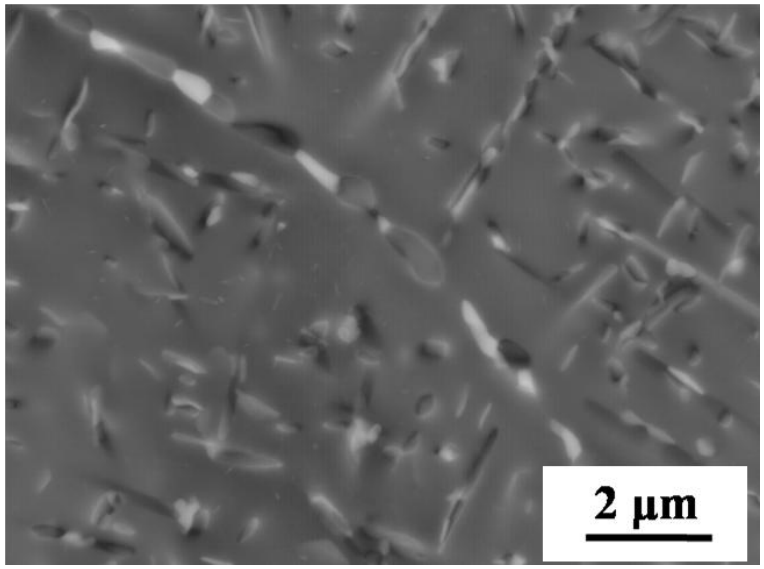


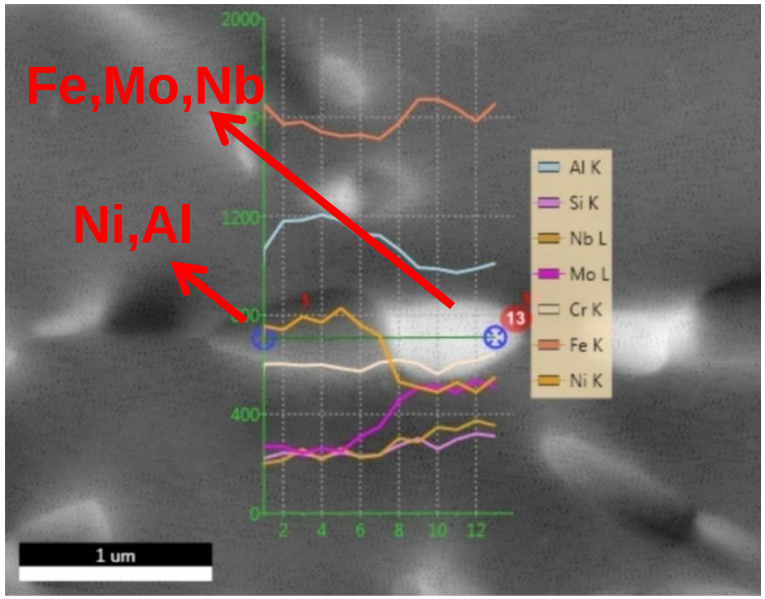
- no grain coarse
- increase of Σ3 GB

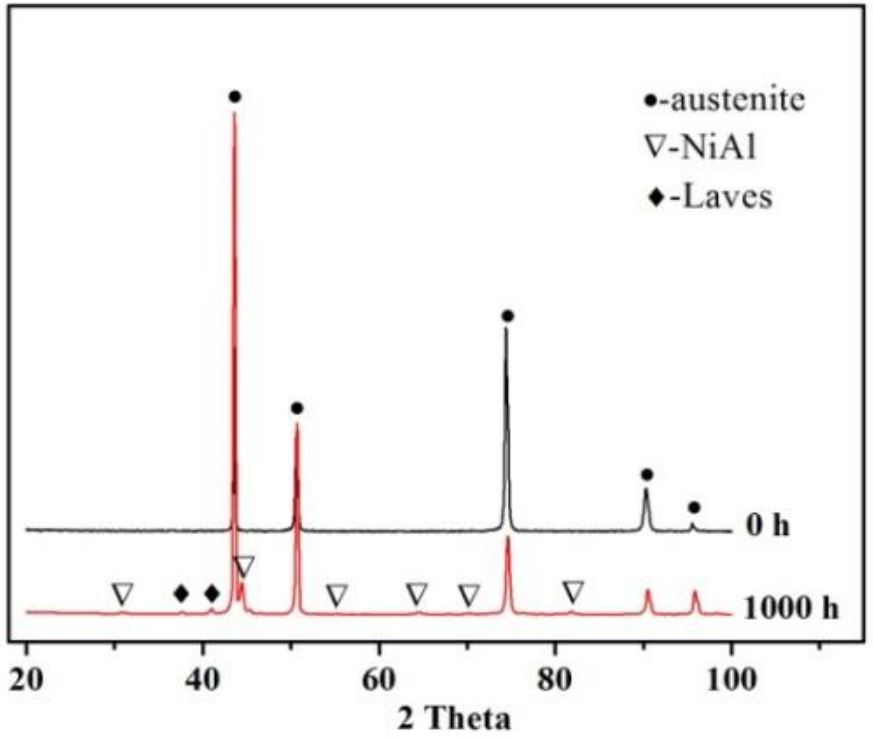
3.2 Precipitation



Precipitation (1000 h)

