The local structure of amorphous pure and Ti-doped Ta2O5 films

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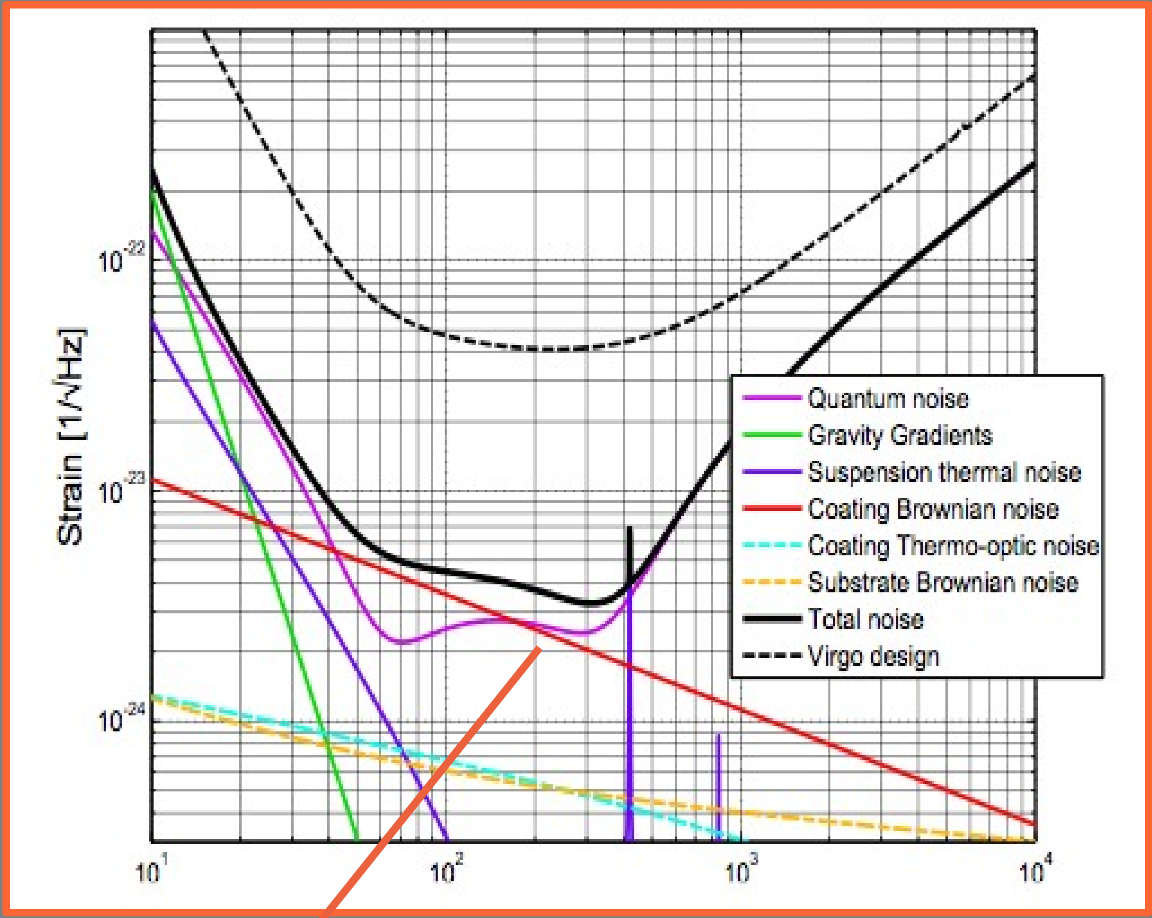
6th ET Symposium, Lyon 19th - 20th November 2014

Introduction

Gravitational waves astronomy:

- Mitigate the noise sources that limit the sensitivity of the IF

- Study of new technologies for future detectors



Coating Brownian Thermal Noise

Introduction

Coating Brownian Thermal Noise:

- Coating of AdV mirrors: multilayer of alternating high (Ta_2O_5) and low (SiO_2) refractive index materials.

