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The results of various methods application for deposition of luminescent vanadate films

O. Chukova[1], S.A. Nedilko[1], S.G. Nedilko[1], T. Voitenko[1],
Androulidaki M.[2], Manousaki A.[2], Papadopoulos A.[2], Savva K.[2], Stratakis E.[2]

[1] 1 Taras Shevchenko National University of Kyiv, Volodymyrska Str., 64/13, Kyiv 01601, Ukraine. E-mail: chukova@univ.kiev.ua
2 Institute of Electronic Structure & Laser (IESL) of Foundation for Research & Technology Hellas (FORTH), Heraklion 711 10 Crete, Greece

Introduction

Luminescent oxide films are widely used for optical material science needs; in particular, as luminescent converters for adaptation of incident solar light to spectral sensitivity of silicon solar cells and for converting of violet and blue LED radiation into white light. Oxide materials are characterized by high radiation and thermal stability that is important property for such applications. Luminescent emission of the oxide compound can be related with electronic transitions in their own molecular oxyaniones as well as with impure ions, especially RE ions.

Row of the orthovanadate compounds is one of the best oxide matrices for luminescent RE ions. Our own studies have also shown that some of developed oxide compositions in the form of micro/nanoparticles are able to demonstrate promising optical and structural characteristics. In particular, we have developed vanadate nanoparticles with enhanced light harvesting from violet spectral range and intensive luminescence emission.

The next important task is to save the obtained high optical characteristics of oxide nanoparticles under their incorporation of the synthesized vanadate nanoparticles into composite film coatings. Noted, that requirements to the properties of the films can be different for various practical tasks, therefore various methods of film application should be used in order to find the most suitable one for each practical application.

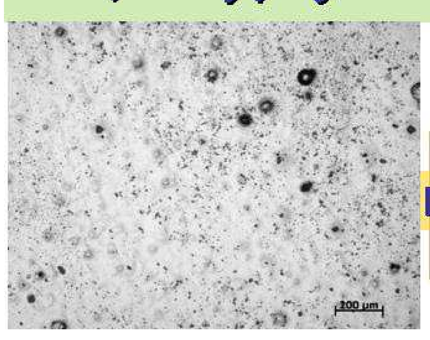
Methods of deposition of the films

Spin-coating (SC). The initial nanoparticles were dissolved in alcohol together with films forming material and placed in the ultrasonic dispergator for 20 min. The 20 microgram droplets of the prepared suspense were deposited on substrates. Then substrates containing suspension for the SC method were placed in a center of rotating disk and spin coated at 4500 rpm for 2 min using MX-20 centrifuge.

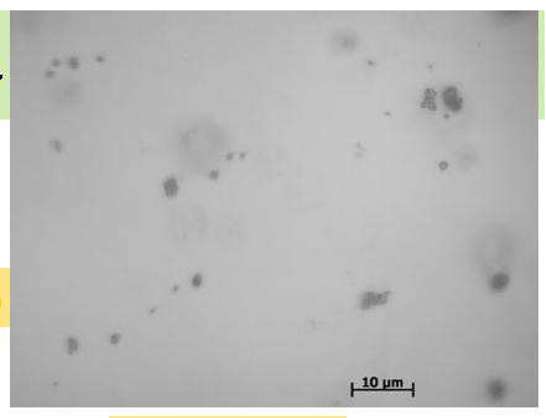
Solution evaporation (SE). The initial nanoparticles were dissolved in alcohol together with films forming material and placed in the ultrasonic dispergator for 20 min. The 20 microgram droplets of the prepared suspense were deposited on substrates. The deposited droplets were evaporated at dried hot air camera conditions for 24 hours.

Pulsed laser deposition (PLD). The initial nanoparticles were pressed into tablets of 15 mm diameter and 2 - 3 mm thickness. These tablets were used as targets for deposition of the films. Deposition was carried out in vacuum camera using KrF excimer laser with λgen = 248 nm, 10 Hertz pulse repetition and 2000 J/cm2 power. The substrates were heated to 300 C.

