INVESTIGATING SPINTRONIC MATERIALS FOR IRIDIUM REPLACEMENT IN ENERGY APPLICATIONS

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BACKGROUND

Moore's law predicted that the number of transistors on microchips doubles every two years [1]. This has been the trend since 1965, but is becoming obsolete as transistors reach their physical limit in terms of size.

Therefore, it is important that we look into quantum alternatives. Spintronics is a field where the intrinsic properties of an electron, called spin, is used in electronic devices.

Iridium Manganese (IrMn) is a popular alloy used in spintronics. This poses a problem because Iridium is a rare-earth metal element.

One candidate material for spintronic devices is Heusler Alloys [2]. CoCrFeAl in particular is an interesting candidate as it is a spin-gapless semiconductor which would allow for more efficient transistors due to its band structure [3].

METHODS

CoCrFeAl thin films were made in the PlasmaQuest Ltd High Target Utilisation Sputtering (HiTUS) system at the University of York.

Thin films were annealed at varying temperatures for two hours in a Carbolite™ CTF Wire-Wound Tube Furnace.

CoCrFeAl Thin film were characteristed using SEM-EDX, Rigaku™ X-Ray Diffractometer (XRD) and LakeShore™ Vibrating Sample Magnetometer (VSM).

REFERENCES

[1] *Moore G. E., Intel, (1965)*
[2] *Elphick K. et al, Science and Technology of Advanced Materials vol. 22, no. 1, 235-271 (2021)*
[3] *Wang X. et al, Physics Reports vol. 888 pg 1-58 (2020)*

RESULTS AND DISCUSSION

The first deposition of CoCrFeAl had a stoichiometry of 1: 0.6 : 0.8 : 0.4 for Co, Cr, Fe, Al respectively. The ideal ratio is 1: 1: 1: 1. Chromium (Cr) and Aluminium (Al) pegs of diameter 2mm and 3mm respectively and lengths 2mm were placed on the target. Samples with one Al peg ($CoCrFeAl_x$), one Cr peg ($CoCr_xFeAl$), and one Al peg and one Cr peg ($CoCr_xFeAl_x$) were made in order to achieve a ratio close to the ideal one. Table 1 shows the stoichiometry of the CoCrFeAl samples.

Thin Film	Ratio
CoCrFeAl	1: 0.6: 0.8: 0.4
$CoCrFeAl_x$	1: 0.73: 0.89: 0.84
$CoCr_xFeAl$	1: 0.82: 0.91: 0.78
$CoCr_xFeAl_x$	1: 0.77: 0.91: 0.83

