

Ni/4H-SiC SBD.

References

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5 - 14 Effect of Temperature on the Oxide Film of Austenitic Steel 15-15Ti in High-temperature CO₂

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Supercritical CO₂ is an important candidate cooling medium in advanced nuclear energy systems. Compared with steam Rankine cycle, the supercritical CO₂ Brayton cycle has higher energy conversion rate, compact power system equipment and lower economic investment, and has great application prospects in advanced nuclear energy systems such as high temperature gas-cooled reactors. However, the core exit temperature of nuclear reactors with the CO₂ Brayton cycle is usually 450~650 °C, which will lead to serious oxidation corrosion problems of candidate materials and significantly shorten their service life. Austenitic steels are a candidate material for advanced nuclear energy systems such as lead-cooled fast reactors (LFR) and supercritical water reactors (SCWR). It is expected to be used in CO₂ Brayton cycle systems because of its excellent corrosion resistance and radiation resistance and high-temperature strength. Therefore, it is necessary to evaluate and study the corrosion behavior of austenitic steels in high-temperature CO₂ and carefully characterize the physical structure and elemental composition of the oxide film at different temperatures.

Table 1 Chemical composition of the 15-15Ti austenitic steel (wt.%).

Steel	Fe	Cr	Ni	Mn	Mo	Si	C	Ti
15-15Ti	Bal.	15.99	14.78	1.41	2.13	0.39	0.058	0.31

In this study, austenitic steel 15-15Ti was tested in the high-temperature CO₂, and the chemical composition is shown in Table 1. A series of corrosion tests were conducted in a high-temperature oxidation furnace at 550~650 °C for a period of 50~200 h.

Figure 1(a) shows the XRD results of the oxide films after exposure to CO₂ at 550~650 °C for 50~200 h. The peaks of matrix (Austenite), Fe₂O₃, Fe₃O₄ and/or spinel (FeCr₂O₄) were observed. When the specimens were exposed to high-temperature CO₂ for 50 h, the intensity of the matrix peaks gradually decreased with increasing temperature and disappeared at 650 °C, indicating that the thickness of the oxide film gradually increased with the increase of temperature. Figure 1(b) shows the results of Raman spectra of the specimens exposed to CO₂ at 550~650 °C for 50~200 h. Similar Raman peaks were observed for the different specimens. The features observed at ~221, 241, 290, 404, 496, 607 and 1 310 cm⁻¹ were attributed to the Fe₂O₃ structure, while the Raman feature at ~661 cm⁻¹ was attributed to the Fe₃O₄ structure^[1]. The results showed that the thickness of oxide film gradually increased with increasing temperature, but the phase structure of the oxide film did not change.

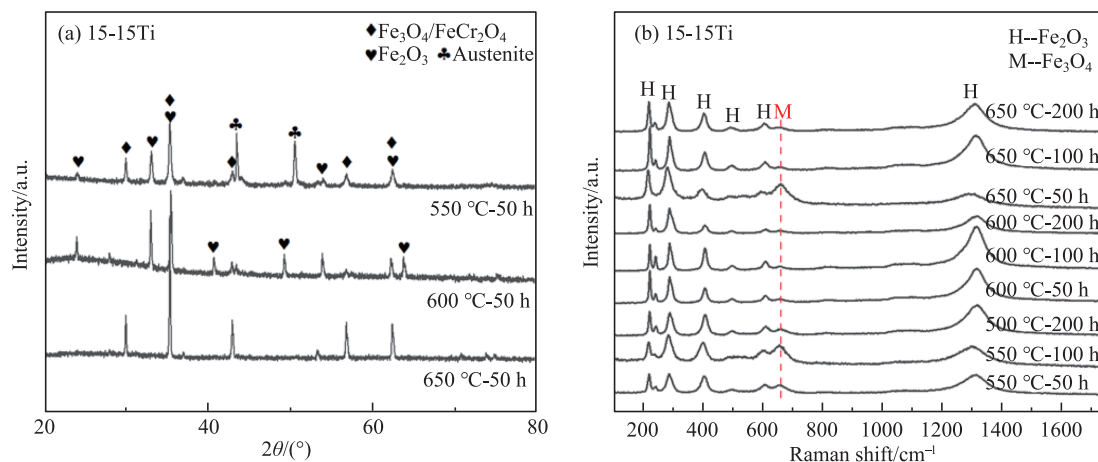


Fig. 1 (color online) (a) XRD patterns and (b) Raman spectra of the oxide films on 15-15Ti steel after exposure to CO₂ at 550~650 °C for 50~200 h.

