Rolling Effects on Advanced Reduced-Activation Alloy Studied by Positron Annihilation Lifetime Spectroscopy

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Introduction

- Positron annihilation lifetime spectroscopy (PALS) is a powerful tool for detecting nanoscale defects. PALS measures the size and amount of defects by measuring the time difference between gamma-ray (Fig. 1).
- The PALS can analyze microstructure due to its high sensitivity to defects.
- The structural materials of the ITER are investigated with fast neutrons and high-temperature helium plasma.
- Advanced reduced-activation alloy (ARAA) is a complementary material that has fewer activation effects. The ARAA is used the 9Cr-1.2W-Fe (Table. 1).

Fig. 1. Positron lifetime (τ): time difference between the start and stop signal.

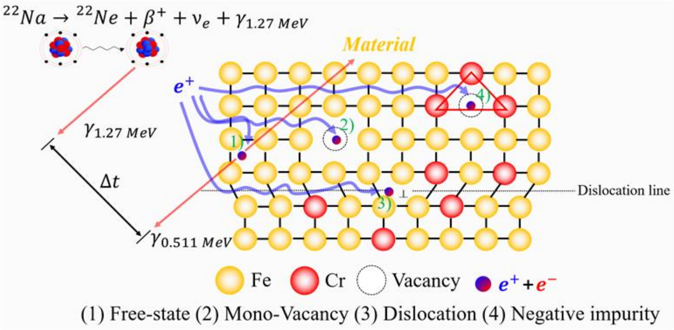

Table. 1. Chemical composition of the advanced reduced-activation alloy (wt%).

Element	Composition(wt%)	Element	Composition(wt%)
C	0.1	V	0.2
Si	0.1	Ta	0.07
Mn	0.45	N	0.01
Cr	9	Ti	0.01
W	1.2	Zr	0.01

Materials & Methods

- The detector used in the PALS system is a pair of plastic scintillators and is applied with the positron lifetime picosecond timing system of KAERI (Fig. 2, 3).

2.1. PALS measured using a Na-22 source.

- The positron source used of PALS was the Na-22 radioactive isotope of 30 μCi as 2.5 μm Ni foil, overlapping like a sandwich on both sides.
- The 8×8 mm² positron source was positioned between the samples (Fig. 4) and sealed the sandwich sample.

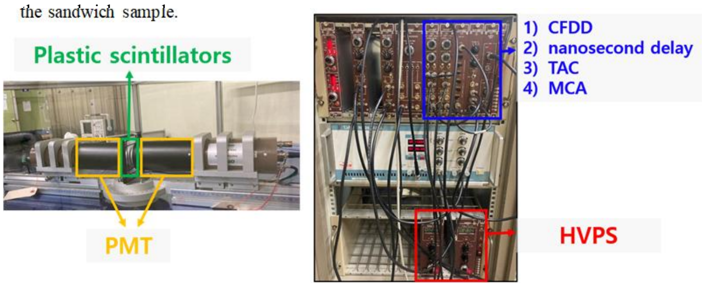

Fig. 2. Positron annihilation lifetime spectroscopy (PALS) system. PMT: photomultiplier tube, HVPS: high voltage power supply, CFDD: constant fraction differential discriminator, TAC: time-to-amplitude converter, MCA: multichannel analyzer.

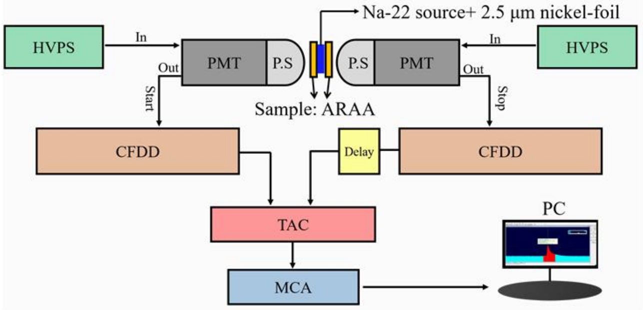

Fig. 3. Schematic diagram of PALS system. P.S: plastic scintillator, PMT: photomultiplier tube, HVPS: high voltage power supply, CFDD: constant fraction differential, TAC: time-to-amplitude converter, MCA: multichannel analyzer, ADC: analogue-to-digital converter, PC: personal computer, ARAA: advanced reduced-activation alloy.

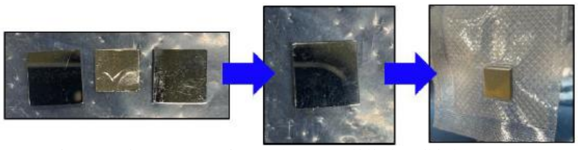

Fig. 4. Sample preparing process for positron annihilation lifetime spectroscopy (PALS). polished blocks were advanced reduced-activation alloy (ARAA) samples, and the center between samples is the positron source with a nickel foil.

2.1. Information from measured samples.

- ARAA was created by adding 0.01wt% zirconium to 9Cr-1.2W based ferritic-martensitic steels (Table. 1).
- All samples were double-normalized and rolled for 40minutes at 1000°C, and each sample was rolled in a different method (Table. 2).
- Each sample size was 10×10×1 mm³, and all samples were rolled at 700°C.

Table. 2. Thermomechanical processes of advanced reduced-activation alloy (ARAA).

Sample	Annealing and rolling method
TMP 13C	[1]N+N
TMT 32	N+N+15%[2]R@700°C
TMP 19(34)	N+N+25%R@700°C
TMP 20	N+N+35%R@700°C

[1]N: normalizing at 1000°C/40 minute/air-cooling.
[2]R: rolling.

Results

- The τ_1 of ARAA was analyzed at as-normalized to be less than 100 ps. There was a difference by 20% in the value of the τ_1 between as-normalized and rolled at 700 °C.
- The τ_2 was observed between 250 ps and 310 ps of positron lifetime. The τ_2 was increased in the τ_2 between as-normalized and rolled at 700 °C.
- The positron lifetime is observed that the mean lifetime (τ_m) increases with increasing rolling strain and then saturated, it appears to have changed when 15% rolling.
- The τ_m gradually increased, and after 15% rolling, the τ_m was saturated.
- The increase in the τ_m before 15% rolling is expected to increase the τ_m due to the slow growth of dislocations and vacancy during the rolling process, and after 15% rolling, the growth is expected to slow and saturate.

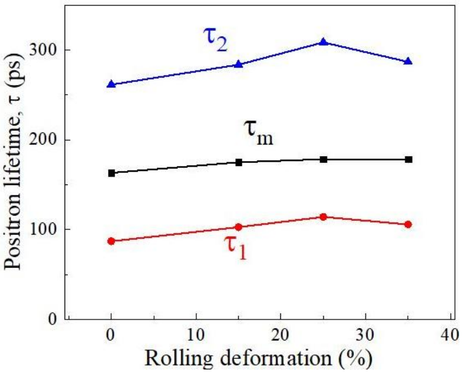

Fig. 5. The short lifetime (τ_1), long lifetime (τ_2), and mean lifetime (τ_m) of the samples in as-normalized and hot-rolling deformation.

Conclusions

- In this study, as-normalized and hot-rolled ARAA were analyzed using PALS.
- It is possible to analyze the properties of structural materials using PALS, and it will be possible to observe changes according to the applied process.

References

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