Radiation Response of Novel Laser Powder Blown Additive Nanostructured Alloy-2

Background

•Additive Nanostructured Alloy-2 (ANA-2) is the first nuclear alloy designed specifically to leverage phase and thermodynamic pathways during additive manufacturing (AM) for customized, radiation-tolerant microstructures [1]

• ANA-2 grain structure is representative of traditional ferritic martensitic steels

• The radiation response of ANA-2 is unknown

Fe	Cr	Mn	Si	Ta	V	C	Mo	N
Bal	8.5-9.5	2.5-3.5	0.4	0.1	0.3-0.6	0.08-0.15	0.3-0.6	0.1

Methods

•Laser powder blown DED was used to fabricate test specimens, no heat treatment was used

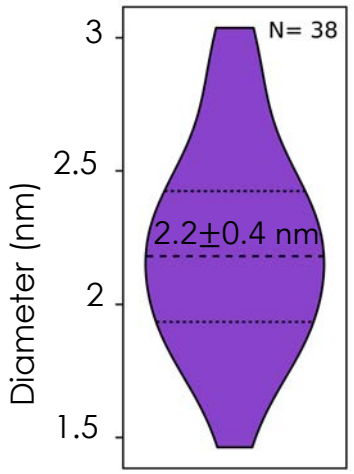
• ANA-2 sample was dual ion irradiated with Fe^{++} and He^{++} ions to 16.6 dpa and 4 appm He^{++}/dpa at 445°C at the Michigan Ion Beam Laboratory

Objective

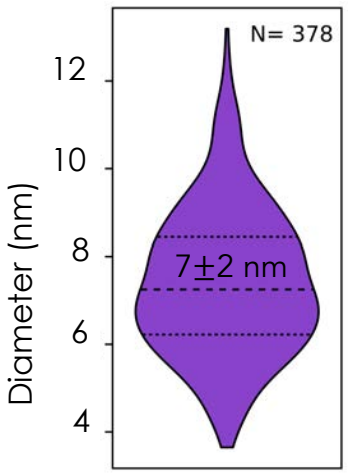
Determine the radiation response of ANA-2

Results

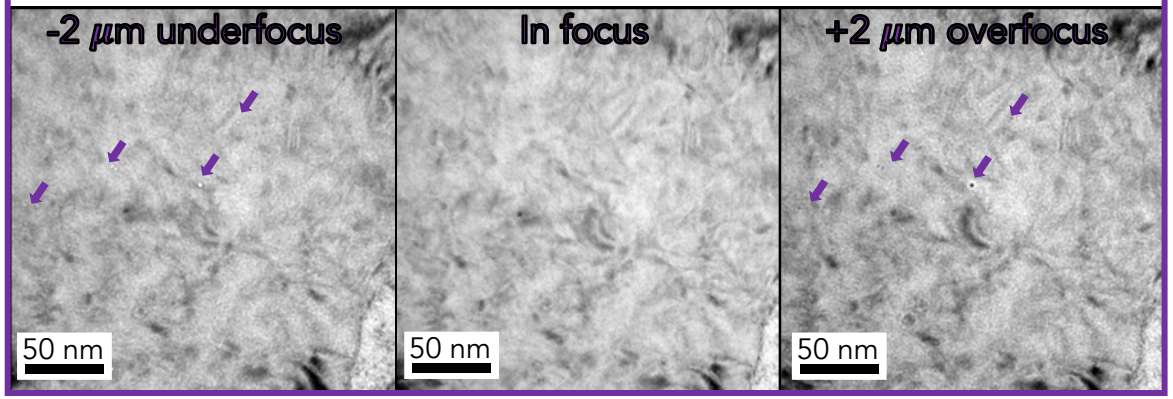
Cavities



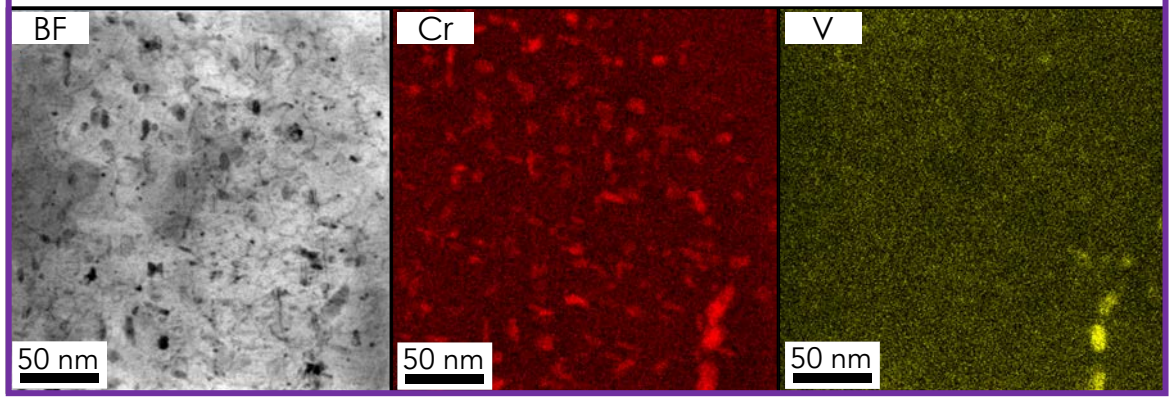
Precipitates



Cavities: A number density of $(1.04\pm0.22)\times10^{21} m^{-3}$ cavities was observed using conventional TEM.



Precipitates: A number density of $(2.0\pm0.4)\times10^{22} m^{-3}$ needle-like precipitates enriched in Cr was observed using STEM-EDX.



Discussion

•Traditional Grade 91 steel exhibited a number density of $5.8\pm10^{20} m^{-3}$ of cavities with an average size of 4.5±0.2 nm under the same irradiation conditions [2]

•The enhanced density of small cavities in ANA-2 is hypothesized to be a consequence of the increased sink strength from the nanoscale precipitation and the residual stress induced from AM

•A high density of small cavities is preferred as this suppresses the cavity growth regime and avoids negative mechanical property effects [3]

Additive manufacturing of a novel alloy enhanced cavity nucleation and suppressed cavity growth.

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References

[1] Weicheng Zhong et al., Microstructures and mechanical properties of a modified 9Cr ferritic-martensitic steel in the as-built condition after additive manufacturing, Journal of Nuclear Materials, submitted for review

[2] S Taller et al., Emulation of fast reactor irradiated T91 using dual ion beam irradiation, Journal of Nuclear Materials (527) 2019 151831

[3] Comprehensive Nuclear Materials (Second Edition) Volume 1, 2020, Pages 406-455