Photoluminescent colour centres in lithium fluoride film detectors for gamma rays

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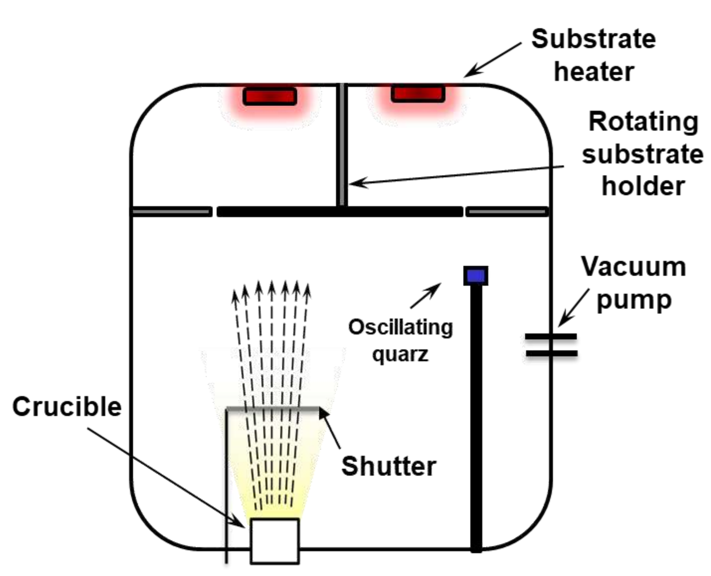
Abstract

Passive solid-state detectors based on lithium fluoride (LiF) thin films, nominal thickness 1, 1.5 and 2 µm, were grown by thermal evaporation on glass, Suprasil® and Si(100) substrates at ENEA C.R. Frascati. These radiation imaging detectors are characterized by high intrinsic spatial resolution over a large field of view, wide dynamic range and simplicity of use. Their principle of operation is the optical reading of the visible photoluminescence (PL), emitted by radiation-induced F_2 and F_3^+ colour centres (CCs) stable at room temperature, by using fluorescence microscopy technique. The LiF film-based detectors grown on Si(100) were irradiated at several doses in the range from 20 to 10^3 Gy with gamma rays at the Calliope irradiation facility (ENEA C.R. Casaccia). Their PL response shows a linear behaviour as a function of the irradiation dose for all three film thicknesses. The lowest detected dose, delivered to the thickest LiF film, is estimated at 20 Gy.

Thermally-evaporated LiF radiation imaging detectors

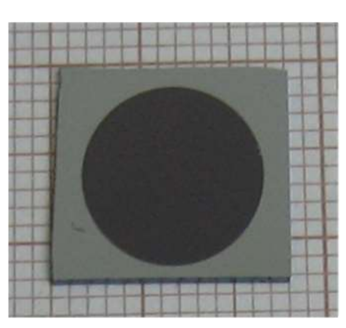


Operating principle of a thermal evaporation system.

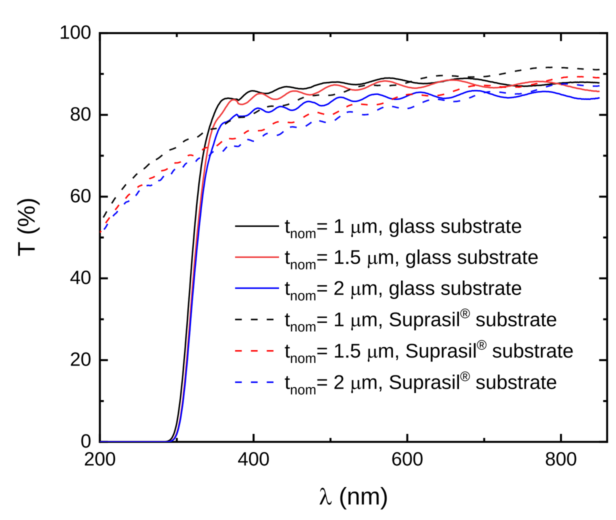
Main deposition parameters

- ✓ pressure < 1 mPa;
- ✓ deposition rate: 0.5 ÷ 2 nm/s;
- ✓ film thickness: up to few µm
- ✓ substrate temperature: 30 ÷ 350 °C
- ✓ substrate material: glass, silica, Si, plastic and metal layers, etc.

Structural, morphological and optical properties of LiF thin films grown by thermal evaporation are strongly dependent on the nature of the substrate and the main deposition parameters such as substrate temperature, total thickness, deposition rate.