The structure, cross-sectional morphology and elemental distribution of the oxide film were further studied on cross-sectional specimens. Figure 2 shows the cross-sectional SEM images and elemental distribution of oxide films after exposure to CO₂ at 550~650 °C for 50 h. The oxide film was a double-layer structure, the outer layer was porous and loose, and the inner layer was relatively dense. From the right figures, it can be seen that the outer layer was rich in Fe and O, while the inner layer contained Fe, Cr, Ni and O. Figure 3 shows the Raman spectra at different zones on the cross-sectional oxide film of 15-15Ti steel after exposure to CO₂ at 650 °C for 50 h, and the numbers 1-4 correspond to zones defined in Fig. 2. The outermost thin oxide layer was Fe₂O₃ (point 1), while the outer oxide layer was Fe₃O₄ (point 2). The Raman feature located at ~680 cm⁻¹ in points 3 and 4 was attributed to the FeCr₂O₄ phase with spinel structure. The results indicated that the oxide film of 15-15Ti steel was a double-layer structure after exposure to CO₂ at 550~650 °C for 50 h, the outer layer was Fe₂O₃ and Fe₃O₄, and the inner layer contained FeCr₂O₄ phase with spinel structure (Fig. 3).

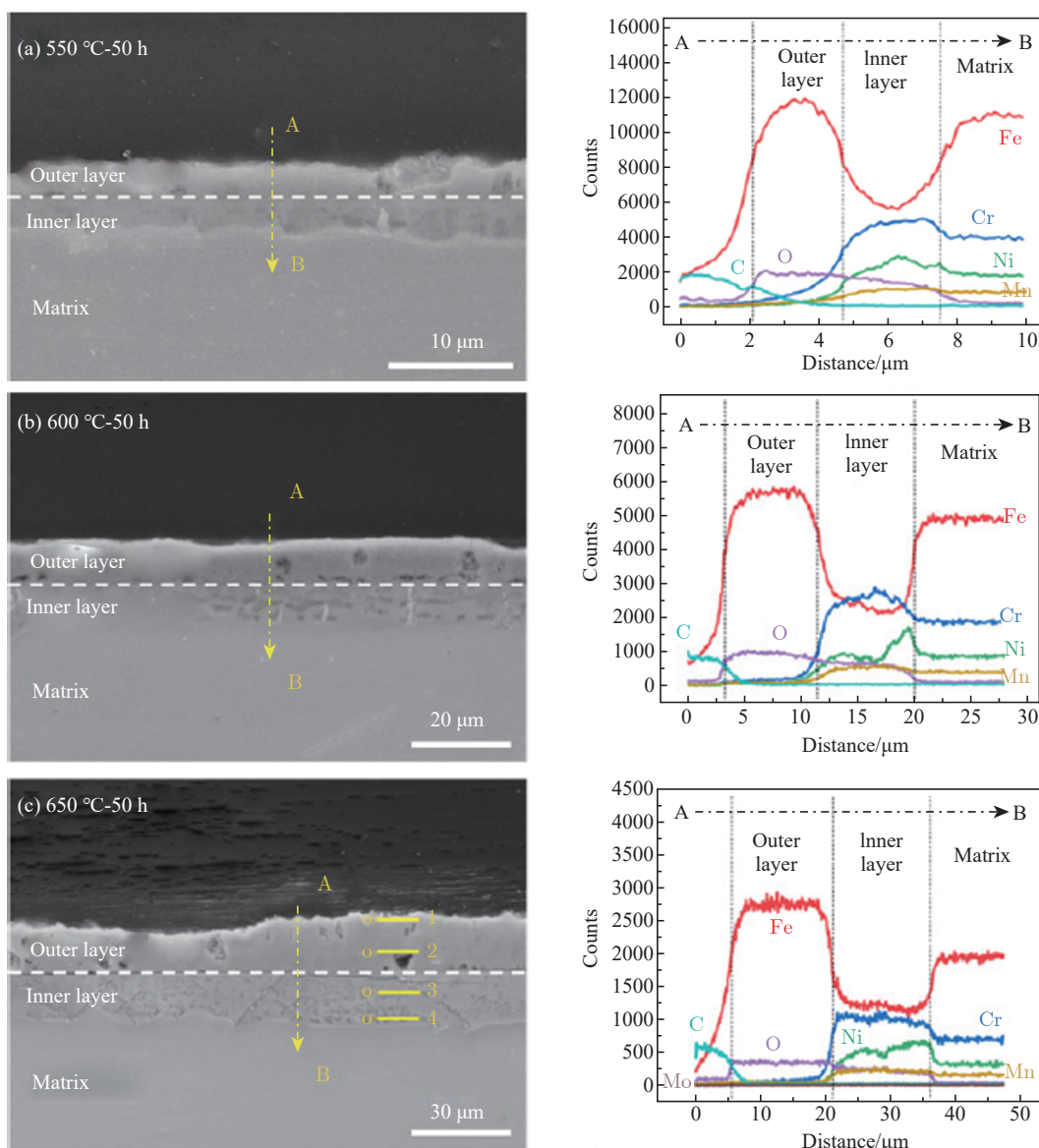


Fig. 2 (color online) Cross-sectional SEM images and elemental distribution of oxide films on 15-15Ti steel exposed to CO₂ at 550~650 °C for 50 h: (a)550 °C, (b)600 °C, (c)650 °C.

The experimental results and analysis showed that the thickness of the oxide film of austenitic steel 15-15Ti gradually increased with increasing temperature in the range of 550~650 °C, but the phase and structure of the oxide film did not change with the temperature.

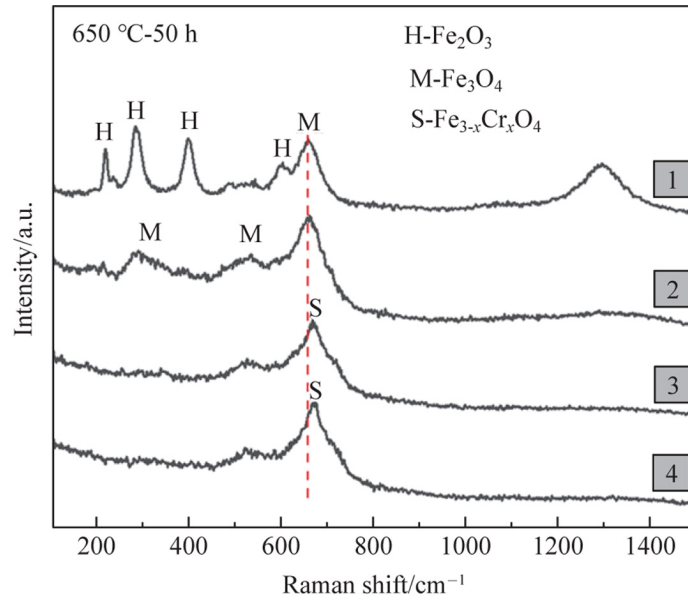