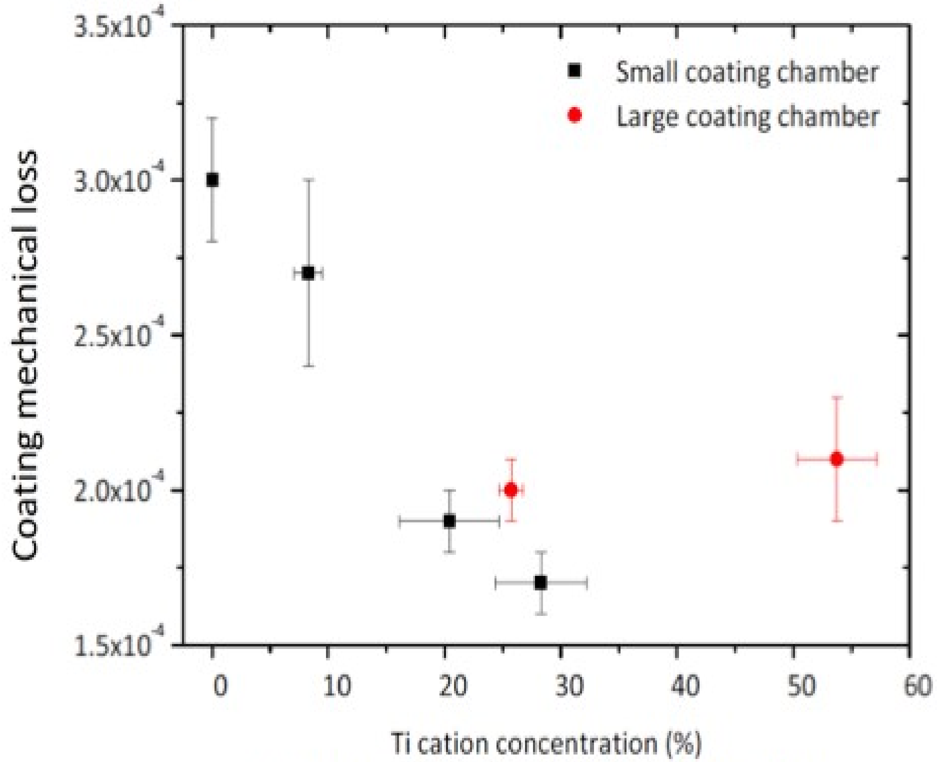
- Ta_2O_5 is the highest source of thermal noise.

- Thermal noise is associated to mechanical dissipations:

$$S_x(f,T) \approx \frac{2K_B T}{\pi^2 f} \frac{d}{\omega^2 Y} \phi \left(\frac{Y'}{Y} + \frac{Y}{Y'} \right)$$

T = temperature
d = coating thickness
ϕ = coating loss angle = coating mechanical dissipations
ω = laser beam radius

Introduction



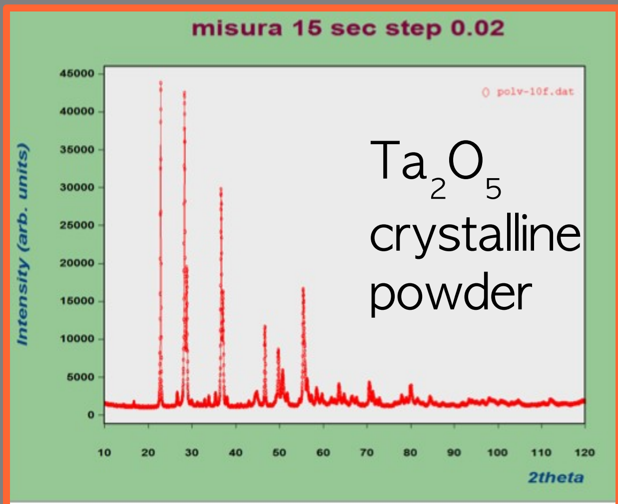
[G M Harry et al, Class. Quant. Grav. **24** 405, 2007]

