学　位　論　文　内　容　の　要　旨

博士の専攻分野の名称　　博士（工学）　　氏名　張　聖華

学　位　論　文　題　名

Development of γ/α Transformable FeCrAl Oxide Dispersion Strengthened Alloys by Cobalt and Nickel Addition

(コバルトやニッケル添加により γ/α 変態を可能とする酸化物分散強化 FeCrAl 合金の開発)

To control microstructure and obtain equiaxial grains in FeCrAl oxide dispersion strengthened (ODS) alloys using γ/α transformation, the austenite-stabilizing element cobalt and nickel were separately introduced into FeCrAl ODS alloys to develop phase transformable FeCrAl ODS alloys. Based on the phase diagram computed using the thermodynamic analysis software FactSage, Fe-12Cr-(3, 5)Al-(15, 25)Co-0.5Y_2O_3 (wt.%) ODS alloys and Fe-12Cr-(5, 7)Al-(12, 18, 23)Ni-0.5Y_2O_3(wt.%) were designed and fabricated using mechanical alloying, spark plasma sintering, hot rolling and final annealing at 1150 ℃.

In chapter 1, the materials for high temperature applications and the development of FeCrAl alloys were introduced. Moreover, the background and aims of this study were illustrated.

In chapter 2, theoretical background and technical methods utilized in this study were introduced.

In chapter 3, the microstructure of Co-added alloys was characterized, three phases were identified: matrix with bcc structure, chromium carbide, and dispersed CoAl intermetallic compound. Nanosized oxide particles were also characterized by transmission electron microscopy. The 3Al alloys with 15 and 25 wt.% Co and 5Al alloy with 25 wt.% Co demonstrated α to γ transformation at 1000 ℃, whilst α-phase remained in the 5Al-alloy with 15 wt.% Co. Suppression of α to γ transformation in specimen 5Al15Co was successfully explained by the pinning of α/γ interface by oxide particles. Continuous cooling transformation curves constructed by in-situ high temperature X-ray diffraction showed that microstructure control using the γ/α phase transformation is feasible.

In chapter 4, the high temperature oxidation behavior of Co-added alloys was studied at 800 ℃, 900 ℃, and 1000 ℃ in air. Exclusive α-Al_2O_3 scales were formed on the surfaces of 5Al alloys at the temperature range from 800 ℃ to 1000 ℃. The discontinuous aluminum oxide in the internal oxidation zone of austenitic 3Al alloys oxidized at 1000 ℃ was found. Y segregation at the grain boundaries was confirmed and the Co addition caused the outer layer thickness and the grain size of alumina increase in 5Al alloys oxidized at 1000 ℃. The decrease of oxidation kinetics of Co-added 5Al alloys was attributed to the increase of the lateral grain size. On the other hand, protective α-Al_2O_3 scales were also formed on the surfaces of 3Al alloys at the temperature range from 800 ^{o}C to 900 ℃ except for the dual phase 3Al15Co alloy oxidized at 900 ℃. The Co addition was detrimental to the oxidation kinetics when 3Al alloys were oxidized at 800 ℃ and 900 ℃.

In chapter 5, the tensile properties of Fe12Cr5Al25Co ODS alloy were evaluated, focusing on the oxide dispersion strengthening and B2-type CoAl ordered strengthening at both ambient and elevated temperatures. The oxide particles and B2-type CoAl precipitate were characterized and strengthening mechanisms for the oxide particles and CoAl-precipitate were evaluated by hardness and tensile tests at room temperature (RT), 300 ℃, and 500 ℃. The calculated values showed good agreement with the experimental results at RT and 300 ℃. However, the order strengthening by CoAl precipitates was significantly reduced at 500 ℃, which is attributed to the increase of thermally activated $\langle 001 \rangle$ slip in the body-centered cubic matrix.

In chapter 6, characterization and high temperature oxidation test of Ni-added alloys were introduced. Combination of the high Al and low Ni leads to stabilization of the α-ferrite at 1000 ℃. In contrast, low Al and high Ni provides γ-austenite at room temperature. The Fe12Cr5Al12Ni ODS alloy and Fe12Cr7Al22Ni ODS alloy are preferable for γ to α phase transformation during cooling. A_{C1} and A_{C3} temperatures and critical cooling rate for the martensite transformation were also clarified. The oxidation test at 1000 ℃ in air revealed that 7 wt.% Al was found to be sufficient to form protective Al_2O_3 scale. Even at 5 wt.% Al, the reduced Ni-content induced superior oxidation resistance via Al_2O_3 formation.

In chapter 7, the main conclusions and most relevant findings of this work are presented and summarized.