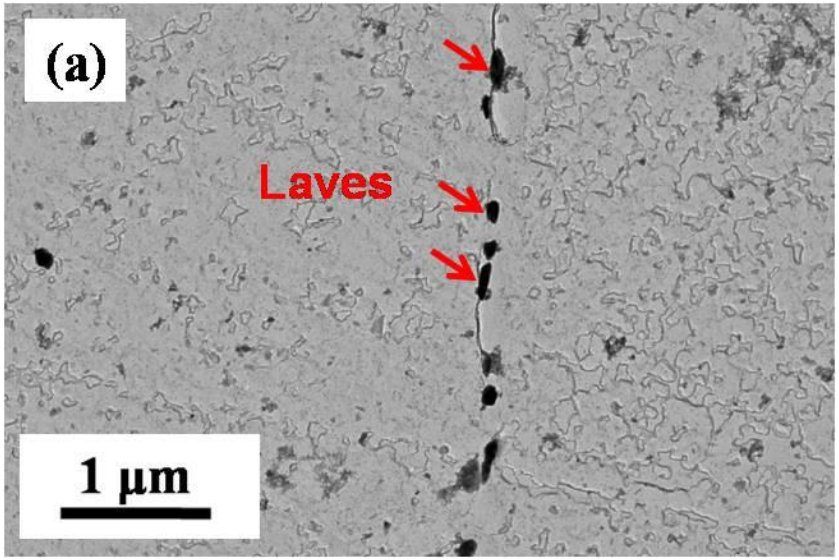


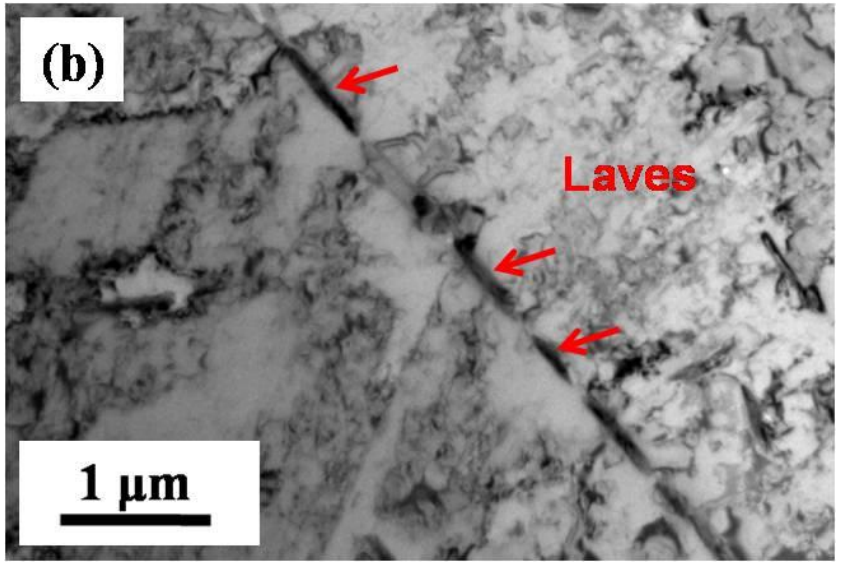


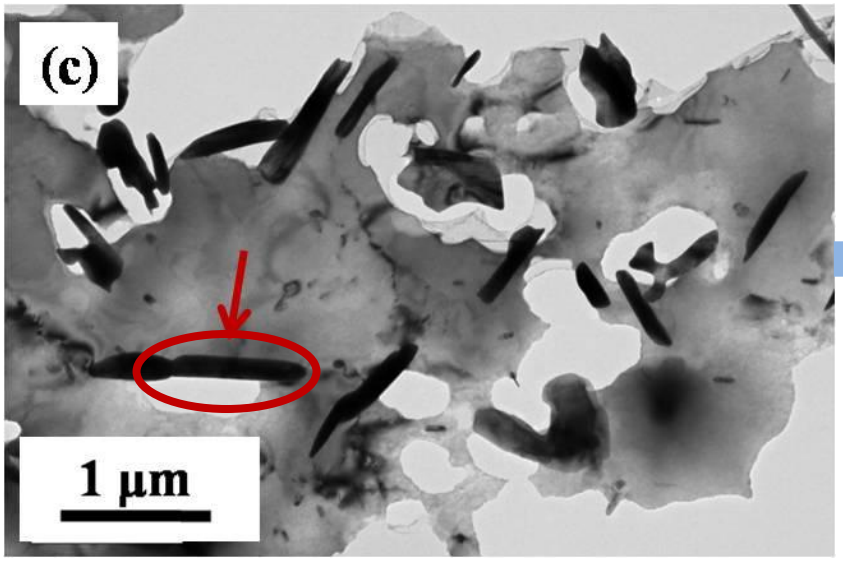


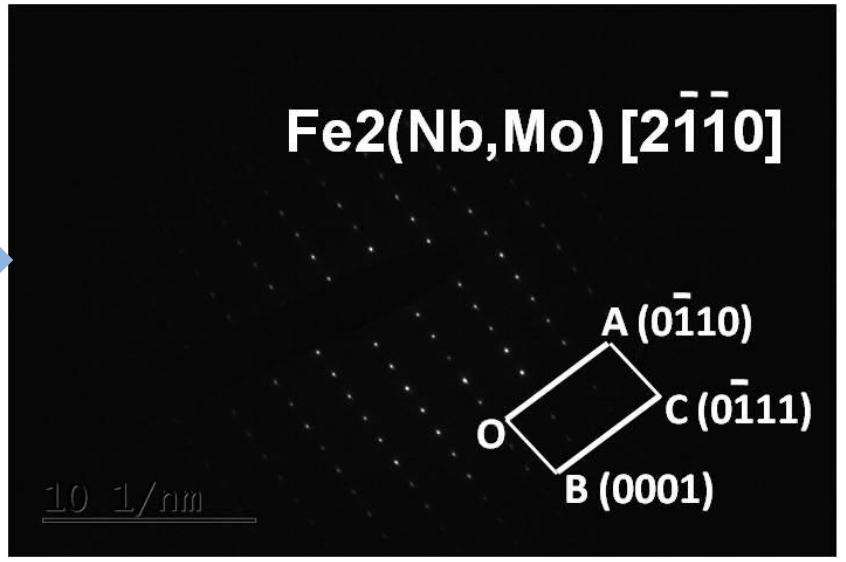
- ◆ B2-NiAl
- ◆ Laves-Fe2(Mo,Nb)