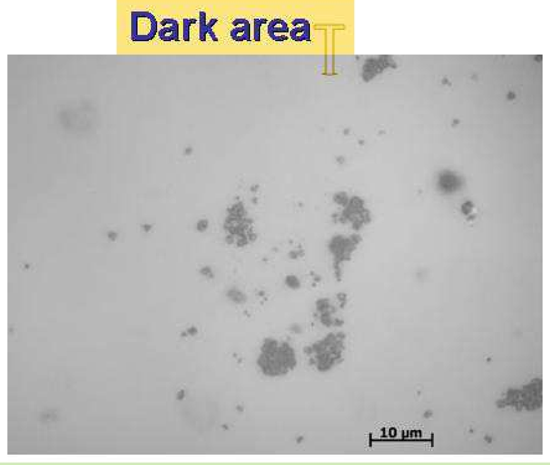
Morphology of the SC films



Dark points

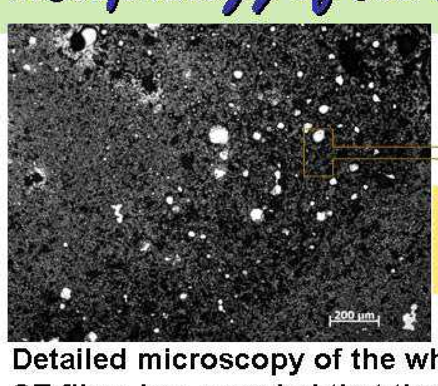


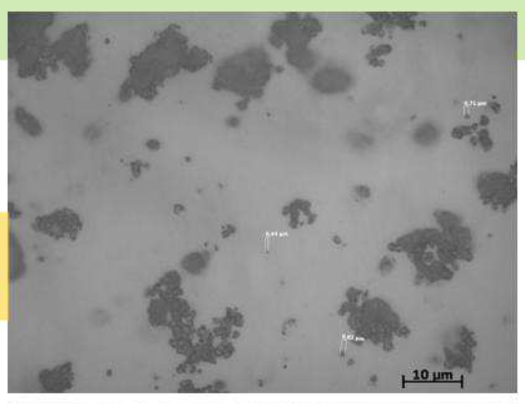
Dark area



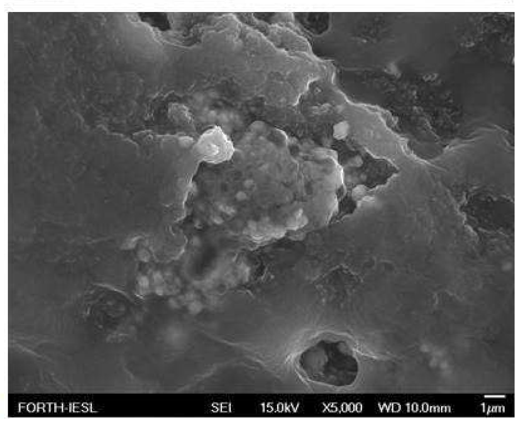
Microscopy of the SC films have shown that they are more homogenous and thin. Their OM images contain many very small dark point inclusions and some dark areas. Dark points are formed by single nanoparticles or by small groups of nanoparticles. Dark area are formed by agglomerates of nanoparticles with dimensions up to 5 microns and by smaller groups of nanoparticles homogenously distributed between the noted agglomerates.

