

Grain Size Effect and Comparison with 304 Stainless Steel

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1. Introduction

- High-temperature steam oxidation is a critical degradation issue for structural materials in SMR-relevant environments. XM-19 is a promising nitrogen-strengthened austenitic stainless steel, but its grain-size dependent oxidation behavior has not been fully clarified.
- Research question: Does grain refinement improve the high-temperature steam oxidation resistance of XM-19?**
- This study compares fine-, coarse-, and very coarse-grained XM-19 with 304 SS under air and steam oxidation at 900–1100 °C.

2. Experimental

- Materials**
 - XM-19 with different grain sizes & 304 SS ($d_{avg} = 29.1 \mu\text{m}$)
 - SG / LG / XL ($d_{avg} = 40.8, 154.3, \text{ and } 265.5 \mu\text{m}$)
- Oxidation tests**
 - Temperature: 900, 1000, and 1100 °C
 - Time: 2 h
 - Atmosphere: air and flowing steam
 - Specimen size: 20 mm × 8 mm × 3.5 mm
- Characterization**
 - Mass gain measurement (real-time)
 - Cross-sectional SEM/EDS analysis, XRD phase identification

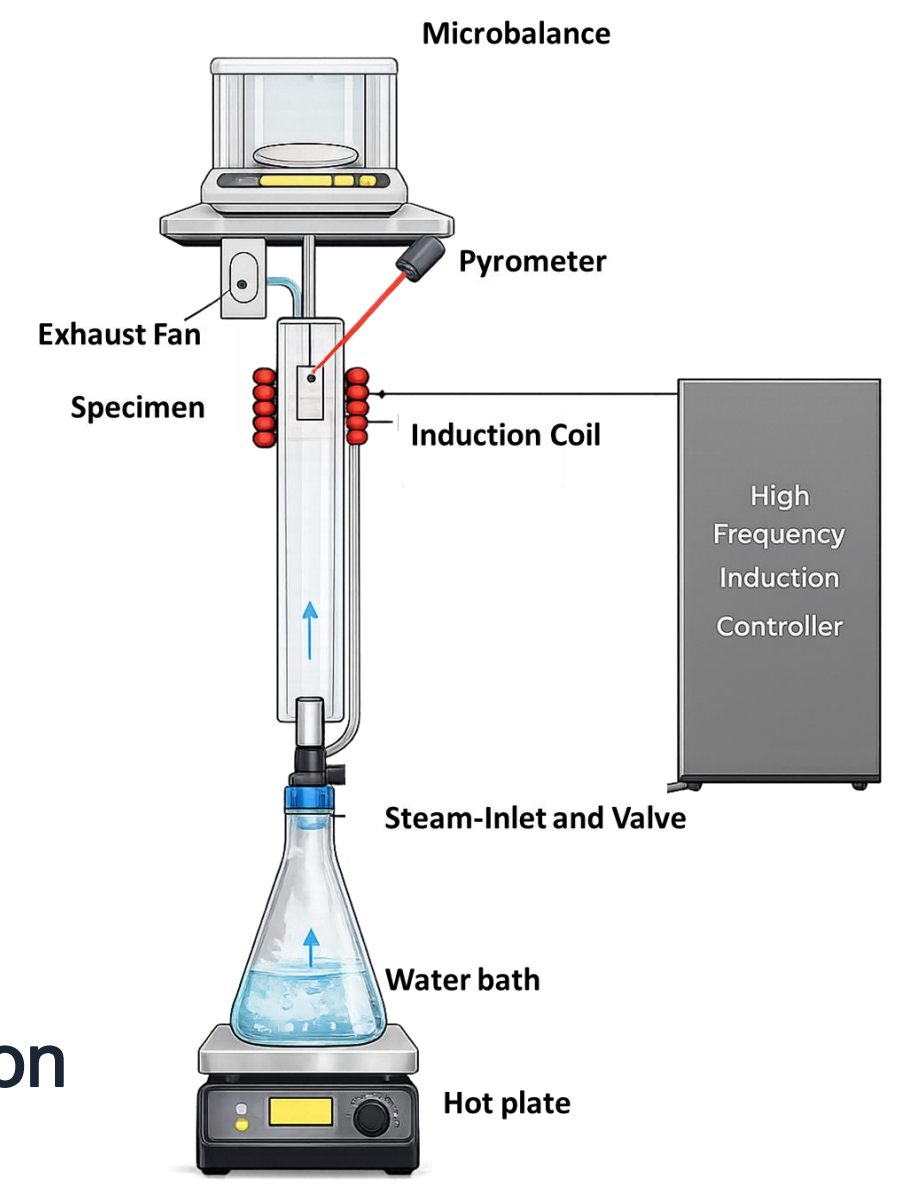
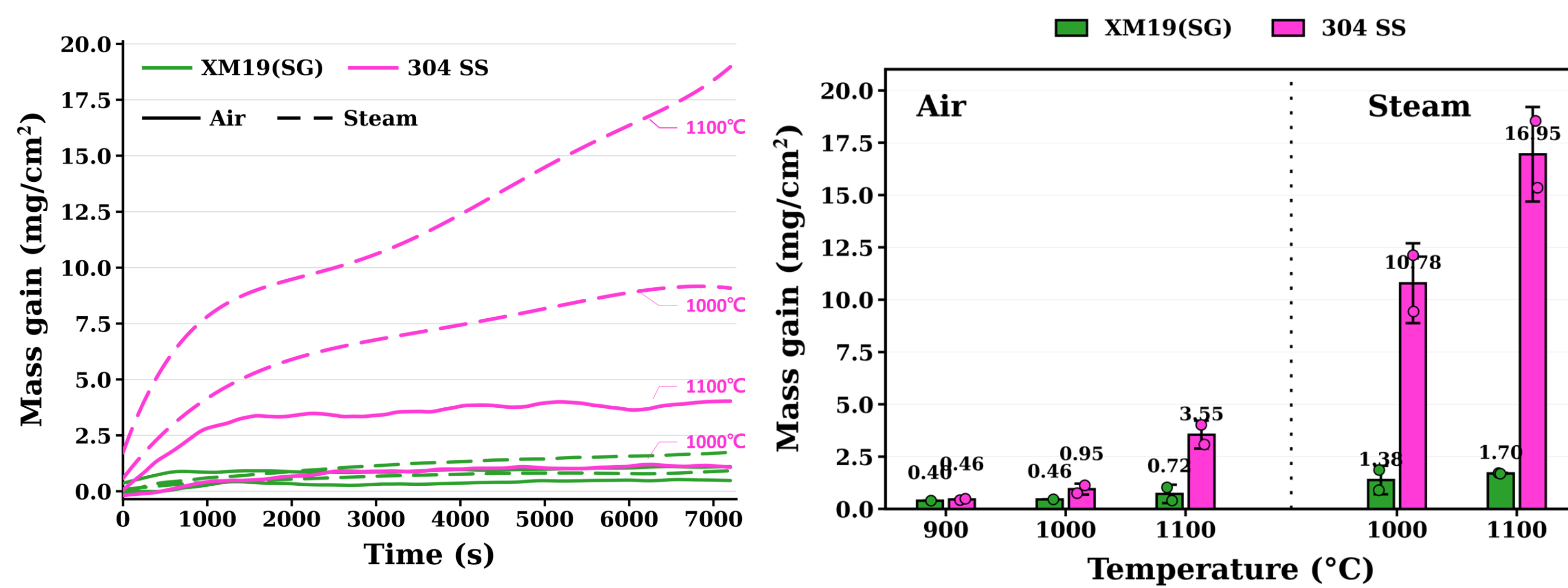


Table 1. Composition of XM-19 (wt%)