3.2.1 Evolution of Laves Phase

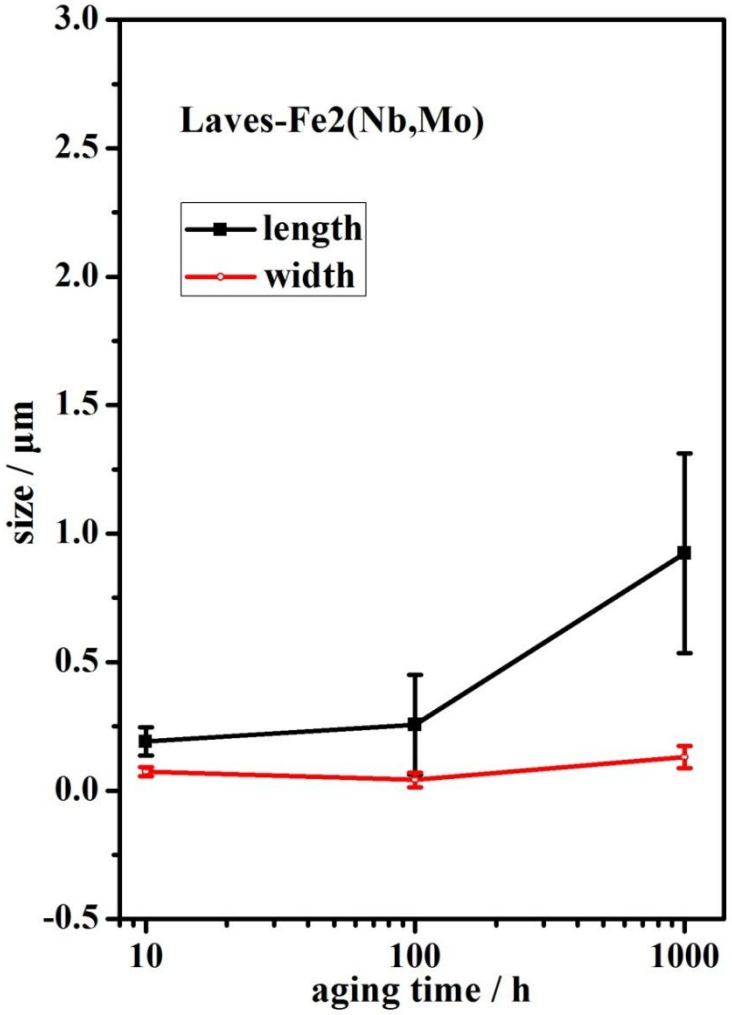


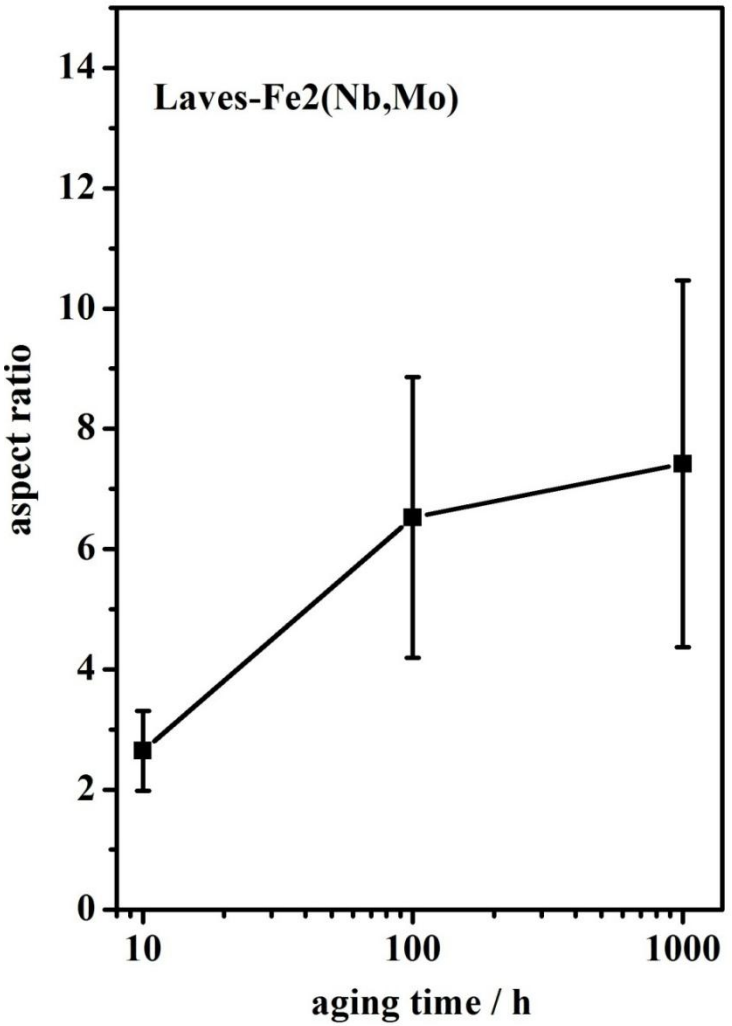






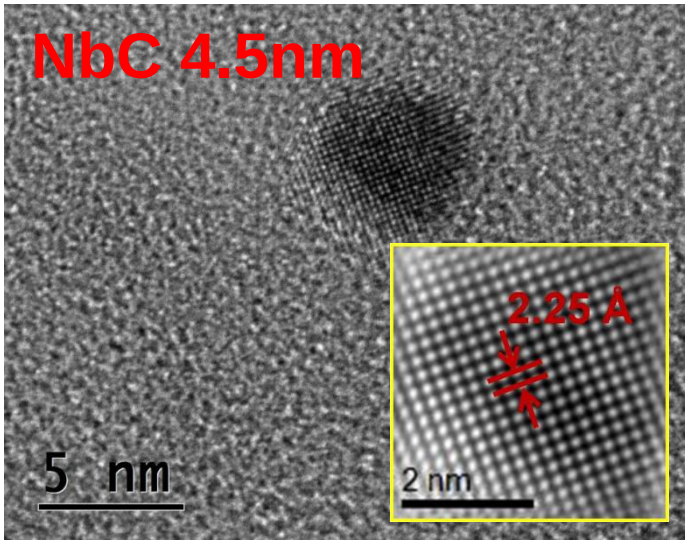
3.2.1 Evolution of Laves Phase

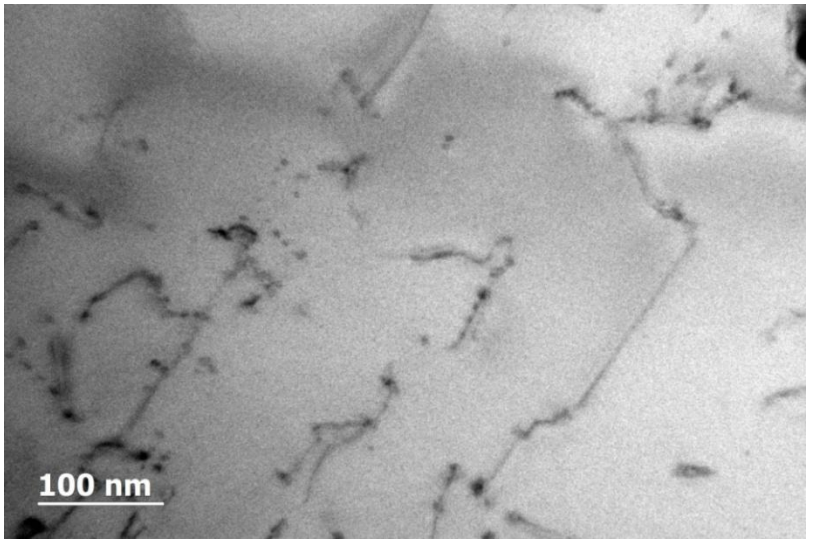




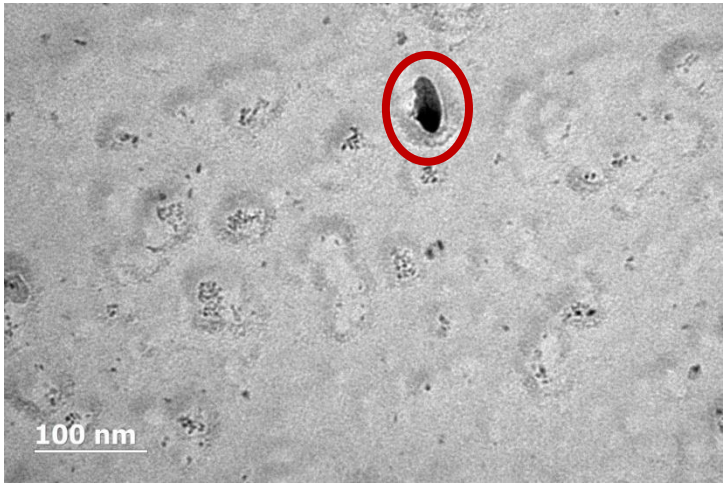