TiO_2 doping:
reduces the mechanical dissipations

Changes in mechanical dissipations are associated to changes in atomic structure

Atomic Structure Study

Crystalline materials: long range order

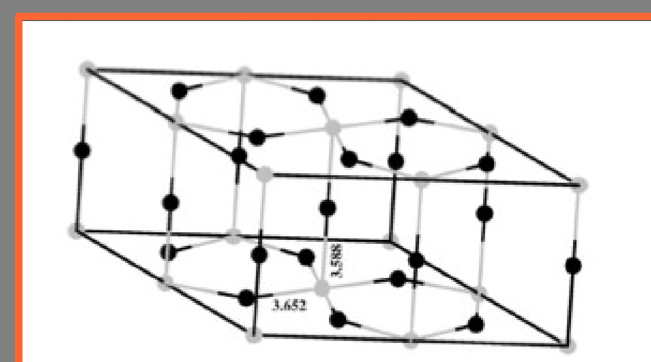


Diffraction pattern: peaks

Lab. diffractometer

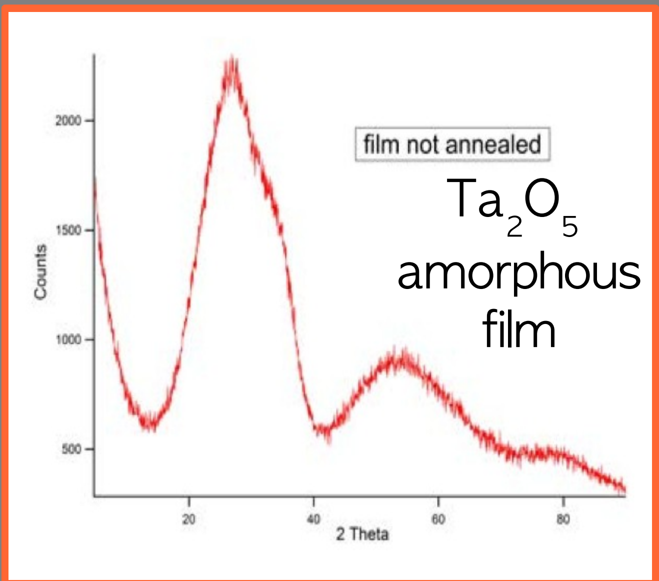
Rietveld method

Atomic structure



Atomic Structure Study

Amorphous materials: short range order



NO peaks
NO Rietveld method

Ordinary crystallography falls in this regime

Total Scattering + Fourier methods

Bragg:
Positions, displacements and occupancies

Diffuse Scattering:
Short range order

Pair Distribution Function (PDF)

Atomic Structure Study

Pair Distribution Function

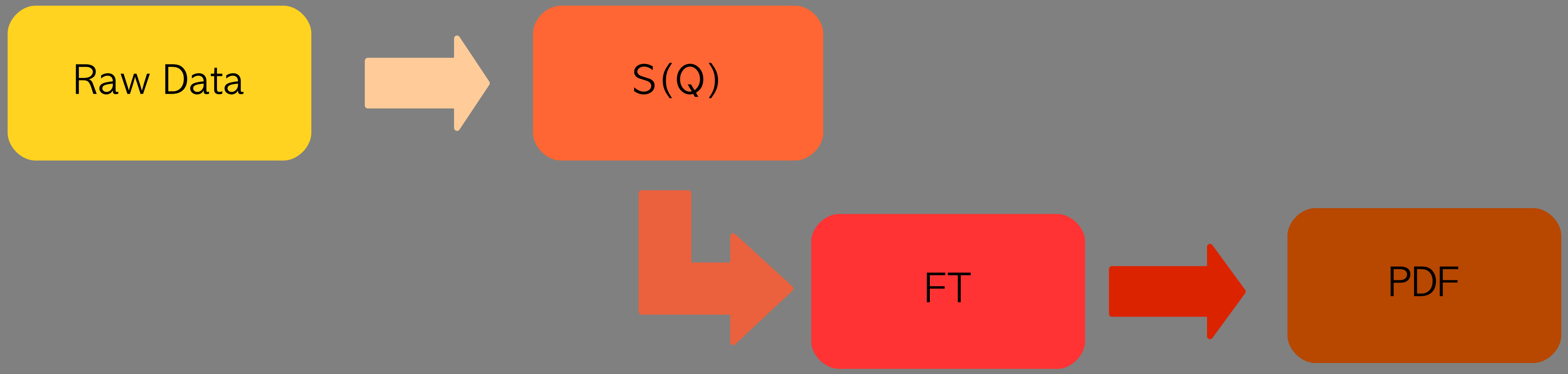
$$G(r) = 4\pi\rho_0(g(r)-1) = \frac{2}{\pi}\int_0^{\infty}(S(Q)-1)Q\sin Q\,dQ$$