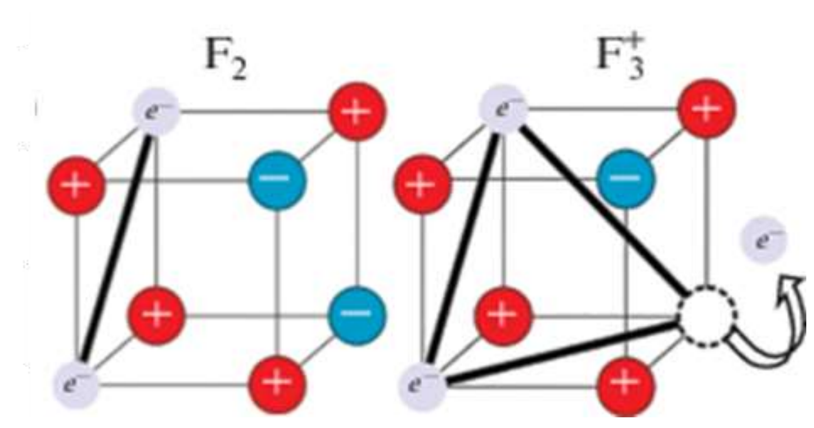
Photograph of a 1 µm thick LiF film grown on Si(100) substrate



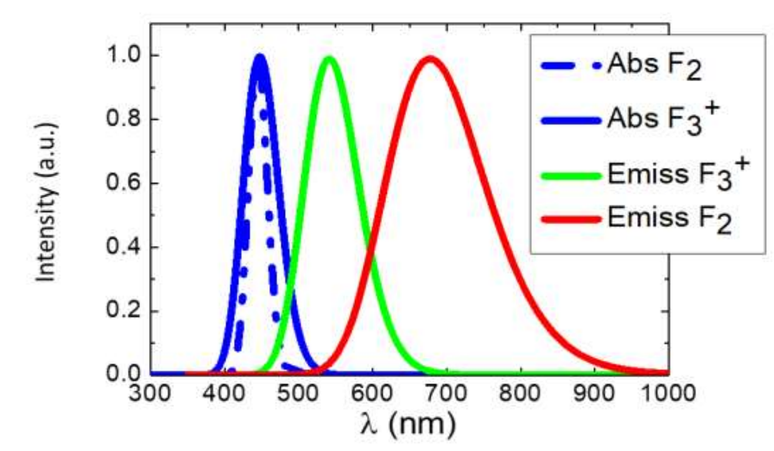
Transmittance spectra of LiF films grown on glass and Suprasil® substrates

Colour Centres in LiF

- Radiation-induced F_2 and F_3^+ CCs (**a**) consisting in two electron bound to two and three close anion vacancies, respectively.
- Irradiation of LiF gives rise to temperature stable formation of F_2 and F_3^+ CCs, with almost overlapping absorption bands peaked at 444 and 448 nm, respectively (**b**).
- Under optical pumping in their optical absorption bands, F_2 and F_3^+ CCs emit broad PL bands peaked at 678 and 541 nm respectively (**b**), which can be read in non-destructive way using fast and efficient optical reading techniques such as fluorescence conventional and confocal microscopy.



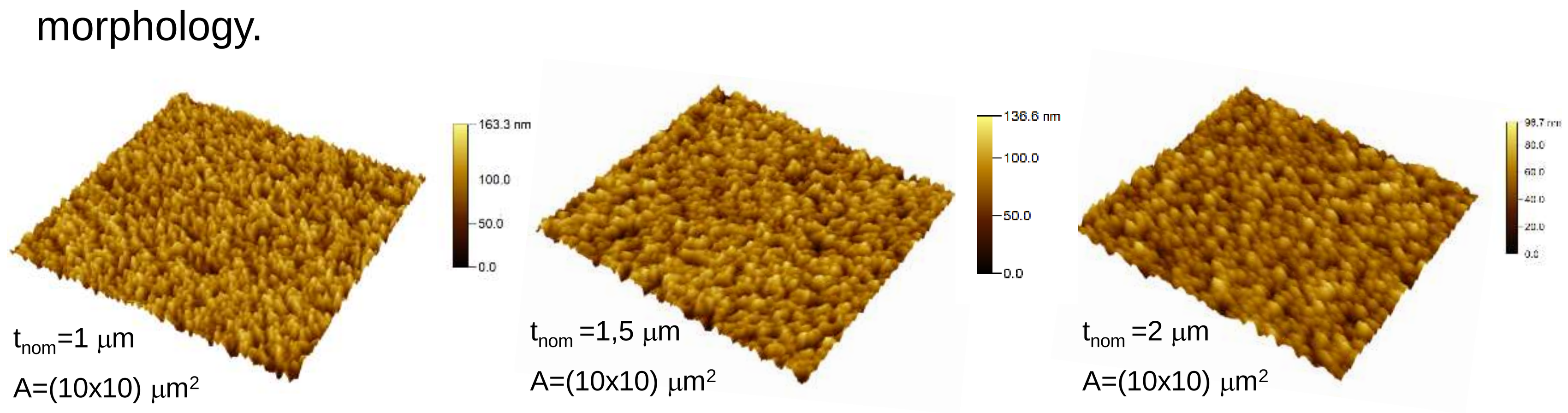
a)