Laves phases increased obviously during aging.

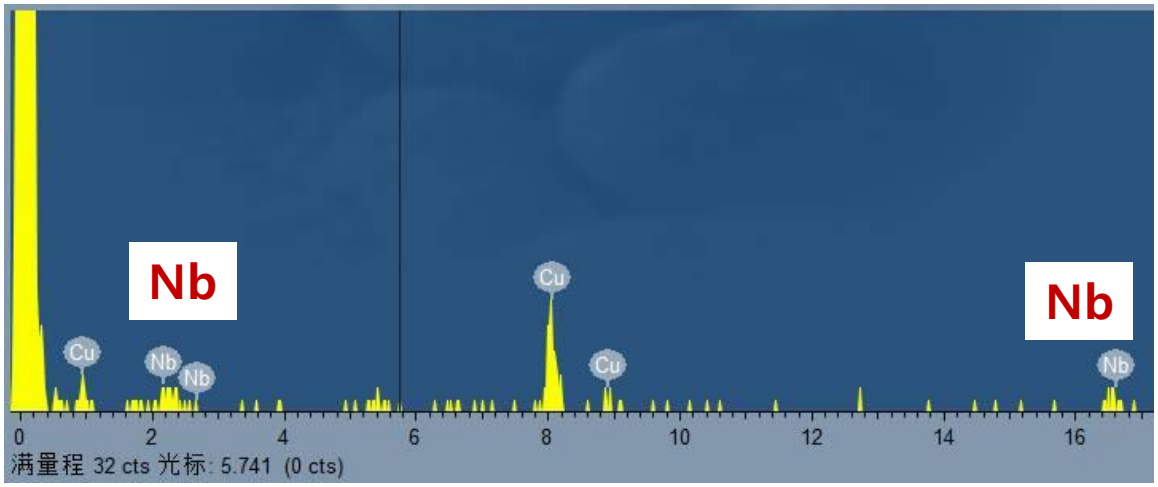
3.2.2 Evolution of NbC (10 h)



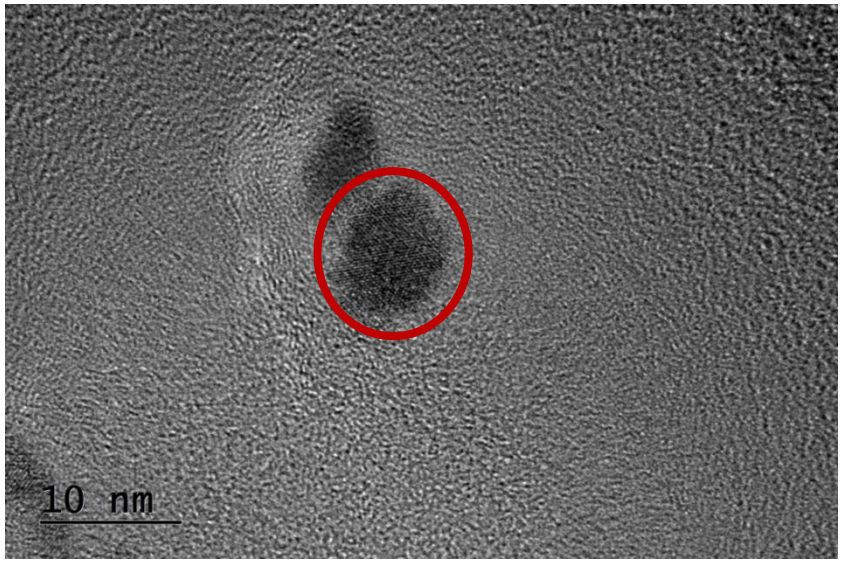


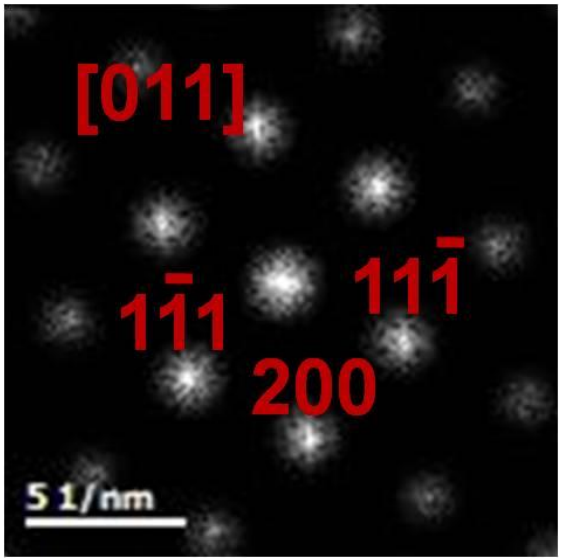
dislocation pinning by the nano-sized NbC