Morphology of the SE films





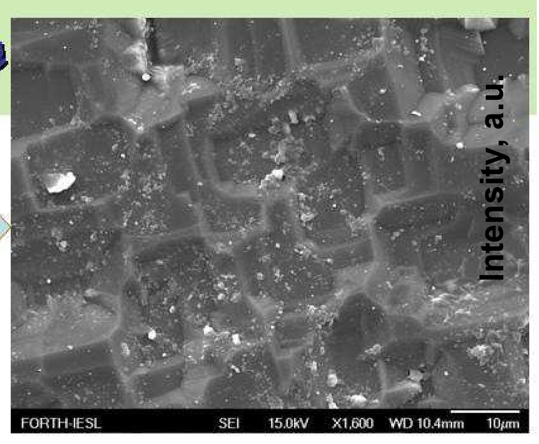
Optical microscopy



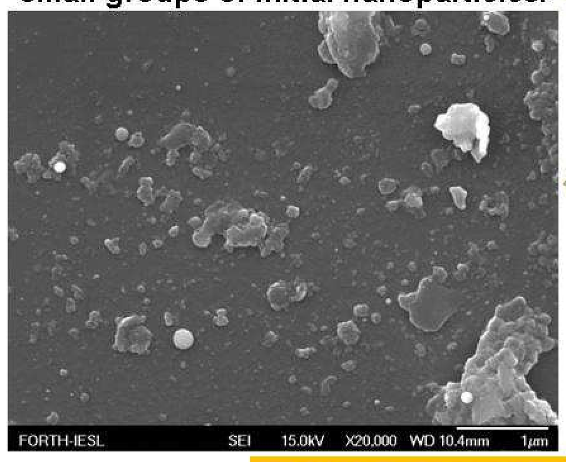
Detailed microscopy of the white spots in the SE films has revealed that these spots are formed by areas of very thin layers of silica gel. These areas contain many nanoparticles those are grouped in big agglomerates with dimensions up to 10 microns. Besides, small agglomerates with dimensions up to 1 micron and agglomerates of few nanoparticles with dimensions 400 – 700 nm and lesser can be found in the round white areas.

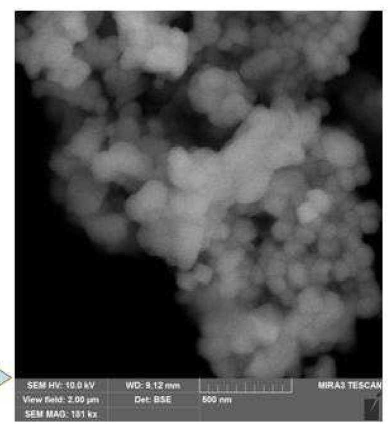
SEM microscopy

Morphology of the PLD films



SEM investigation of the PLD films deposited with 1000 pulses on amorphous silicon substrate have shown that these films are the most homogenous, they are formed by single initial nanoparticles or by small groups of initial nanoparticles.

