Defects and structural modifications in MgF_2 with high energy heavy ion irradiation aiming at improving UV optical applications

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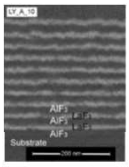
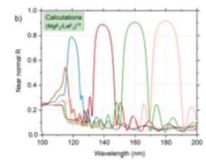
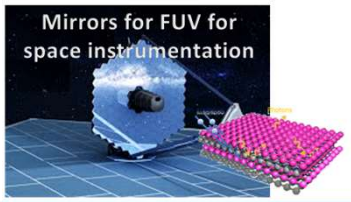
Introduction and Motivation

GOLD is one of the few laboratories in the world preparing FUV (λ< 200 nm) coatings, especially for space instrumentation, preparing transmittance filters for on-orbit observation instruments [1,2].

Developing high-quality optical components for far ultraviolet (FUV) spectrum is gaining significance in space observations. Optical elements designed for a narrowband FUV response rely on coatings made of thin multilayers (MLs), alternating between two materials with low optical absorption and significantly contrasting refractive indices, typically, LaF_3 and MgF_2. That's the reason for renewing the interest and study of the MgF_2. With this project we aim to understand and clarify the damage we make in our materials with heavy ions irradiations with the main objective of findings novel ways of improving far UV coatings.



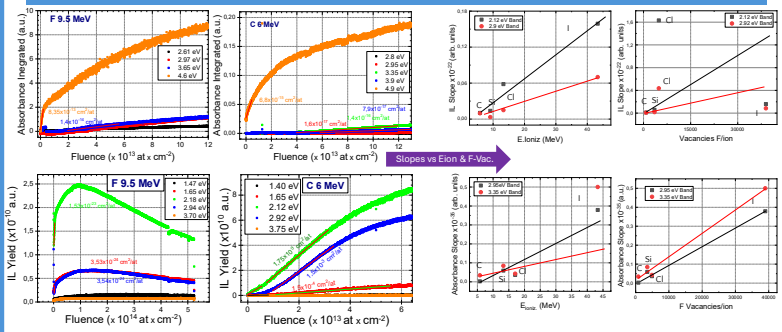




Results

a) Irradiation in Vacuum. Dependence of OD and IL with the S_e or S_n

IL & OD Kinetics In-situ



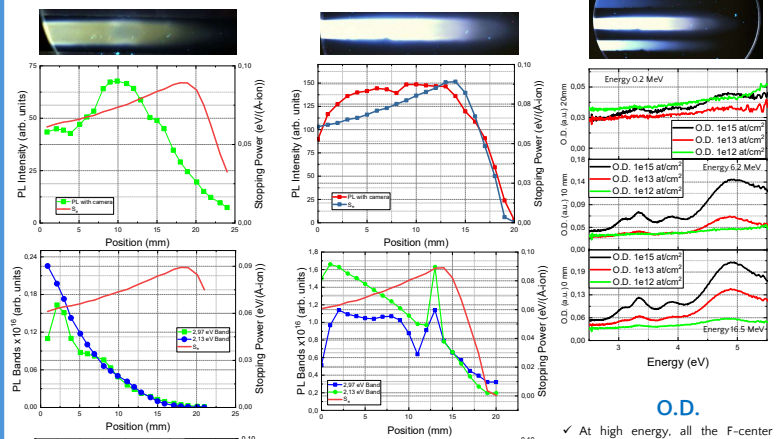
- For C, F-centers grows rapidly while F2 experiment a delay. IL increase gradually until the saturation is reached.
- In F, all the color centers increase since the beginning and the IL increases abruptly at the beginning and decreases after the maximum is reached.
- IL appears before F2-centers are created which suggests that F-centers already produce some IL.
- This result suggest that the IL is correlated with the E.ioniz while the O.D. is correlated with the F vacancies.
- Spectroscopic Stripes may help us to understand the dependence of the optical properties with S_e and S_n.

b) Study of the bands obtained by External Macro-beam irradiation in the Spectroscopic Stripes.

Band peaks (PL & O.D.) & Stopping Power vs Distance for C20.5MeV 1e15 at/cm²

Band peaks (PL & O.D.) & Stopping Power vs Distance for F 16.5MeV 1e15 at/cm²

O.D evolution with fluence and Energy



O.D.

- ✓ At high energy, all the F-center bands are created, but that's not the case for smaller energies, except for 1e15 at/cm² (already saturated).
- ✓ It seems that Nuclear Stopping power barely generates F-centers.
- ✓ So, with the last conclusion we might conclude that the F-centers are being generated primarily with the Electronic Stopping power.