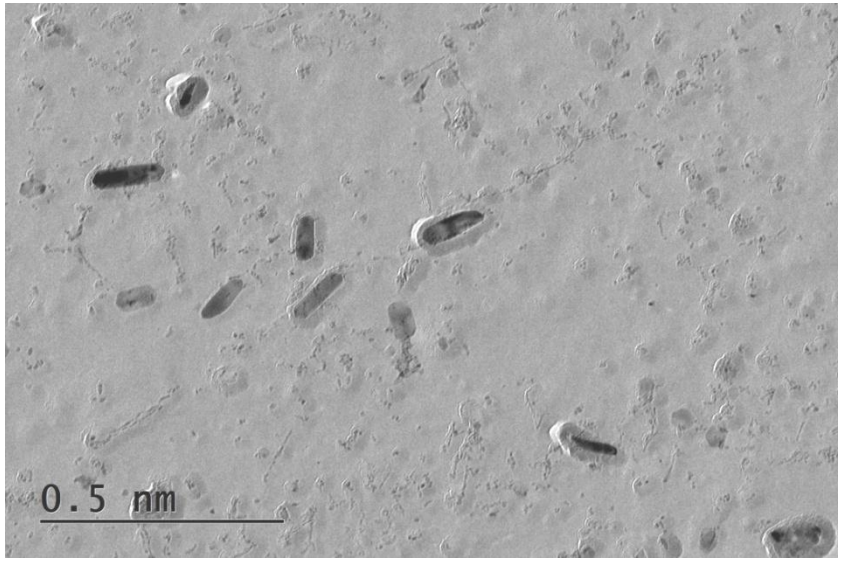




Evolution of NbC (100 h)

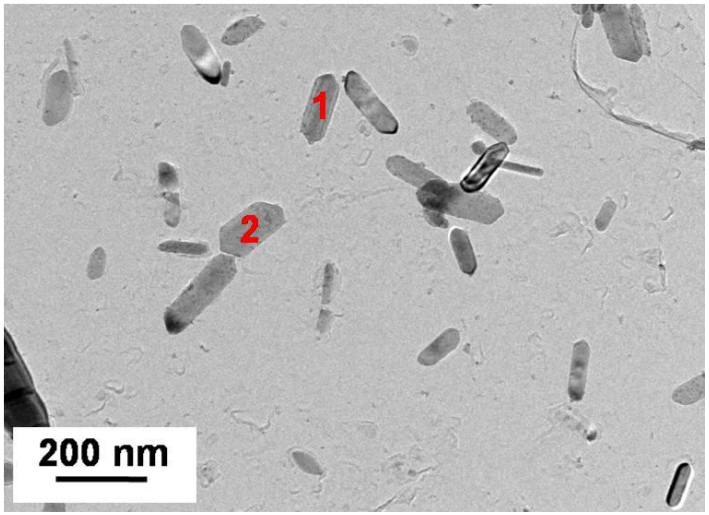


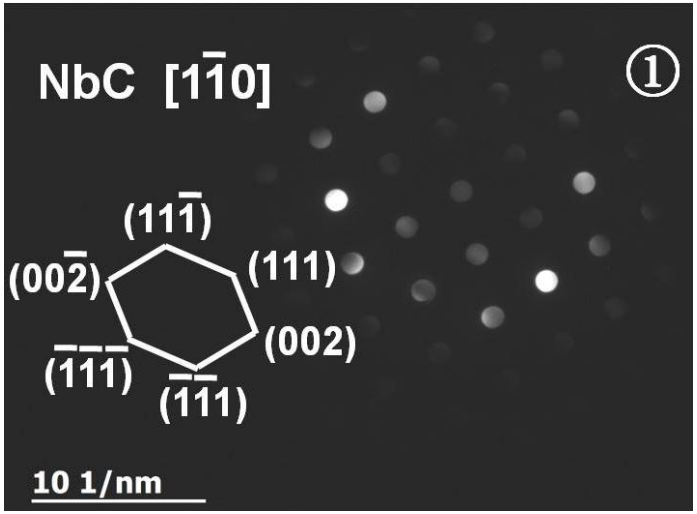




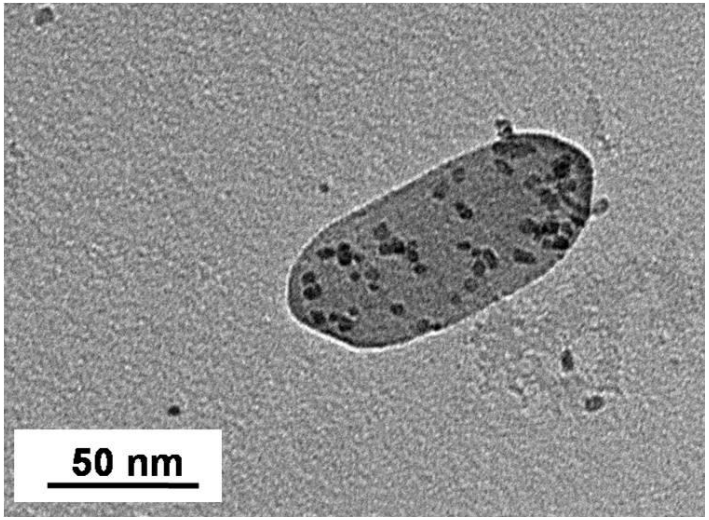
NbC with different shapes

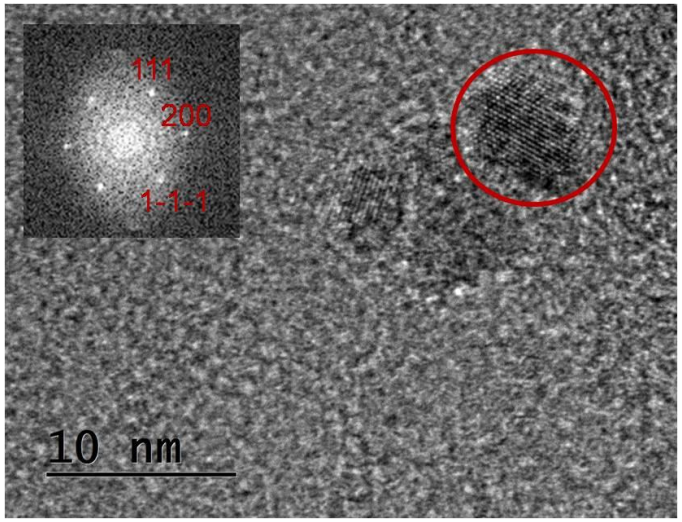
Evolution of NbC (1000 h)