b)

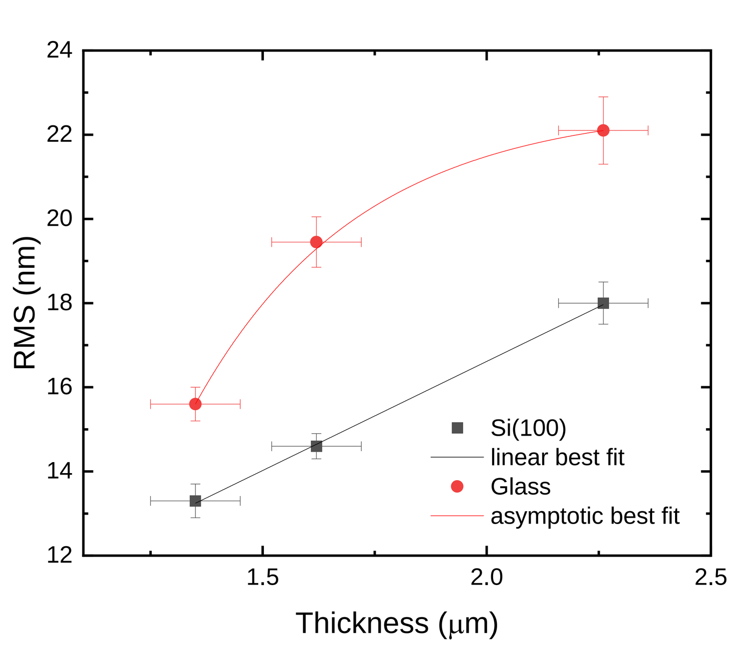
Atomic Force Microscopy Characterization

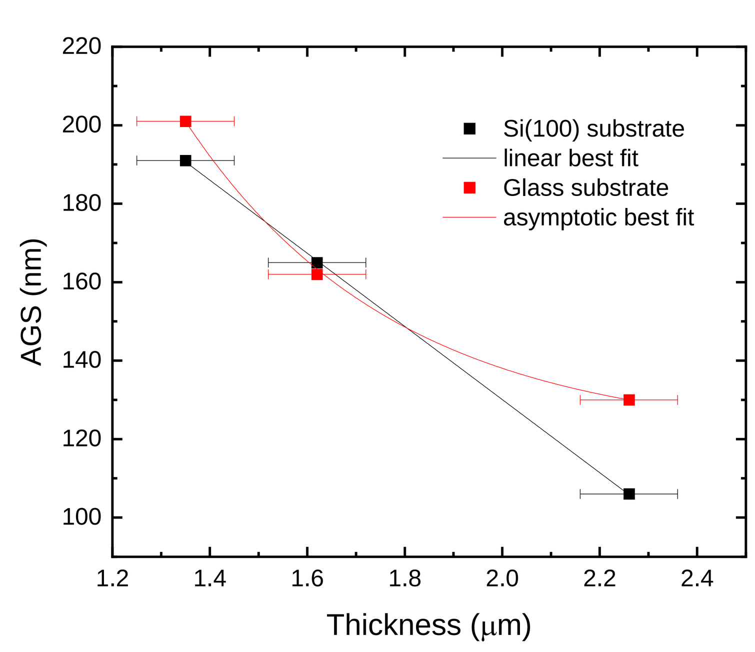
- The polycrystalline LiF films grown on Si(100) and glass substrates were characterized with Atomic Force Microscopy (AFM) investigating their surface morphology.



