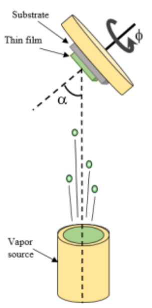
# Acoustic properties and morphological features in structured thin films

**Asma Chargui, Raya El Beainou, Sébastien Euphrasie, Alexis Mosset, Nicolas Martin, Pascal Vairac**

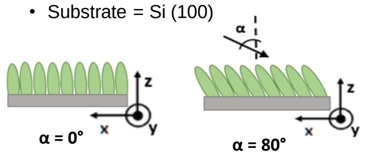
*Institut FEMTO-ST, CNRS UMR 6174, Université de Bourgogne Franche-Comté, 15 B avenue des Montboucons, 25030 Besançon, France*

We studied the acoustic wave propagation in micro-structured thin films using a femtosecond heterodyne pump probe setup. Metallic thin films are prepared by Glancing Angle Deposition (GLAD) magnetron sputtering. Emphasis is put on the correlations between the structural shape of columnar thin films and their acoustic anisotropy.

## GLAD Technique

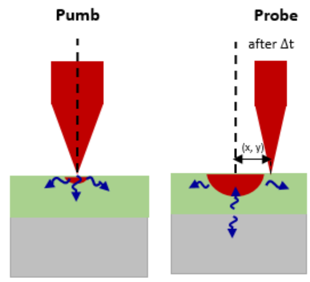



- GLAD : GLancing Angle Deposition
- Magnetron sputtering
- Deposition angle α = 80°
- Film thikness ~ 400 nm
- Substrate = Si (100)

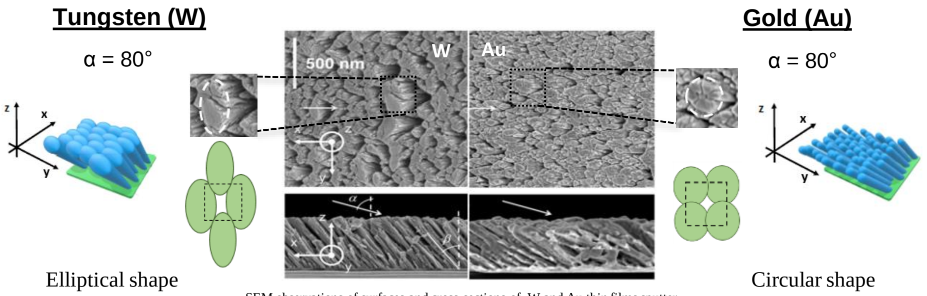



## Femtosecond pump probe setup (TDTR)

- 2 femtosecond lasers with ≠ repetition rates
  - $f_p$ ~ 48,1 MHz
  - $f_s = f_p - \Delta f$ with Δf ~ 700 Hz
- Increasing pump-probe delay by
  - $\delta t = T_s - T_p$ ~ 300 fs
- Thermal and acoustic properties
- With scanning :
  - → Acoustic wave velocity $V_x$ and $V_y$
  - → Acoustic anisotropy




## Morphology



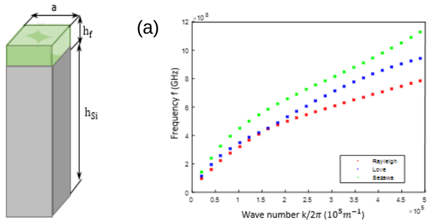

Elliptical shape

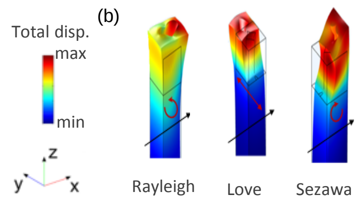
Circular shape

SEM observations of surfaces and cross-sections of W and Au thin films sputter-deposited by GLAD with an incident angle α=80°.

## Numerical simulations with FEM

- Finite element method with periodic conditions [1]
- The three first modes are shown
- a = 500nm
- $h_f$ = 400nm
- $h_{Si}$ = 25µm

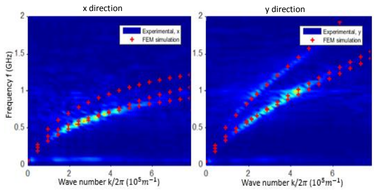


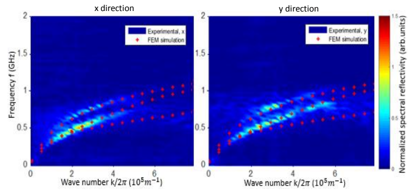

(a) Calculated band diagram of Au film. (b) The distributions of displacement of modes.

[1] : E. Coffy et al., J. Phys. D: Appl. Phys. 50, 484005 (2017)

## Surface acoustic wave propagation




Dispersion curves of W film for x and y directions




Dispersion curves of Au film for x and y directions

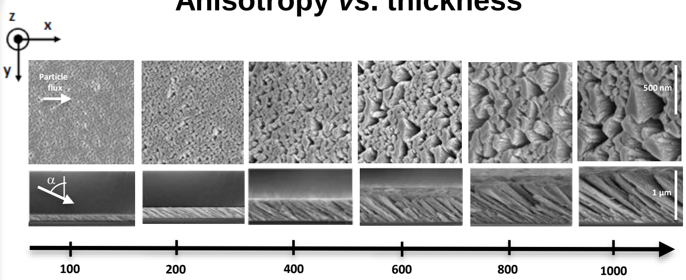
$V_x < V_y$

**→anisotropic microstructured film**

$V_x = V_y$

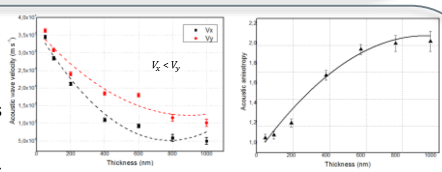
**→isotropic microstructured film**

## Anisotropy *vs.* thickness




**W - thickness (nm)**

- Tunable shape vs. thickness of W
- From circular shape to elongated as the thickness increases
- Acoustic wave velocity decreases with thickness due to elliptical shapes and a more porous structure between the columns
- Anisotropy and porosity are connected to the column fanning, which are favored at high thickness



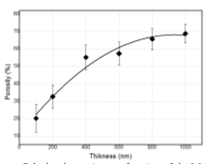

Group velocities of pseudo-Rayleigh waves (at $k/2\pi = 3\times10^5 m^{-1}$) along x, y axes and anisotropic coefficient as a function of the W films thickness.

From literature [2] :

$V = V_0 \times (1-p)^t$

$\rho = \rho_0\ (1\text{-}p)$

$V$: speed of the porous media
$V_0$ : speed for the bulk media
$p$: porosity
$t$: factor ($1 < t < 4$)
$\rho_0$ : density at zero porosity




Calculated porosity as a function of the W films thickness.

[2] : G.N. Aliev et al., J. Appl. Phys. 110, 43534-43541 (2011)

Acoustic wave propagation is connected to the structural anisotropy of the film's architecture. The GLAD approach is among the most attractive ways to produce original surface morphologies and the microstructural shape can be changed as a function of the thickness of the film, the incident angle of the particle flux and the sputtering pressure.

**Contact**
Asma Chargui
E-mail : asma.chargui@femto-st.fr

INSTITUT FEMTO-ST
15 B AVENUE DES MONTBOUCONS
25030 BESANÇON - www.femto-st.fr