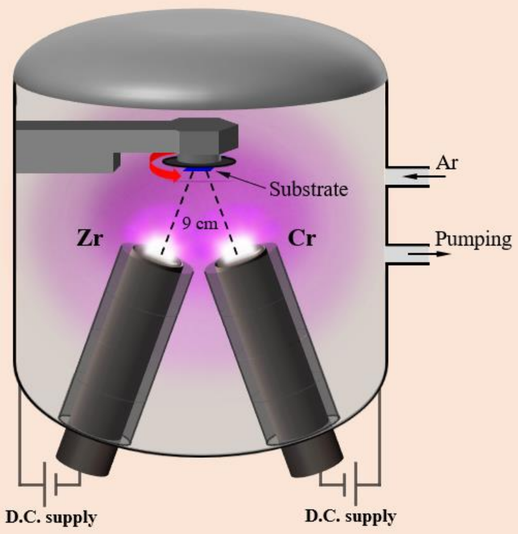
Effect of the deposition rate on competitive growth between amorphous and crystalline phases in sputtered Zr-Cr thin films

Q. Liebgott[1,2], A. Borroto[1], Z. Fernandez-Gutierrez[1], S. Bruyère[1], D. Horwat[1]

I. Introduction

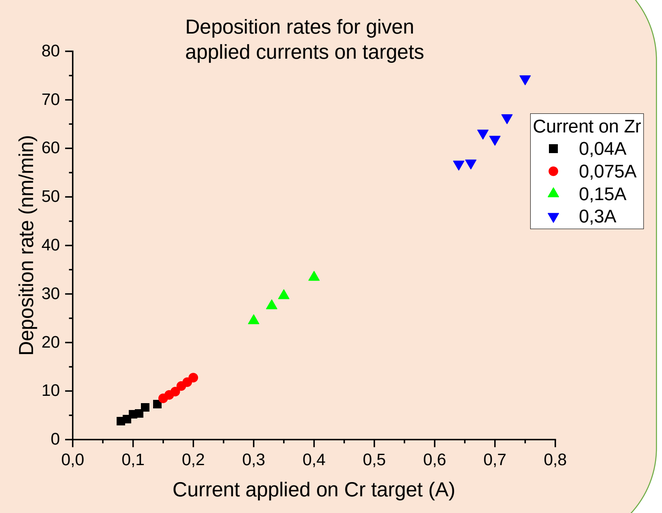
Previous studies found that for some Zr-based binary deposited at the transition between the amorphous and crystalline phases, a self-separation of these two phases occurs during deposition. It is shown in Zr-Cr that this competitive growth between the two phases also occurs, with conical shaped crystallites growing in an amorphous matrix.

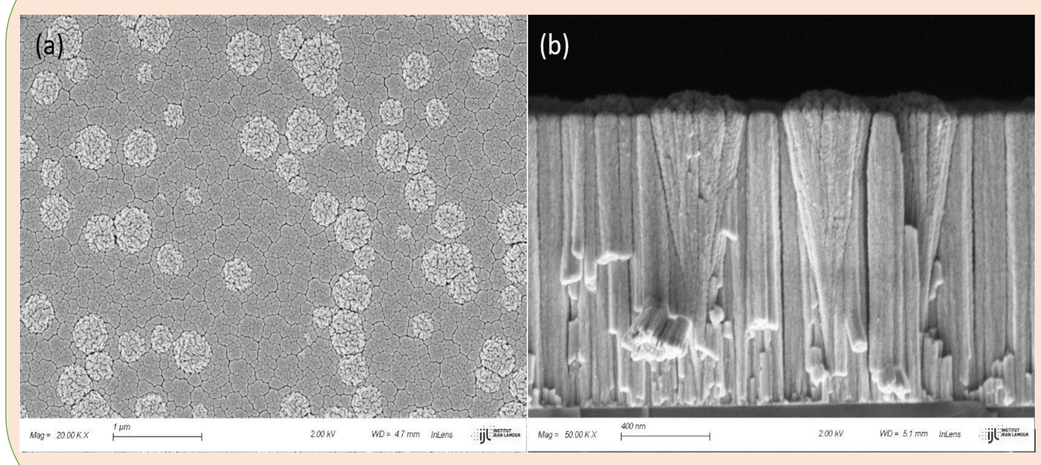


II. Experimental details

The Zr-Cr thin films are deposited on Si substrates using DC magnetron co-sputtering in confocal configuration. The deposition rates and composition of the thin films are controlled with the currents applied to the Zr and Cr targets, respectively. The films' thickness is approximately 1 µm.

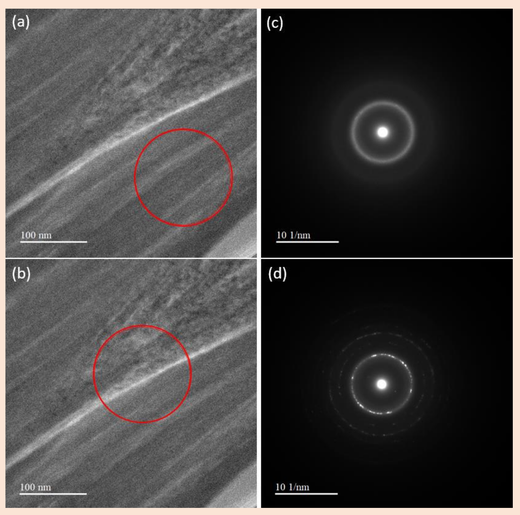
Deposition rate varies between 4 and 74 nm/min. The aim of this work is to see if the deposition rate has an effect on the geometry of the crystalline cones.