Photoluminescence

- ✓ Intensity of PL approximately correlates with the electronic stopping power for both ions (if forgot the anomalous effect in the C probably produced while measuring).
- ✓ PL Bands are not showing any clear dependence with the Electronic Stopping power.

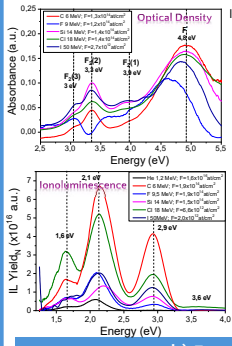
Modification of the optical properties because of the measurement with strong UV light?

"Burned" spots on some samples.

Experimental methods

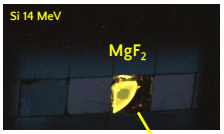
a) Irradiation inside vacuum chamber

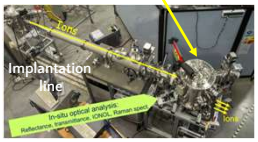
We have irradiated **in vacuum** with the novelty of measuring *in-situ* and simultaneously the Optical Density and Ionoluminescence.

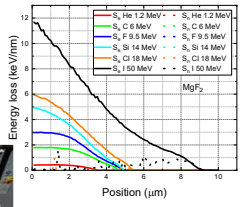


In order to sweep all the stopping power range, we have irradiated with the following ions:

He 1,2 MeV, C 6MeV, F 9.5 MeV, Si 14MeV, Cl 18MeV, I 50MeV







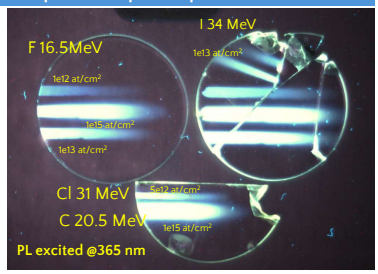
SRIM simulation of Se and Sn for ion species used in this work

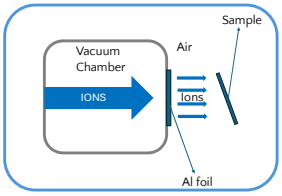
b) External Macro-beam: Spectroscopic Stripes

With the goal of "recording" the effects of the full stopping power curve in one irradiation, we propose the irradiation of **Spectroscopic Stripes** in air, using suitable thin Al foils as exit window/port.

This novel irradiation might help us to fully understand the evolution of optical properties and its dependence with the S_e or the S_n.

Results obtained by this method allow us to compare and complement the results attained with the traditional method on vacuum.

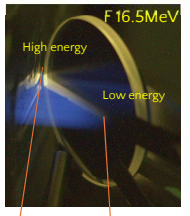




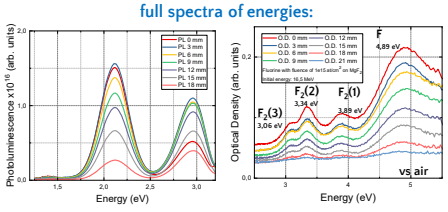
SEQUENCE OF ENERGY LOSS

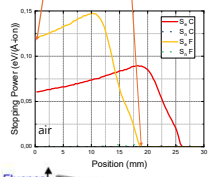
Ion	Vacuum energy (MeV)	Al foil (thickness in μm)	Energy in air (MeV)
C	25	4.5	20
F	20	4.5	16.5
Cl	40	2	31
I	50	2	34

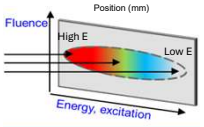
Spectroscopic Stripe



O.D. and PL were measured point by point to gain a full spectra of energies:







- F2 (2) absorbs at 3.35 eV and emits at 2.9 eV and 1.65 eV.
- F2 (3) absorbs at 3.1 eV and emits at 2.2 eV.

Conclusions

- ✓ Optical Density is highly correlated with the increase of the fluence as well as with the electronic stopping power.
- ✓ It seems to be a correlation between the electronic stopping power and the PL Intensity.
- ✓ IL has a purely electronic origin (linear fit with the ionization energy).
- ✓ Therefore, Spectroscopic Stripes suggests that both O.D. and PL correlate with the Se which is contradictory with the results measured in vacuum.
- ✓ In depth analysis should be done for other ions towards the extraction of deeper conclusions.

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Acknowledgements

The authors acknowledge funding support by the following projects: PID2022-142417OB-100 from the Spanish Ministry of Science and Innovation, TechnoFusión (III)-CM (S2018/EMT-4437) from Comunidad de Madrid (cofinanced by ERDF and ESF).
We also acknowledge CMAM for the beamtime and its technical staff for their contribution to the operation of the accelerator.

IBMM2024
3-5 July 2024
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