S(Q): structure function

$$S(Q) = \frac{I(Q)}{N}\frac{1}{scattpower}$$

Atomic form factor

$$\langle f(Q)\rangle^2$$



Atomic Structure Study

1. Very high momentum transfer (Q) → $Q=4\pi\frac{\sin\theta}{\lambda}$ $Q_{max}\rightarrow\sin(\theta)=1$

In lab:

Ag anode: (λ =0.559 A); Q_{max}=22 A^{-1}

Cu anode: (λ =15418 A); Q_{max}=8 A^{-1}

2. Very high energy photons → λ 〈0.3A

Need of third generation synchrotrons

Experimental Set-Up

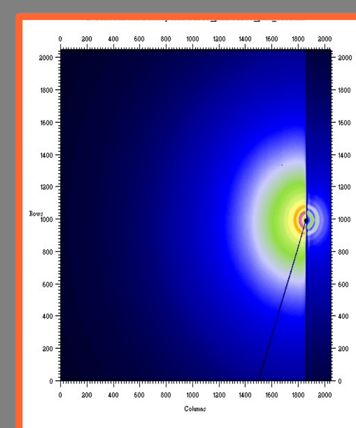
Amorphous Ta_2O_5 films deposited (IBS) on SiO_2 substrates.

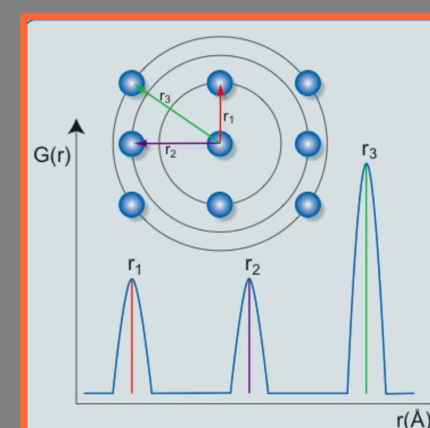
↓

X-Ray Diffraction

- Syncrothron Facility: ESRF, Grenoble ID15

- Pair Distribution Function (PDF), G(r)





Experimental Set-Up

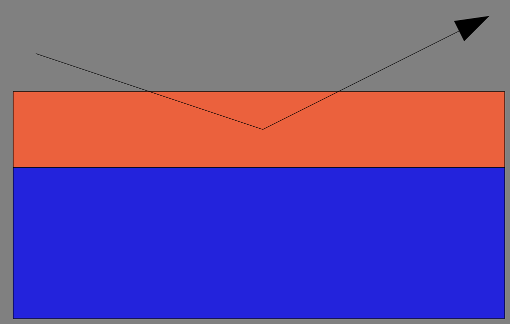
Goal:

Study of the atomic structure changes caused by annealing and doping

4 Samples (2 um films):

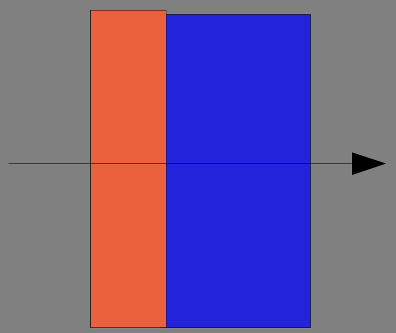
- pure Ta_2O_5
- annealed Ta_2O_5
- TiO_2 doped Ta_2O_5
- annealed TiO_2 doped Ta_2O_5