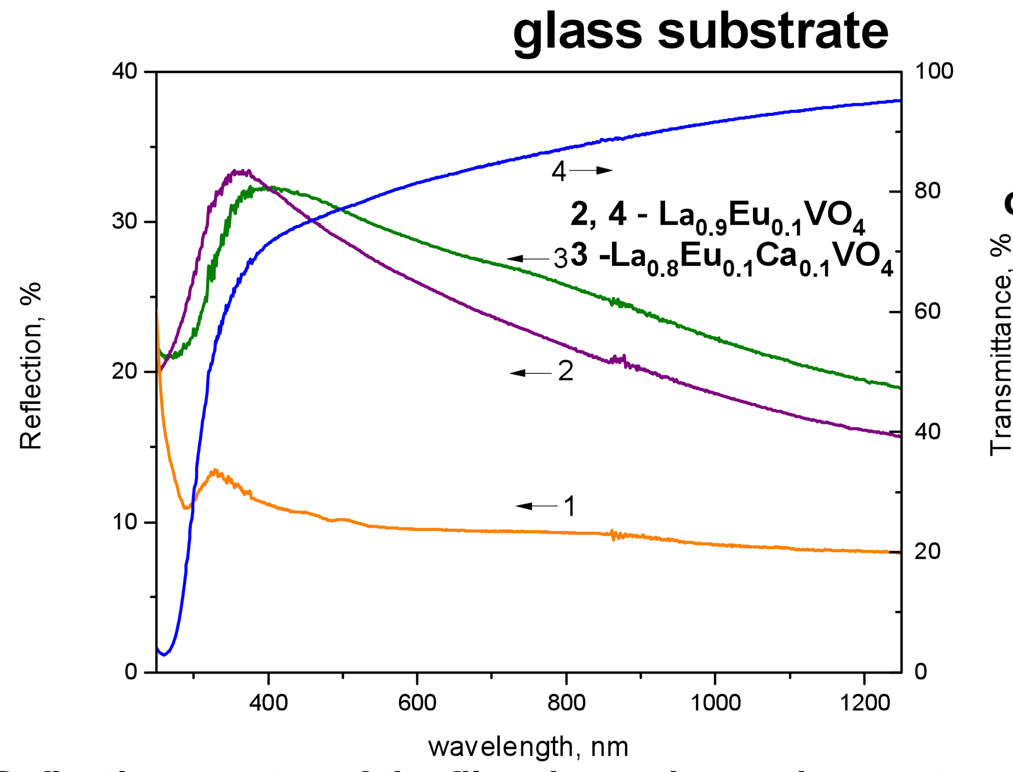




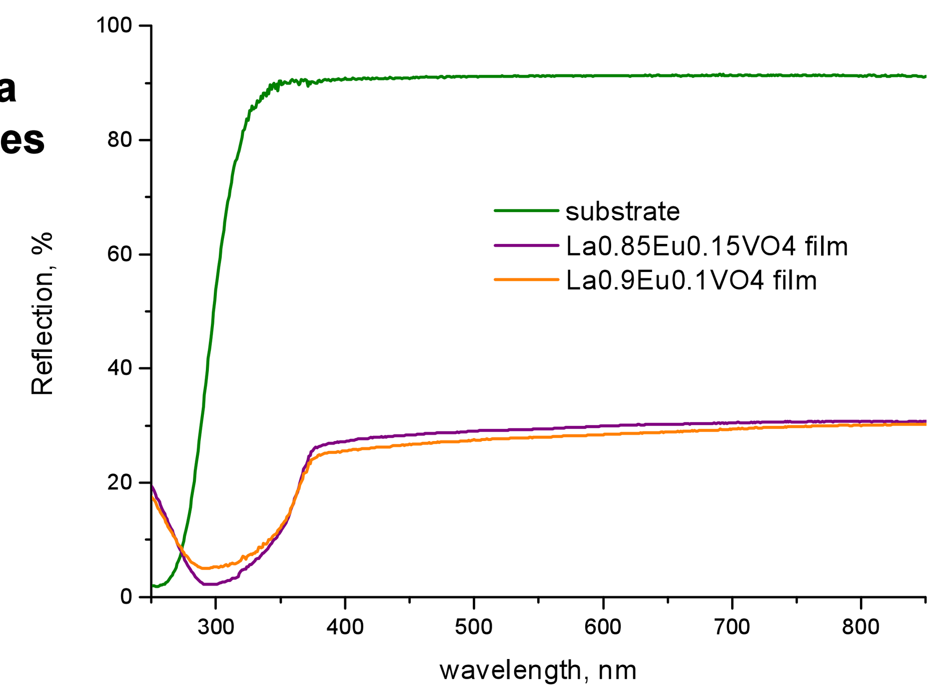
Initial nanoparticles

Optical spectroscopy of the films on different substrates

glass substrate

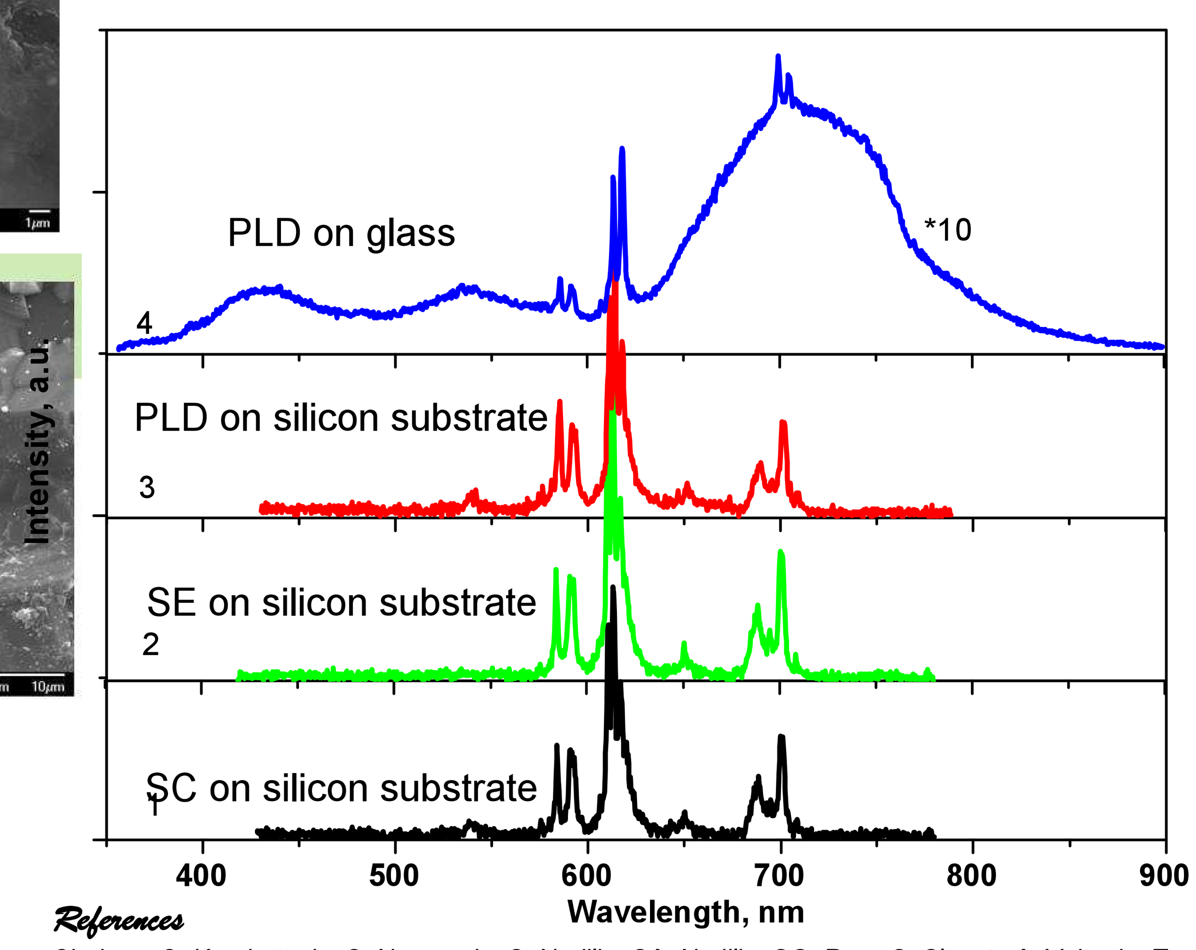


silicon substrate



Reflection spectra of the films have sharp edge centered at 350 nm for the $La_{1-x}Eu_xVO_4$ films. Difference of 50 nm in the position of sharp edge of the reflection spectra of the films obtained from same nanoparticles appears due to contribution of glass substrate in the total reflection spectra of the samples, whereas silicon substrate doesn't essentially contribute in reflection spectra up to 300 nm. We have also registered strong decrease of total reflection of the samples with the films on silicon substrates from 90 % to 30 % observed over all the visible range. As this decrease have no any spectral features and the same for various samples, we assume that it is caused by multiple scattering followed with absorption of the incident light in the deposited films. This agrees with morphology of the films formed by separated nanoparticles and agglomerates.

Luminescent properties of films grown by different methods



Conclusions

Morphology, optical characteristics and luminescent properties of the vanadate films depend on method of their deposition.

Comparing the results of microscope investigations of the films obtained by three different methods, we clearly see that PLD and SC films are characterized by a more homogenous thickness and by a lower rate of agglomeration of the deposited vanadate nanoparticles and this fact evidences a higher quality of these films. From the other hand, content of the incorporated nanoparticles is higher for the SE films that can effects on luminescence intensity of the obtained samples.

The PLD vanadate films on silicon substrates have demonstrated arise of antireflection properties as a result of laser-induced random nanostructured profile.

Luminescence spectra of the investigated films consist of narrow lines caused by f-f transitions in the Eu^{3+} ions. Intensity of the Eu^{3+} emission is higher for the films deposited by SE method and for the films on silicon substrates. For the samples on glass substrates the wide bands of glass emission are also contributed in the spectra.

The used experimental conditions in the PLD method are not enough to obtain films on glass substrates with luminescent characteristics of the films sufficient for their applications, whereas the films deposited on silicon substrates have demonstrated promising antireflection and luminescent characteristics.

Acknowledgments

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