Multilayer nanometric iron and chromium oxide structures suitable for the energy harvesting

Kryshtab T[1]*, Mulenko SA[2], Savkina RK[3], Smirnov OB[3], Paszkowicz W[4]
*Tetyana Kryshtab: kryshtab@gmail.com
1 Instituto Politécnico Nacional - ESFM, Mexico
2 G. Kurdyumov Institute for Metal Physics NAS of Ukraine, Ukraine
3 V. Lashkaryov Institute of Semiconductor Physics NAS of Ukraine, Ukraine
4 Institute of Physics PAS, Poland

The solid solutions or multilayer composite structures based on isostructural and isovalent iron and chromium oxides combine its different functional peculiarities in one system to achieve novel applications. Combining these materials enhances the antiferromagnetic spin correlation in the Cr_2O_3 film by forming a junction with the Fe_2O_3 layer as well as results in the magnetic hysteresis and magnetoresistivity switching effect in the low magnetic fields for iron/chromium oxides heterostructure [1,2]. Fe_2O_3 can be applied as a sensitizer for wide band gap photocatalyst such as Cr_2O_3 [3]. Noncommutative band offset at α-Cr_2O_3/α-Fe_2O_3 (0001) superlattices results in an occurrence of the potential gradient and photocurrent growth [4]. And finally, Cr_2O_3 and Fe_2O_3 are known as thermoelectric materials, which is important for our work.

In this work, nanometric iron oxide Fe_2O_3 layers, multilayer combinations with chromium oxide Cr_2O_3 and their solid solutions grown on silicon and glass substrates by the reactive pulsed laser deposition technique were studied at various technological parameters such as oxygen pressure in the reactor, substrate temperature, number of laser pulses. For surface and in-depth composition identification of oxide-based structures XPS, XRD and TOF SIMS technique were successfully used. It was shown that oxides are present on the surface in different phases, and the technological parameters and composition of these films significantly affect their optical properties in NIR/VIS/UV range. Methods of low-temperature photoluminescence and Raman spectroscopy techniques were used for the investigation of the recombination and vibrational properties of the samples studied.

Investigation of the charge carriers transport kinetics was carried out by surface photovoltage and impedance spectroscopy technique. We have observed that the nanometric multilayer structures based on combinations of Fe and Cr oxides demonstrate a surprising improvement in the photoelectric properties The results reveal that optimal bilayer structure grown on a cold substrate has demonstrated photovoltage enhancement that corresponds to the high separation rate of photo-induced charges. We considered structures investigated as a hybrid photothermoelectric harvester of the solar energy.

[1] Kota Y, Imamura H, Sasaki M. Enhancement of spin correlation in Cr2O3 film above néel temperature induced by forming a junction with Fe2O3 layer: First-Principles and Monte-Carlo Study. IEEE Transactions on Magnetics 2014;50(11):1-4.
[2] Smirnov AB, Kryvyi SB, Mulenko SA, Sadovnikova ML, Savkina RK and Stefan N. Structural and magnetoresistive properties of nanometric films based on iron and chromium oxides on the Si substrate. Nanoscale Res Lett 2016;11(1):467-472.
[3] Salar H, Kinetics and mechanism of enhanced photocatalytic activity under visible light irradiation using Cr2O3/Fe2O3 nanostructure derived from bimetallic metalorganic framework. Journal of Environmental Chemical Engineering 2019;7:103092-10
[4] Kaspar TC, Schreiber DK, Spurgeon SR, Mc Briarty ME, Carroll GM, Gamelin DR, and Chambers SA. Built-in potential in Fe2O3-Cr2O3 superlattices for improved photoexcited carrier separation. Adv. Mater. 2016;28(8):1616-1622.