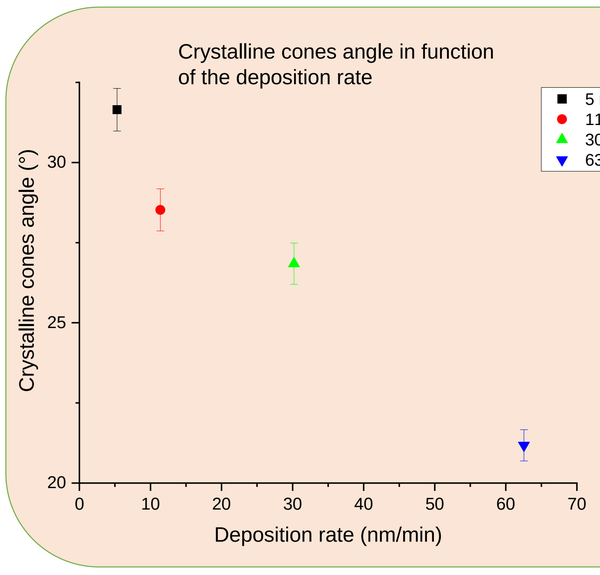




III. Results

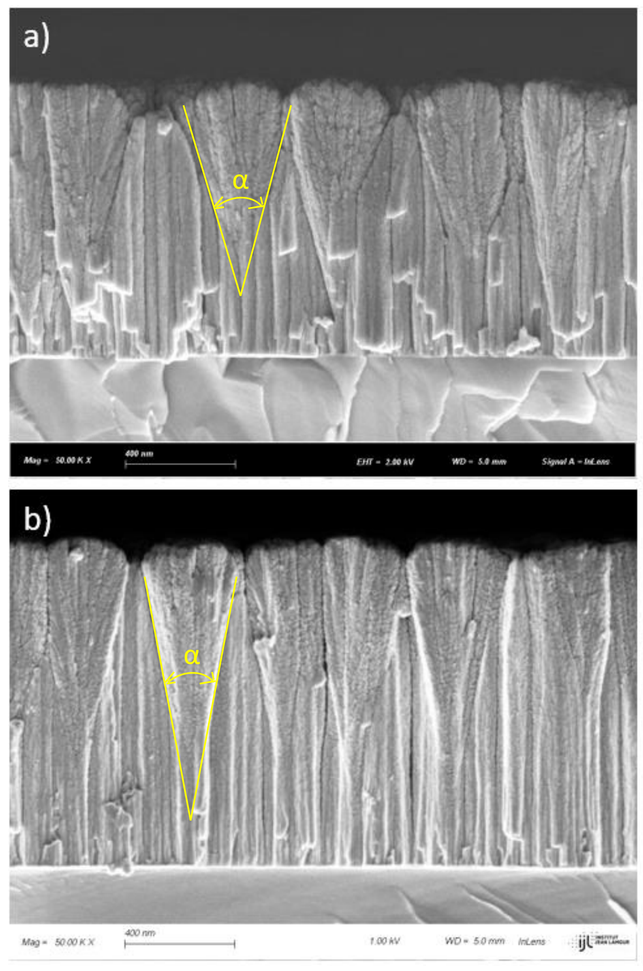
The competitive growth has been observed in the Zr-Cr system, and the surface (a) and transversal (b) SEM micrographs can be seen on the left. The columns are the amorphous matrix, which represent 100% of the film at the beginning of the growth, and then the crystalline cones grow in competition with the matrix. The crystallinity of the cones has been confirmed by electron diffraction (right). Electron diffraction in the matrix (a,b) shows amorphous columns and in the cone (c,d) shows crystallinity.

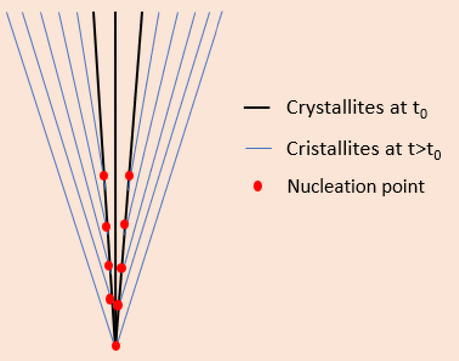




III. Results – Cones angle

The deposition rate is shown to have an impact on the cone angle. As can be seen on the left graph, an increase in the deposition rate leads to a decrease in the crystalline cone angle. For an increase in deposition rate from 5 to 63 nm/min, the cone angle decreased from 32° to 21°. This decrease can be observed on the SEM micrographs (right), showing films deposited at low (a) and high (b) deposition rates. If cone angle did only depend on surface diffusion, increasing 20-fold the deposition rate would lead to a ~20-fold decrease in cone angle. However, it is not what is observed, hence another phenomenon occurs changing the cone angle.





IV. Proposed mechanism

A mechanism of nucleation and growth is proposed to explain these results. At the start of the crystalline phase nucleation (t_0), a single crystallite nucleates. Then, other crystallites nucleate at the interface between the crystallite and the amorphous matrix and grow. Thus, modifying the deposition rate can have an influence on the nucleation rate and the growth kinetics, changing the cone angle.

V. Conclusions

- Competitive growth has been extended to a new alloy : Zr-Cr.
- We highlighted the influence of the deposition rate on the geometry of the crystalline cones.
- A mechanism has been proposed to explain the angle difference due to the change in deposition rate.

[1] Université de Lorraine, CNRS, IJL, F-54000 Nancy, France
[2] Chair of Functional Materials, Saarland University, Campus D3.3, D-66123 Saarbrücken, Germany