ID 15, ESRF Grenoble: λ =0.1774 A



Grazing Configuration:
not annealed samples

Allignement
problems

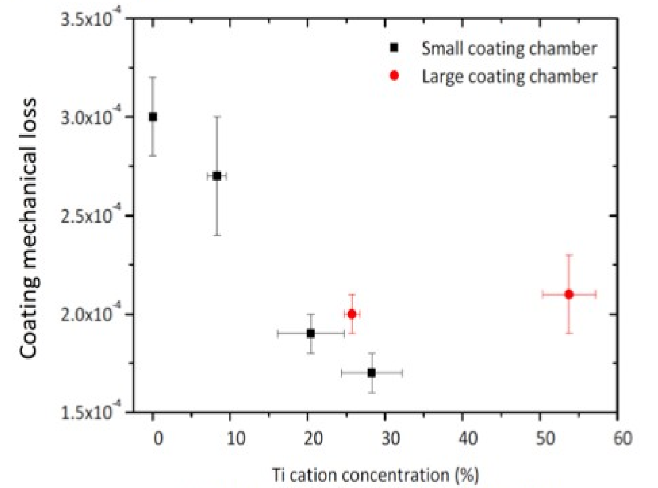


Trasmission Configuration:
annealed samples

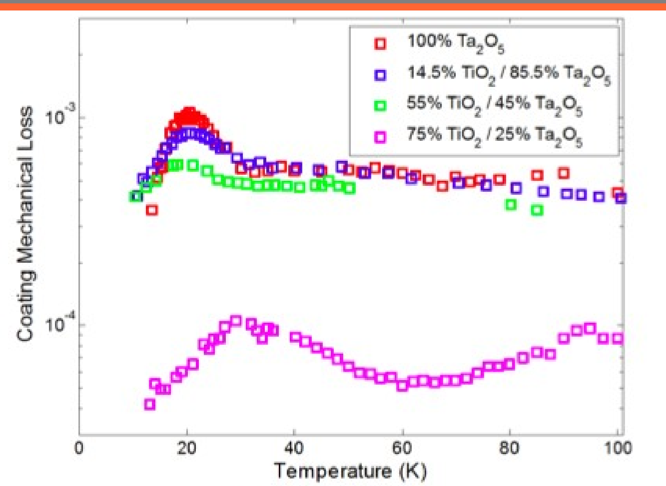
Measurements made on 12th November 2014 → no analysis