plated NbC
100-200 nm

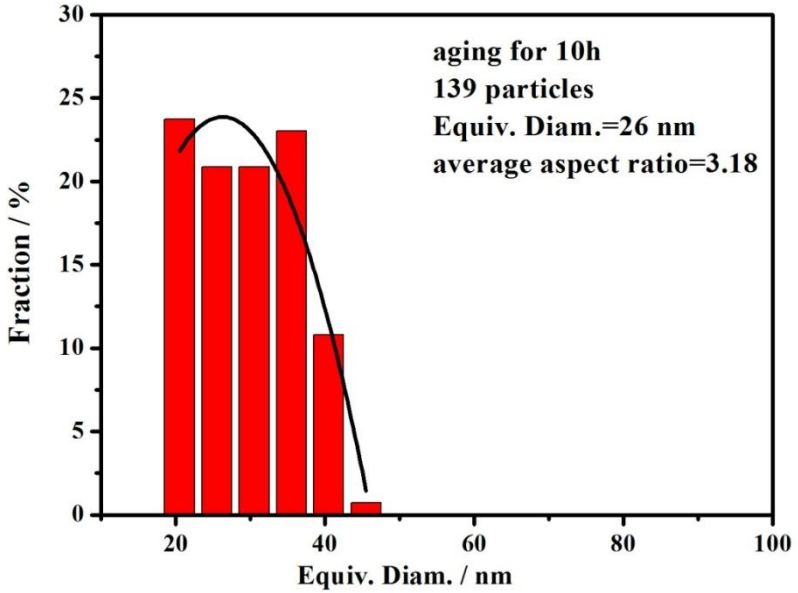


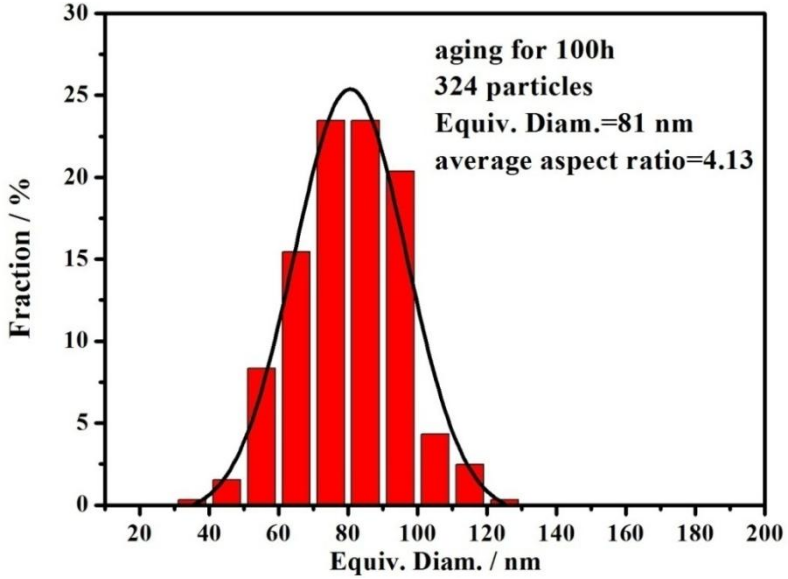


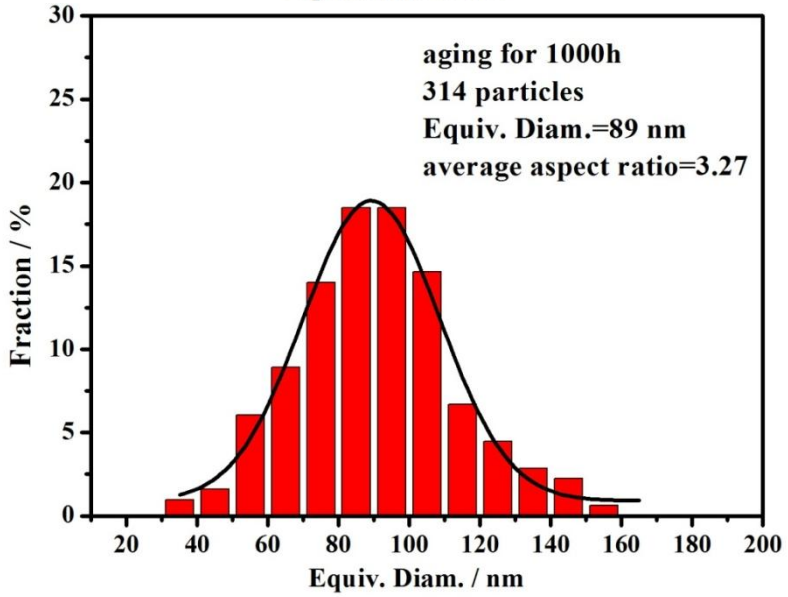
round NbC
5 nm

Evolution of Plated NbC

- Round NbC was stable (～5nm)
- Plated NbC increased quickly during aging from 10 h to 100 h.