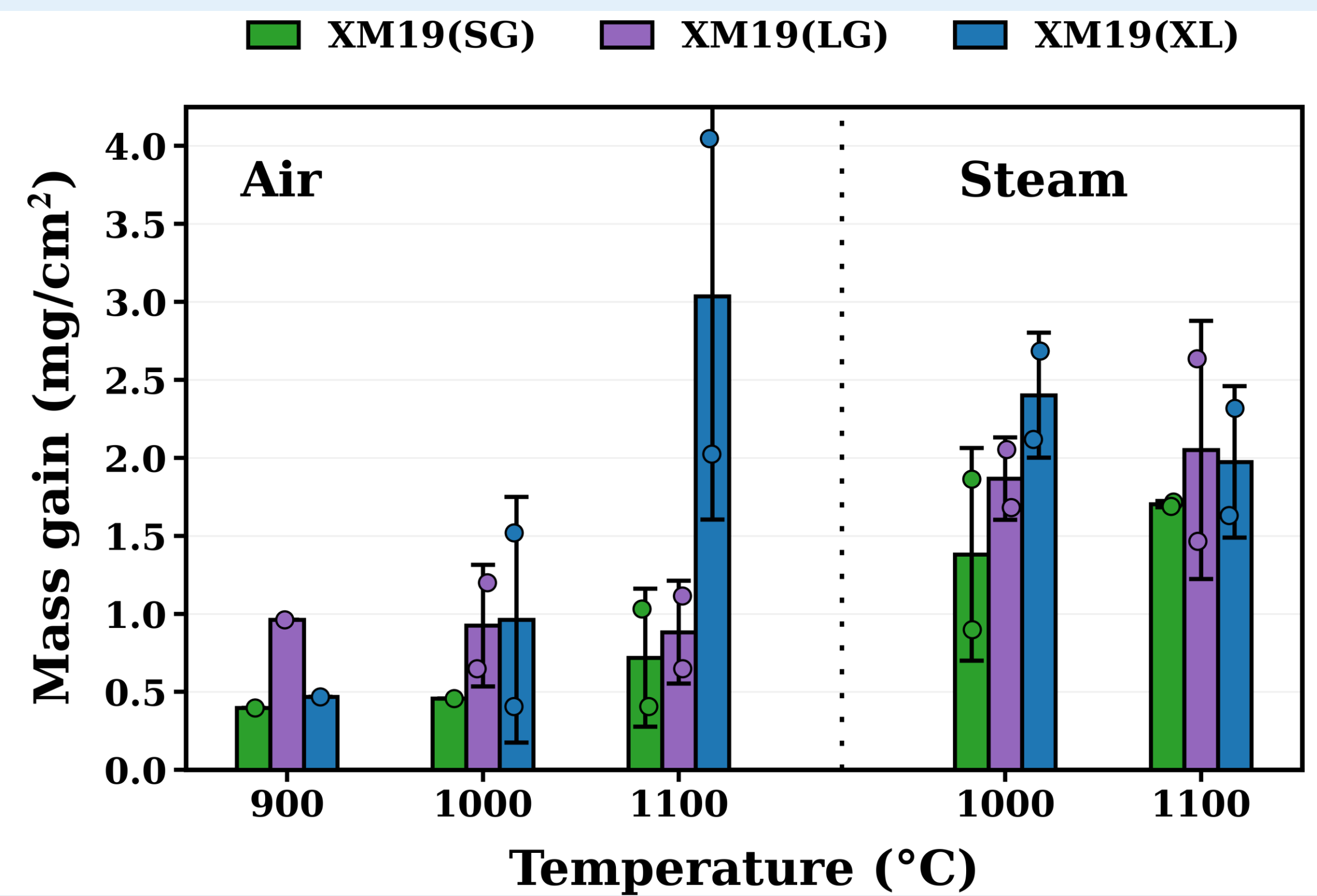
C	Si	Mn	Cr	Ni	Mo	Nb	N	V	P	S	Fe
≤0.06	≤0.75	4.0–6.0	20.5–23.5	11.5–13.5	1.5–3.0	0.1–0.3	0.2–0.4	0.1–0.3	≤0.04	≤0.03	Bal.