Fig. 3 (color online) Raman spectra at different locations on the cross-sectional oxide films of 15-15Ti steel after exposure to CO_2 at $650\text{ }^\circ\text{C}$ for 50 h (numbers correspond to zones defined in Fig. 2).

Reference

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5 - 15 Surface Nanostructures and Formation Mechanism on TeO_2 Induced by Swift Heavy Ions under Grazing Incidence*

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Surface nanostructures (surface ion track) such as multiple nanodots or/and groove could be produced by single heavy ions (SHIs), when some materials are irradiated with SHIs under grazing incidence. The creation of equally spaced nanodots on the surface of the irradiated SrTiO_3 single crystal with grazing SHIs was previously explained as the periodic oscillation of electronic energy loss^[1]. Essentially, it was believed to be related to the periodicity of crystal structure. In the scenario proposed by Akcöltekin, *et al*^[1], a reasonable inference is that intermittent nanodots should not be expected on the surface of an amorphous material irradiated with grazing-incidence SHIs, because there is no long-range order in the amorphous material. However, it was observed clearly by atomic force microscopy (AFM) that the intermittent nanodots were formed on the surface of amorphous SiO_2/Si after grazing-angle heavy ion irradiation^[2]. Therefore, the formation mechanism remains still unclear.

In this work, single crystal samples of TeO_2 were irradiated with 1 569 MeV ^{86}Kr ions (10.1 keV/nm), 2 430 MeV ^{129}Xe ions (20.1 keV/nm) and 2 765 MeV ^{181}Ta ions (30.4 keV/nm), respectively, under grazing incidence conditions at Heavy Ion Research Facility in Lanzhou (HIRFL) in Institute of Modern Physics, Chinese Academy of Sciences. It was observed by using AFM that surface ion tracks could be formed for these three kinds of SHIs(Fig.1).