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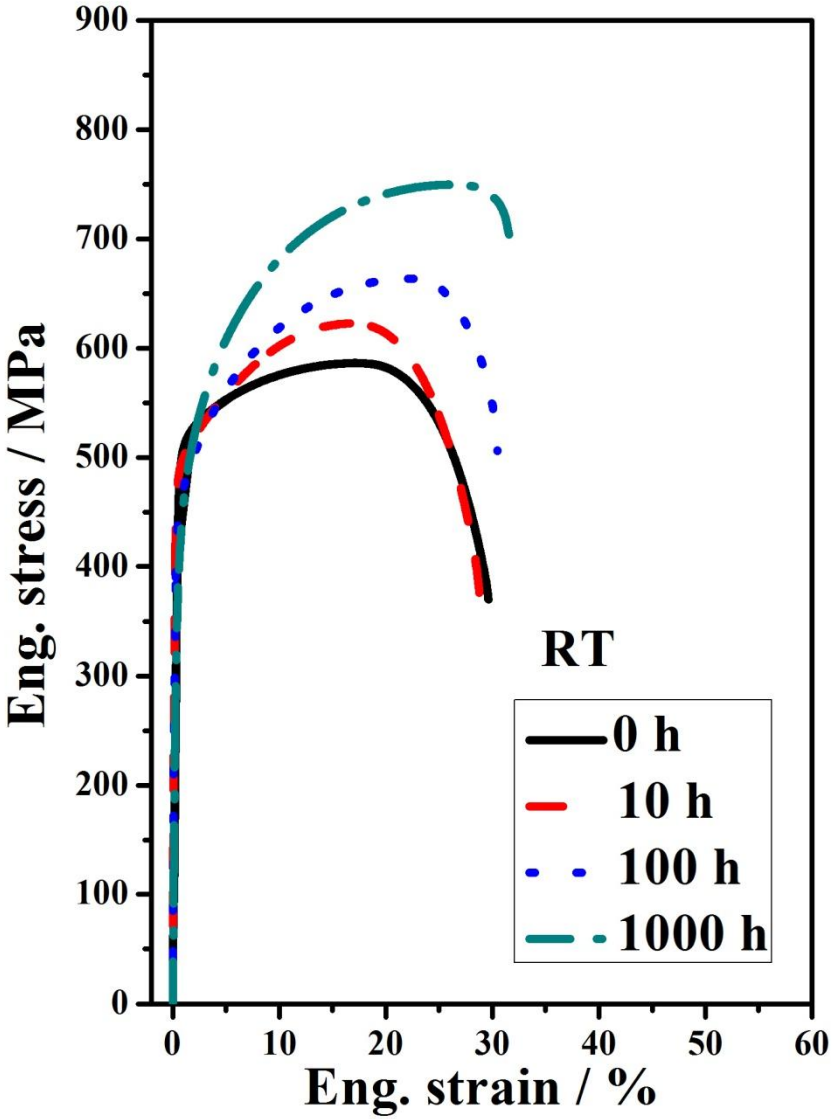
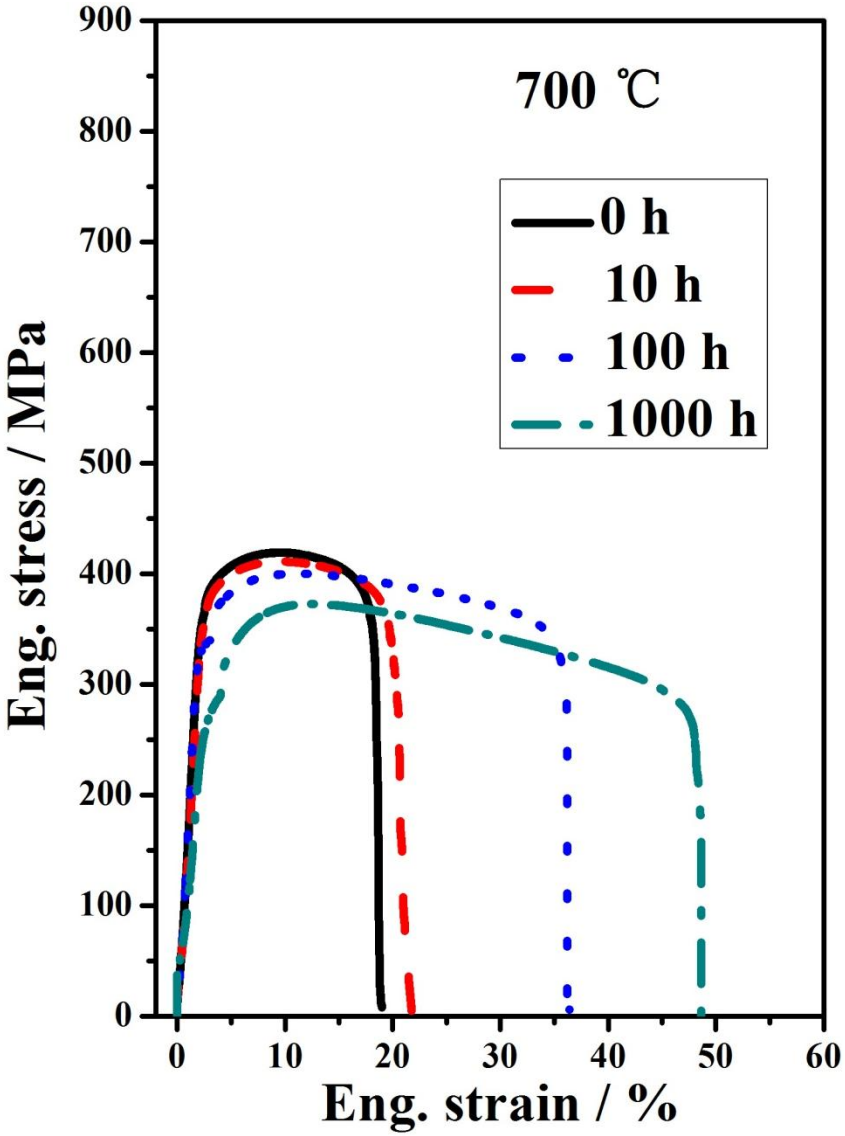
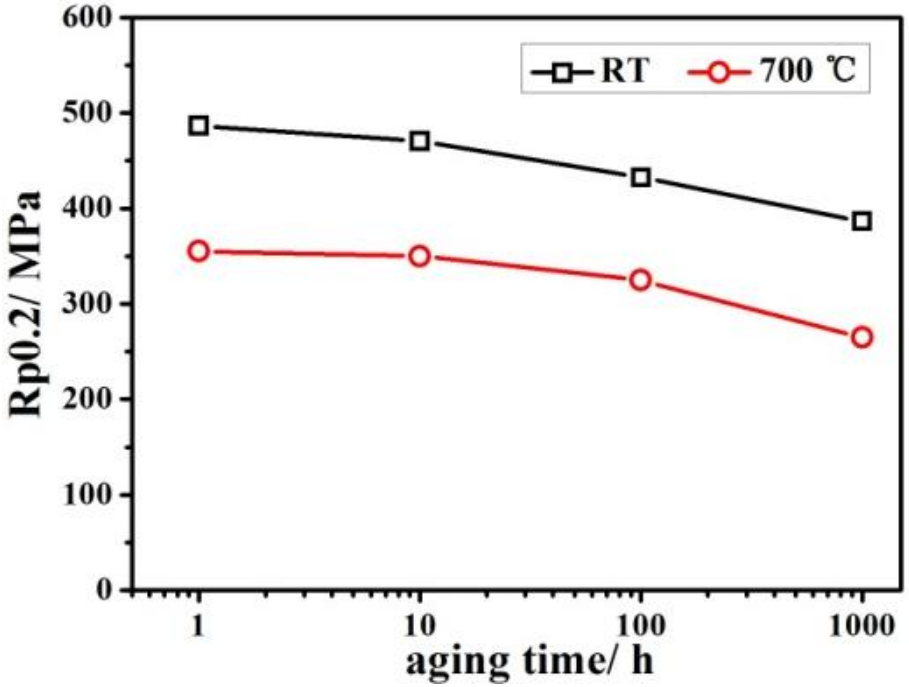
4.1 Tensile Curves