3. Results & Discussion

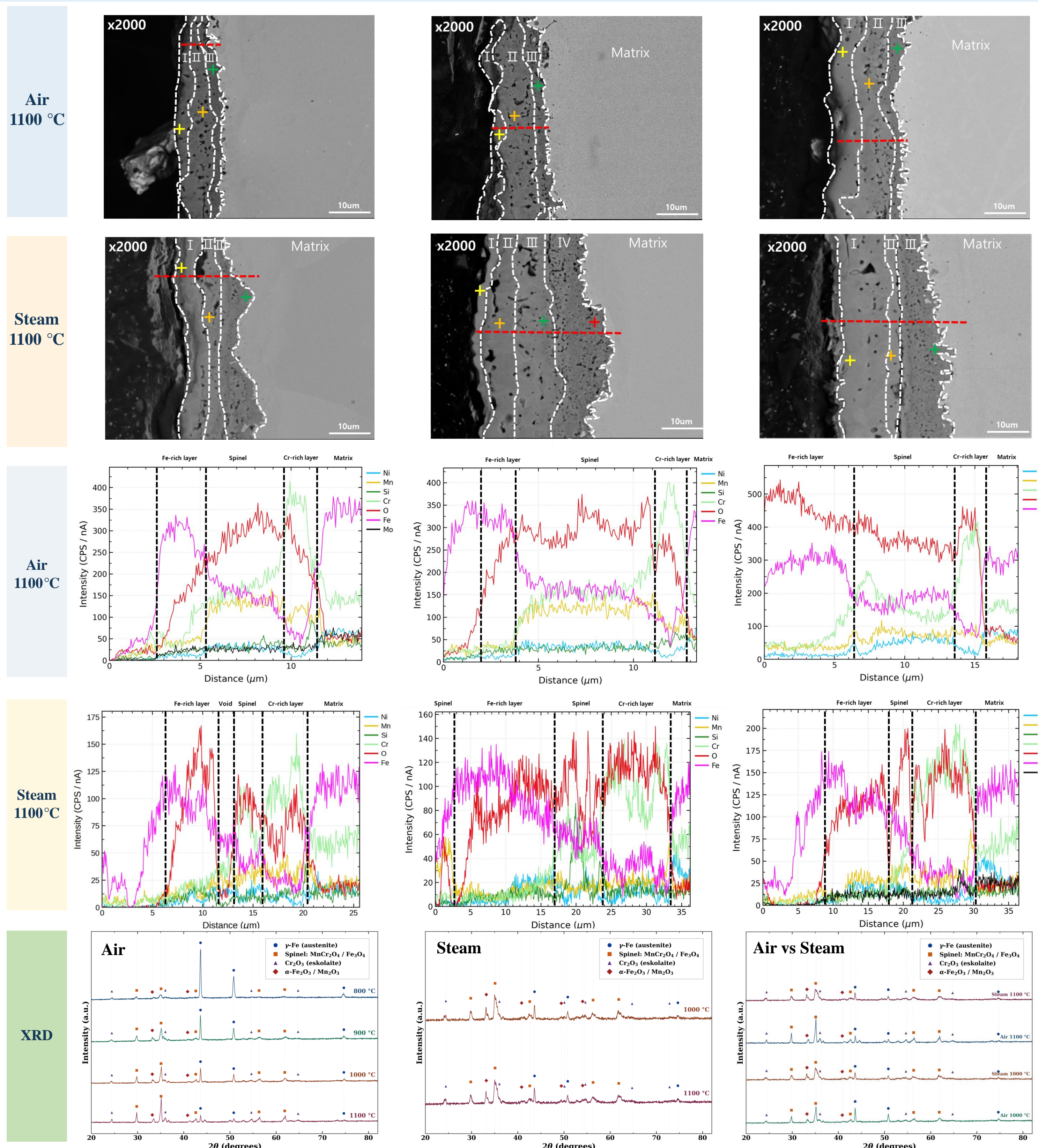
Finding 1: Steam is much more aggressive than air, but XM-19 exhibits better oxidation resistance than 304 SS.