3D AFM images of LiF films grown on Si(100) substrate

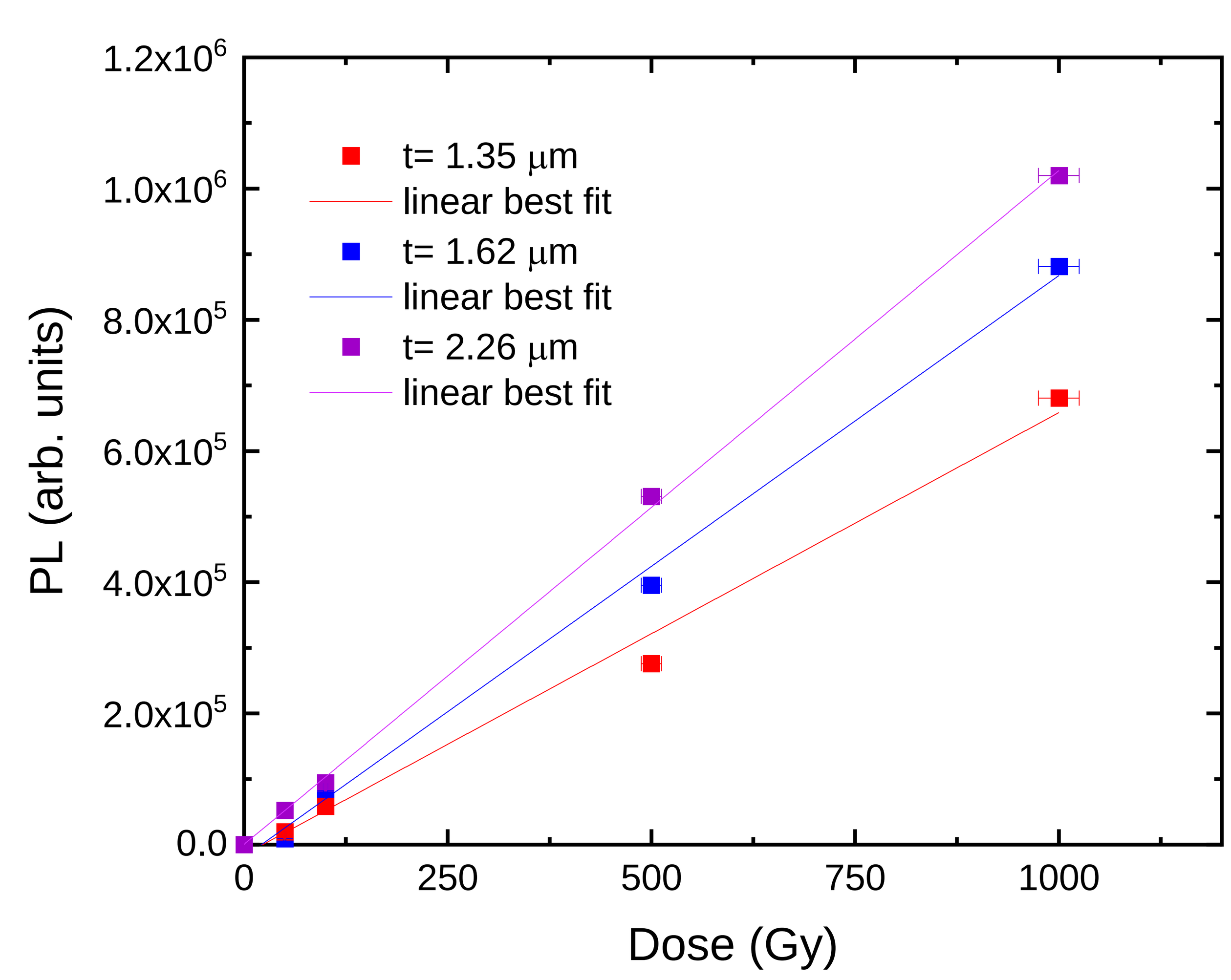
- Root Mean Square roughness (RMS) and Average Grain Size (AGS) were investigated for LiF film-based detectors grown on glass and Si(100) substrate.





LiF film detectors PL response

- The LiF films grown on Si(100) were irradiated with gamma rays at several doses in the range from 20 to 10^3 Gy.
- LiF film detectors PL response, investigated by using a fluorescence microscope, shows a linear behaviour as a function of the irradiation dose for all three film thicknesses.
- The lowest detected dose, delivered to the thickest LiF film, was estimated at 20 Gy.



CONCLUSIONS

- Preliminary AFM characterization shows that RMS and AGS respectively increases and decreases with LiF film thickness.
- The PL response of LiF film-based detectors grown on Si(100) substrates irradiated with gamma rays shows a linear behavior as a function of the irradiation dose in the investigated dose range from 20 to 10^3 Gy for three film thicknesses;
- The minimum detected dose is 20 Gy delivered to the 2 µm thick LiF film.