CaF_2:Tm^{3+} nano-composites fabricated by pulsed laser deposition at 157 nm.

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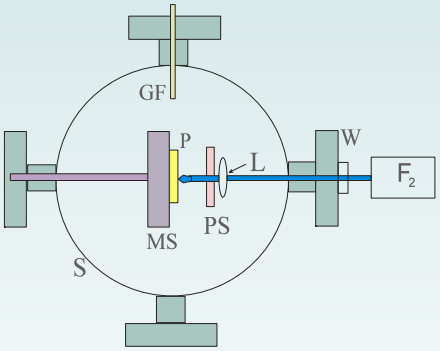
Abstract

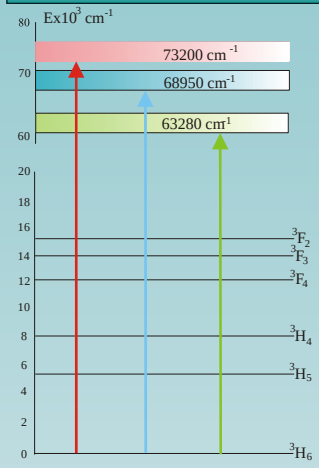
The work is intending to micro-fabricate a *novel class of EUV/VUV solar blind detector array, (SBD), and tunable optical filters* for narrow VUV spectral windows for space applications using wide band gap (~ 10 eV) fluoride/oxide dielectric nano-crystals, doped with trivalent rare earth (RE) ions-WBGDC-RE. The overall aim will be to design and construct a *"device on chip"* state of the art integrated VUV micro-array detector, operated in narrow spectral windows from 110-180 nm and a novel class of SBD micro-array devices in the EUV/X-ray spectral regions with improved S/N ratio, sensitivity and detection efficiency. Initial work involves fabrication of thin films of CaF_2:Tm^{3+} by pulse laser deposition at 157 nm from initial CaF_2:Tm^{3+} (1% Tm) targets on Si—Au substrates. The films consist of crystalline nano-composites, which retains the initial target stoichiometry and with sharp size distribution of the nano-composites, allowing thus fabrication of tunable VUV crystal filters over narrow spectral regions mainly for space vacuum ultraviolet imaging.

Experimental

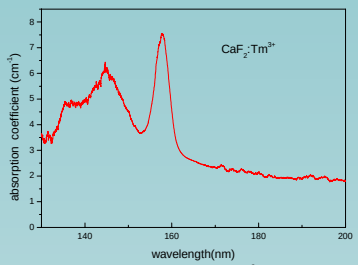


- CaF_2:Tm^{3+} (1 % Tm) crystal samples were grown with the Bridgmann-Stockbarger method and were used as targets in a laser ablative experimental configuration at 157 nm.
- The ablated products were deposited on a thin Au film on a Si wafer. The targets were placed on a on a X-Y-Z translation stage in order to scan an area of 5X5 mm^2 with the focused laser beam.
- The films were examined with scanning electron microscopy (SEM) equipped with an EDXS spectrometer with 50 nm electron beam diameter and AFM.
- The film stoichiometry was examined with VUV absorption spectroscopy for samples deposited on high optical quality CaF_2 substrates.
- Initial target stoichiometry was additionally analyzed with mass spectrometry and laser ablation at 213 nm using the forth harmonic of a Nd:YAG laser.

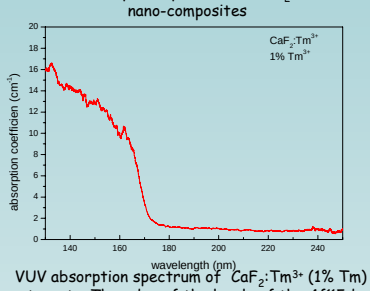
Results and discussion



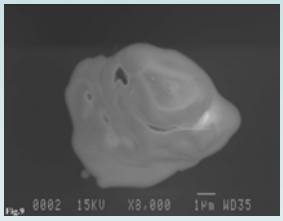
Simplified energy diagram of Tm^{3+} ion where the transitions between the ground $^3H_6$ state of the $4f^{12}$ electronic configuration and the electronic states of the $4f^{11}5d$ configuration are indicated. The maximum of absorption is taking place at 158, 145 and 136 nm



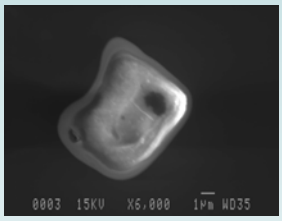
VUV absorption spectrum of CaF_2:Tm^{3+} nano-composites



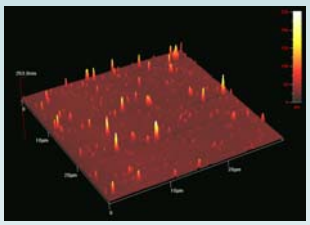
VUV absorption spectrum of CaF_2:Tm^{3+} (1% Tm) targets. The edge of the levels of the $4f^{11}5d$ electronic configuration is at 59500cm^{-1}.



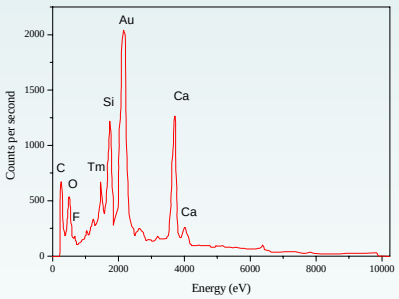
SEM image of a large CaF_2:Tm^{3+} micro-composite liquid droplet. The concentration of the Tm atoms in such droplets was much higher than the concentration of Tm in the target crystal.



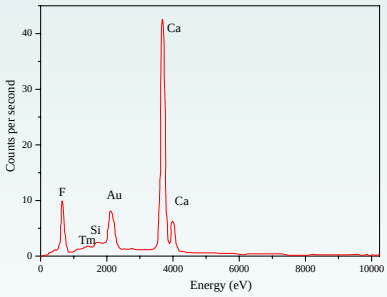
SEM image of CaF_2:Tm^{3+} nano-composite. The laser energy, which was delivered on the target, was 0.1-50 mJ per pulse and the laser fluence was 0.1-50 mJ/cm^2.



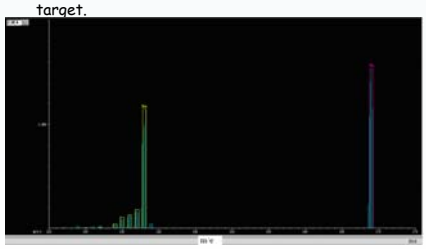
AFM image of CaF_2:Tm^{3+} film.



X-ray spectrum of CaF_2:Tm^{3+}nano-composites. The stochiometry of the various nano-composites was analyzed by X-ray microanalysis with a 50 nm wide electron beam. Analysis of individual nano-composites reveals the presence of Ca, F, and Tm, which reflects the stochiometry of the initial target.



EDXS spectrum of a crystalline composite of the film indicates 0.5-1 % concentration of Tm atoms.



Mass spectrum of laser ablated moieties by the forth harmonic of the Nd:YAG laser at 213 nm. Target surface mapping indicated the presence of Ba impurities in the crystal.

Conclusions

- Thin films consisted of CaF_2:Tm^{3+} nano-composites were fabricated by pulse laser deposition at 157 nm.
- The films retain the initial target stoichiometry allowing thus the fabrication of nano-VUV filters over a narrow spectral region.

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