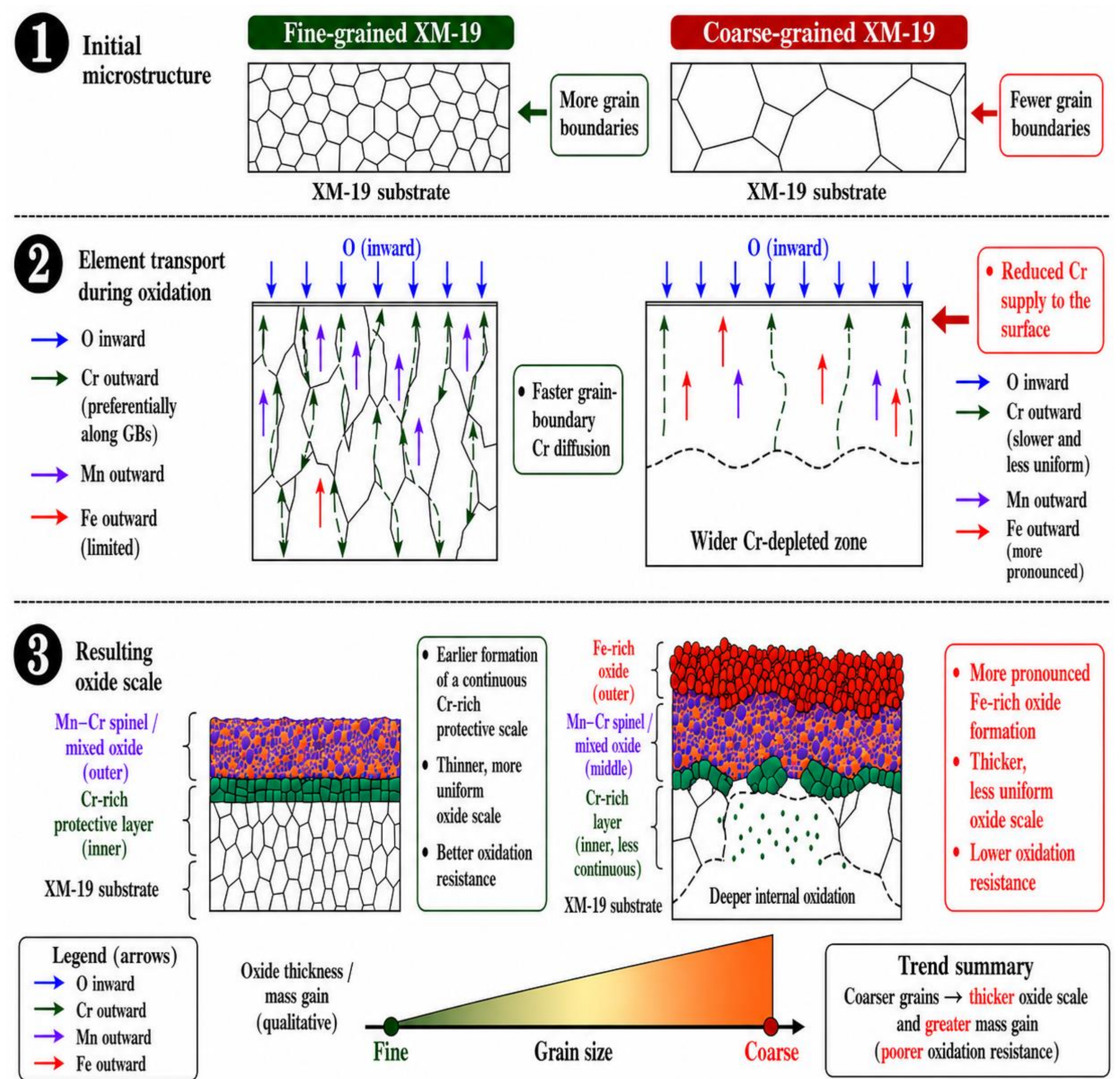
Finding 2: Mass gain increased with grain size in the order SG < LG < XL. Grain refinement improves oxidation resistance.



Finding 3: Fine-grained XM-19 forms a thinner and more continuous Cr-rich protective scale.



Proposed mechanism: Grain boundaries promote protective Cr-rich scale formation.



4. Conclusion

Grain refinement improves the high-temperature steam oxidation resistance of XM-19 by promoting the formation of a continuous Cr-rich protective scale.

- Steam exposure caused higher mass gain and more severe oxide-scale degradation than air.
- XM-19 showed lower mass gain than 304 SS under high-temperature air and steam conditions.
- Fine-grained XM-19 formed a thinner and more stable Cr-rich oxide scale than coarse-grained XM-19.
- The improved oxidation resistance is attributed to enhanced Cr transport through grain boundaries.