Table 1: Stoichiometry of CoCrFeAl samples

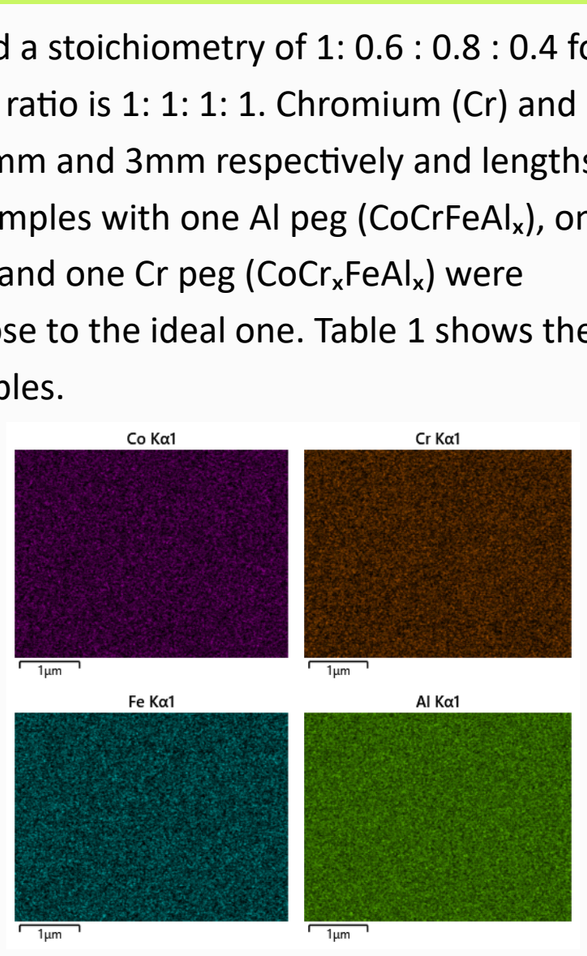

Figure 1: SEM-EDX mapping of $CoCr_xFeAl_x$

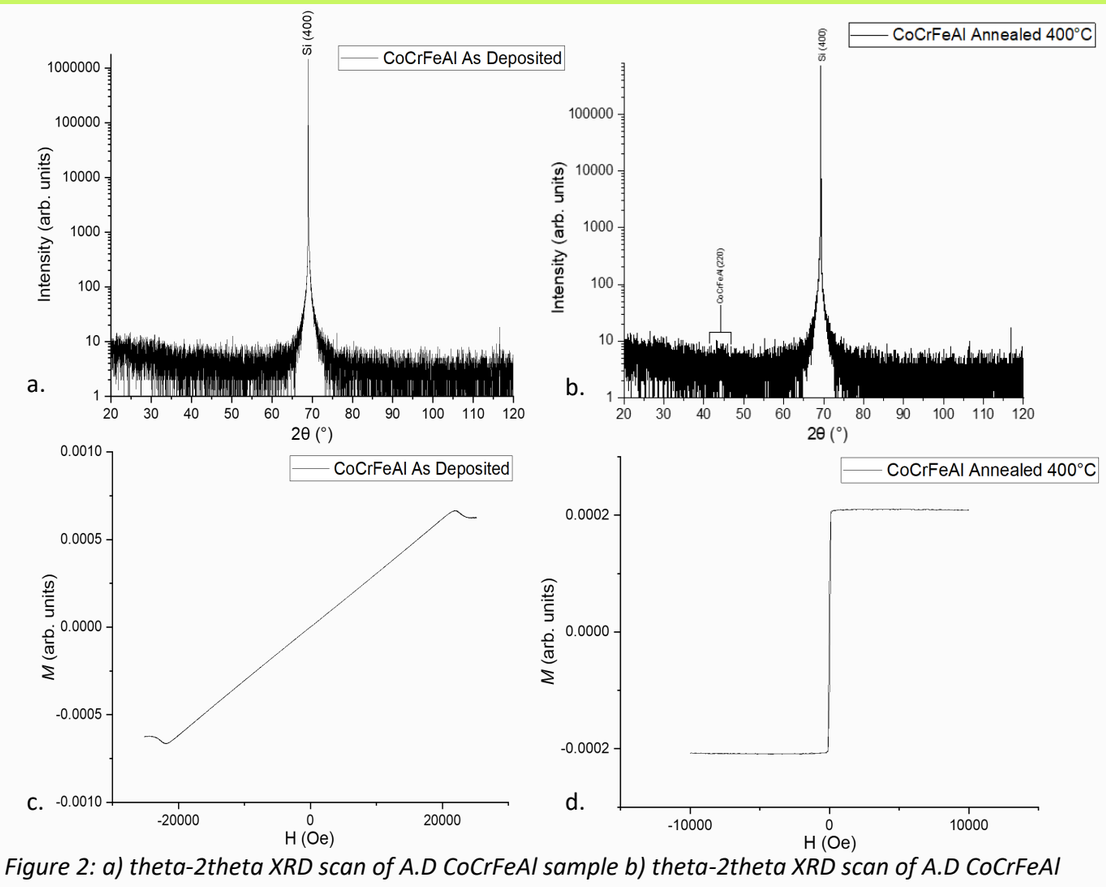

Figure 2: a) theta-2theta XRD scan of A.D CoCrFeAl sample b) theta-2theta XRD scan of A.D CoCrFeAl annealed at 400°C c) hysteresis loop of A.D CoCrFeAl sample d) hysteresis loop of CoCrFeAl annealed at 400°C

Samples were annealed at 300°C, 400°C and 500°C. 300°C and As Deposited (A.D) samples did not show any peaks indicating no crystallisation. Coupled with the paramagnetic behaviour shown in Figure 2c it was concluded that the A.D samples were amorphous. However, at 400°C a very subtle principle peak is visible at 44°. 500°C showed very little difference in structure compared to 400°C. The sample also showed magnetic behaviour at 400°C as seen in Figure 2d, which suggests that it becomes ferromagnetic at 400°C. Therefore, 400°C was used as the optimal annealing temperature.

All samples showed improved crystallisation after being annealed at 400°C, with $CoCr_xFeAl_x$ showing the most prominent principle peak.

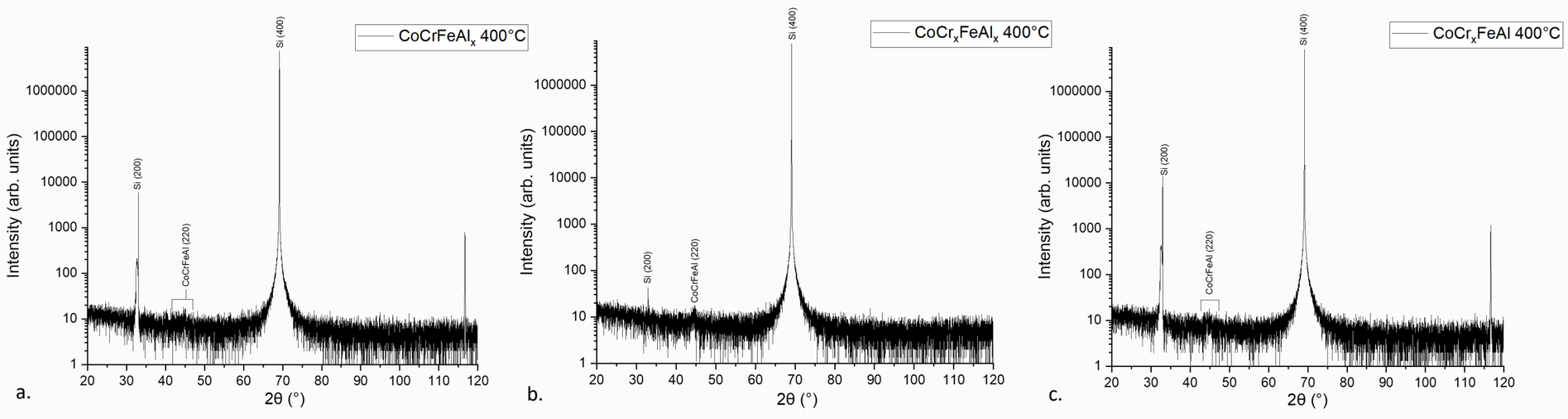

Figure 3: theta-2theta XRD scan of a) $CoCr_xFeAl$ b) $CoCr_xFeAl_x$ c) $CoCr_xFeAl$

CONCLUSION

Heusler Alloy CoCrFeAl shows potential to being an alternative to IrMn as it crystallises and demonstrates magnetic properties once annealed. Further work is needed to investigate the full potential of CoCrFeAl for spintronic applications.

FURTHER WORK

Research is still in progress; the next step of this project will be to calculate the lattice constants from the XRD data and to characterise the electronic properties of CoCrFeAl to investigate whether it can produce a spin Hall voltage. This will be done using a four-point probe.