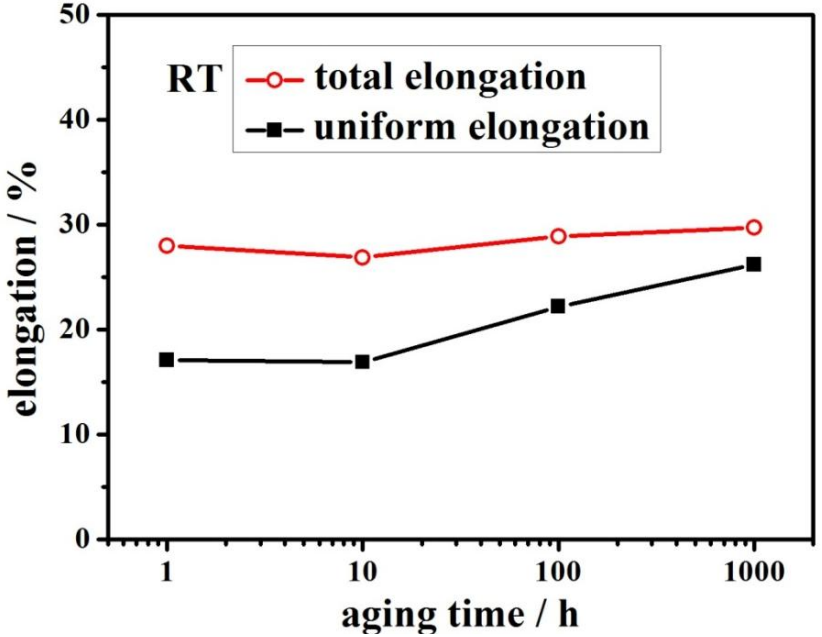
Evolution of Tensile Properties

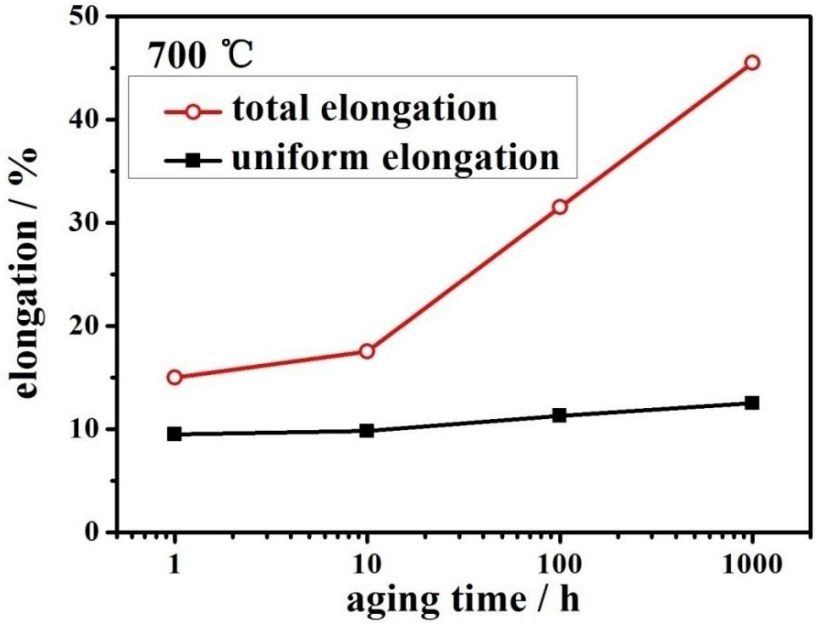


Potential reasons for decrease of Rp0.2 during aging

- decrease of solution strengthening
- growth of precipitates (Laves phase and plated NbC)

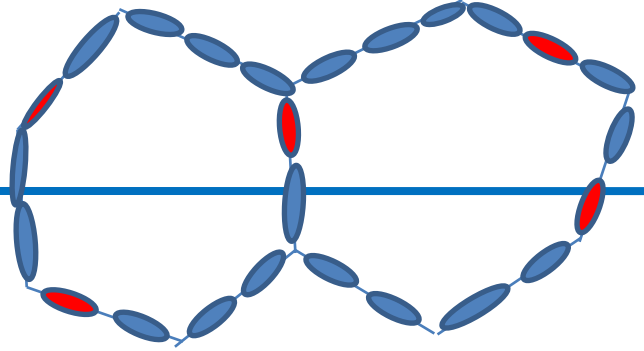
Evolution of Tensile Properties





no deterioration in elongation

Summary



1. Grains did not coarsen during aging due to the pinning of precipitates on GB.
2. Laves phase showed a high growth rate. However it did not impair ductility.
3. Two kinds of NbC were observed. The round particles had good stability, with the size of 5 nm after aging for 1000 h. while the plated NbC showed a relatively high growth rate in the initial stage, then a slow growth rate with further aging.
4. The relationship between the two kinds of NbC needs more investigation.

Thanks for your kind attention!