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Defect engineered structural evolution and mechanical characterisation of $\text{Fe}_x\text{CoCrNi}_{(100-x)}$ complex compositional alloy thin films

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Complex compositional alloy thin films (CCA-TFs) are gaining interest for their large strength/ductility balance, owing to FCC nanocrystalline structure [1]. CoCrNi reported hardness (H), elastic modulus (E) up to 9 and 180 GPa, respectively, due to a columnar structure with planar defects [2]. Adding Fe to form Fe_xCoCrNi stabilised the FCC phase and a small grain size of ~ 20 nm, mildly increasing H up to ~ 10 GPa [3]. However, research on CCA-TFs is still in its early stages, particularly their growth mechanisms and relationship with mechanical behaviour, while a nanoengineered approach to develop new thin film nanoarchitectures with boosted mechanical properties remains an open field.

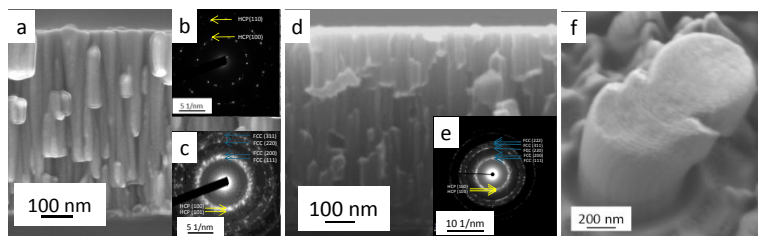


Figure 1 – (a) SEM cross section of 630 nm (b,c) SAED TEM of 15 nm and 40 nm thick CoCrNi film (d) SEM cross section of 730 nm (e) SAED-TEM (inset) of 10 nm thick $\text{Fe}_{25}(\text{CoCrNi})_{75}$ film (f) CoCrNi/Fe (Λ 35 nm) micropillar post compression

Here, we synthesised CoCrNi and $\text{Fe}_x(\text{CoCrNi})_{100-x}$ CCA-TFs by magnetron sputtering, controlling thickness from 15 nm up to 730 nm while varying Fe from 13 up to 29 % at. Thick CoCrNi film (Fig. 1a) shows a columnar structure with an average grain size of ~ 26 nm and (111) textured FCC structure with a minor HCP phase. Additionally, we observed a transition from HCP to co-existing HCP/FCC (insets in Fig. 1a) upon increasing thickness from 15 to 40 nm. Nanoindentation and optoacoustic techniques report $H = 9.7$ GPa and $E = 204.4$ GPa, in line with literature [3].

Moreover, adding Fe retained the columnar structure (Fig. 1d) while stabilising FCC phase, reporting a preferred (111) orientation without phase segregation. H and E decrease down to 7.6 and 185 GPa due to fewer defects like stacking faults (SFs) and twins, owing to a higher stacking fault energy 32.5 mJ m^{-2} [4]

Finally, we synthesised $1.3 \mu\text{m}$ thick CoCrNi/Fe (FCC/BCC) nanolaminates with bi-layer periods (Λ) of 35 and 70 nm, featuring incoherent interfaces, aimed at blocking dislocations and crack propagation. We show high adhesion at the interfaces with limited crack formation during indentation, while compression of micropillars resulted in high yield strengths (5.4 GPa) without fracture up to 12% and high plasticity up to 40% due to the high density of interfaces and thickness confinement.

Overall, our study shed light on the structure–mechanical properties of CoCrNi, $\text{Fe}_x(\text{CoCrNi})_{100-x}$ films, and CoCrNi/Fe nanolaminates, with potential applications in hard coatings and microelectronics.

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