Doping effect

TiO_2 doped Ta_2O_5

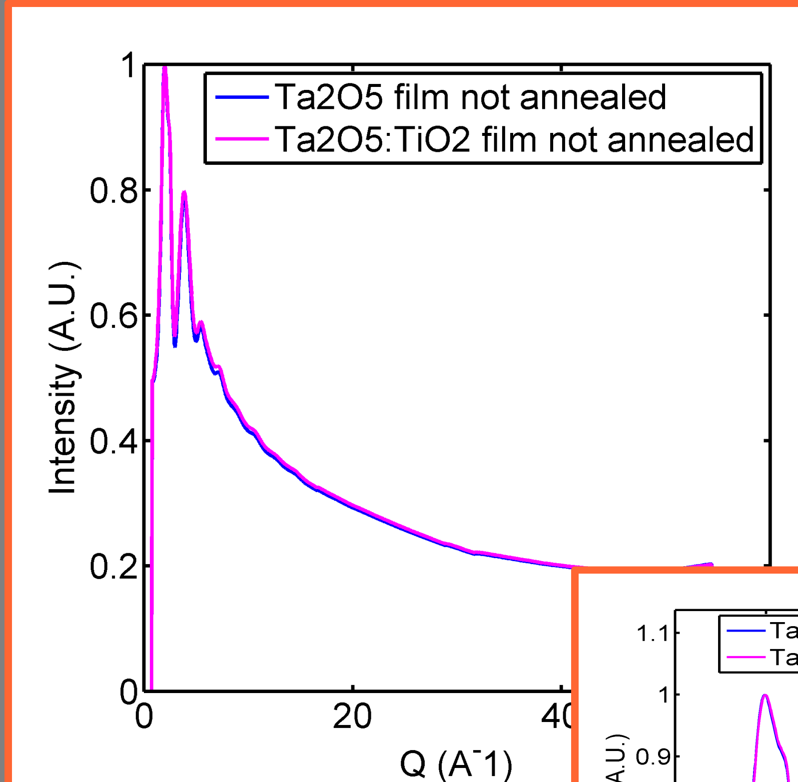


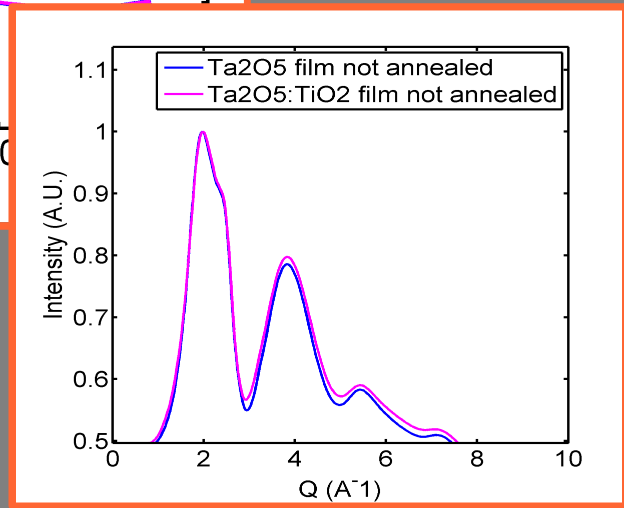
[G M Harry et al, Class. Quant. Grav. **24** 405, 2007]



[P. Murray et al, Glasgow]

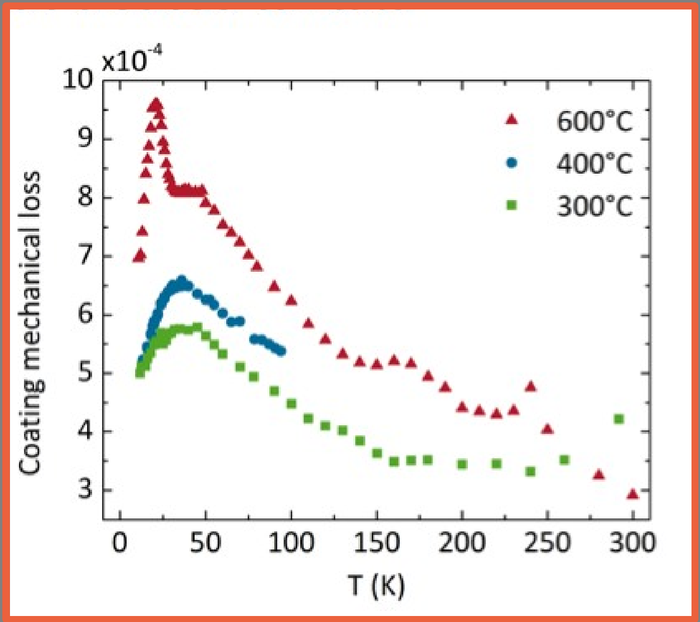
Diffraction pattern: grazing configuration





Annealing effect

Annealed pure and doped Ta_2O_5



- Improvement of the optical properties
- Low temperature loss peaks

I. W. Martin et al.Clas & Quant. Grav.27 225020, 2010

Annealed samples (doped and pure) have been measured in transmission configuration.

Treatment data: subtraction of the substrate

No time to do the treatment

Conclusions

- Work on the study of the local atomic structure of Tantala films.
- Doping effect: comparison between pure and Ti-doped films.
- Annealing effect: comparison between annealed and not annealed films.
- X-Ray Diffraction measurements: done.
- Analysis with the Pair Distrbution Function: to do.
- Study of the doping concentration (XPS): to do.

Thank you
for the attention!