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Article / Book Information

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論文要旨

THESIS SUMMARY

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要旨 (英文 800 語程度)

Thesis Summary (approx.800 English Words)

The structural and magnetic characterizations of FeCoNiAlCr HEA films have been studied in this thesis. In this work, the FeCoNiAlCr HEA films with different compositions are prepared on the quartz glass substrate by DC reactive magnetron sputtering. The microstructure and magnetic, electrical, and mechanical properties were investigated. Annealing is used as the main treatment to achieve the adjustment of the magnetic properties of the films, due to the microstructure change and element migration during the annealing process. Then, Al content, which can introduce crystal structure change to the films, was chosen as the variable. The effect of the Al content on magnetic properties and the mechanism were studied. Finally, by introducing nitrogen to the system, nitrogen incorporating FeCoNiAlCr HEA films were prepared. The effect of nitrogen incorporation on microstructure and magnetic properties was studied. The main conclusions and detailed experiment results are summarized as follows:

1) $\text{Fe}_{0.18}\text{Co}_{0.36}\text{Ni}_{0.21}\text{Al}_{0.10}\text{Cr}_{0.15}$ of HEA films with soft magnetic properties

The as-deposited $\text{Fe}_{0.18}\text{Co}_{0.36}\text{Ni}_{0.21}\text{Al}_{0.10}\text{Cr}_{0.15}$ HEA films have an FCC structure, which is consistent with the VEC criterion ($\text{VEC}=7.98$).

The soft magnetic properties are evaluated of $\text{Fe}_{0.18}\text{Co}_{0.36}\text{Ni}_{0.21}\text{Al}_{0.10}\text{Cr}_{0.15}$ thin films exhibit a dynamic magnetic evolution as the annealing temperature changes, In this study, the soft magnetic properties are mainly evaluated by Ms, Hc and resistivity. The annealing treatment can effectively improve the Ms within a certain temperature range (400-800 °C) due to the segregation of antiferromagnetic element Cr after annealing. The Hc shows nonlinear change due to the grain growth during annealing. The resistivity and mechanical properties are thermally stable, and the influence of the annealing process is almost negligible up to 800 °C.

The optimal properties can be obtained after annealing under 800 °C. At this time, $\text{Fe}_{0.18}\text{Co}_{0.36}\text{Ni}_{0.21}\text{Al}_{0.10}\text{Cr}_{0.15}$ HEA films have high Ms (698 emu/cm³), moderate Hc (87 Oe), high resistivity, good mechanical properties, and good thermal stability, which can be applied as functional soft magnetic thin films with outstanding performance.

2) Effect of Al content on microstructure and magnetic properties of $\text{FeCoNiAl}_x\text{Cr}$ HEA films

Al, as a major alloying element in most of the HEAs studied to date, could lead to the crystal structure transformation from FCC to BCC. In this study, the crystal structure of $\text{FeCoNiAl}_x\text{Cr}$ films can transform from FCC ($x=0.10, 0.14$) to BCC ($x=0.10, 0.14$).

The magnetic measurements show that the as-deposited FCC ($x=0.10, 0.14$) films can show soft magnetism, and BCC ($x=0.10, 0.14$) films show poor magnetism. After the annealing process, all the FeCoNiAl x Cr films can show soft magnetism and in-plane anisotropy. The FeCoNiAl $_{0.14}$ Cr HEA films annealed at 700 °C show the best soft magnetism. At this time, M_s is 996 emu/cm³, and H_c is 105 Oe. For as-deposited films, the effect of Al content on M_s is limited. The increase of the Al component can refine the grain and increase the H_c .

During the annealing process, the segregation behavior of elements can explain the change of microstructure and the change of M_s . The Al element plays an important role in the segregation behavior of elements. When the ratio of Al increased, the Fe, Co, and Ni elements were easier to segregate. Al element acts as a sort of migration channel that facilitates the segregation of the Fe/Co/Cr, especially Cr elements, which in turn affects the M_s of FeCoNiAl x Cr HEA films.

Increasing the annealing temperature facilitates the growth of grains, which is the main reason causing the change of coercivity.

The FeCoNiAl x Cr films also show high resistivity. When the Al component increase, the resistivity increase.

Overall, the optimal magnetic properties can be obtained for FeCoNiAl $_{0.14}$ Cr films after annealing at 700 °C.

3) Effect of nitrogen incorporating on microstructure and magnetic properties of FeCoNiAlCr HEA films

The magnetic properties and microstructure of FeCoNiAl $_{0.14}$ Cr nitrogen incorporating HEA films have been investigated.

The as-deposited film has an amorphous-like structure, which is due to the nitrogen lead high mixing entropy and large atomic size difference. The as-deposited films show ultra-good soft magnetism. Because the combination between N and Cr can reduce the influence on the magnetic elements.

The films were annealed at 400-800 °C. The annealing treatment can effectively improve the M_s within a certain temperature range (400-700 °C) due to the segregation of magnetic elements after annealing. The phase transition from amorphous to partial FCC also is observed after annealing.

In summary, during the annealing process, because nitrogen stabilizes the microstructure and tends to bind with Al and Cr, Al and Cr are localized by N, and relatively Fe/Co/Ni may segregate first. The higher the proportion of nitrogen is, the easier the segregation happens. The segregated Fe-Co-Ni phase enhances the M_s .

Overall, the optimal properties can be obtained for the as-deposited FeCoNiAl $_{0.14}$ Cr N-HEA films. At this time, nitrogen incorporating FeCoNiAl $_{0.14}$ Cr HEA films have high M_s (1147 emu/cm³), not too high H_c (75Oe), high resistivity (153 $\mu\Omega\cdot\text{cm}$), and commendable mechanical properties. This combination of characteristics makes them suitable for application as high-performance functional soft magnetic thin films.