METALORGANIC AEROSOL DEPOSITION: THE BUILDING OF OXIDE FILMS

DEPUNEREA DIN AEROSOLII COMPUŞILOR METALORGANICI: DESIGN-UL FILMELOR DE OXID

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Oxides have been attracting continuous interest in the study and fabrication of many devices, ranging from optoelectronics, microelectronics, sensors, and detectors, to energy harvesting. The functionality of oxide materials (semiconductors, insulators, metals, ferromagnetics, ferroelectrics) meets the broad needs of materials scientists and electronic engineers. Oxide thin films for use in functional devices are manufactured using a variety of technologies, among which non-vacuum chemistry technologies are attractive due to their low environmental impact, low cost, simple system configuration, and ease of maintenance. Developed by our group, a cost-effective chemical vacuum-free Metalorganic Aerosol Deposition (MAD) technique is a convenient and flexible laboratory tool for materials scientists involved in the synthesis of oxides with an accurate selection of composition and in the development of artificial oxide structures. Here we present a wide range of high-quality oxide materials (thin films, multilayer materials, and composite structures) that have been fabricated using MAD technology.

Single phase films: Starting with the deposition of epitaxial films of manganates to study the effect of colossal magnetoresistance, MAD technology has mastered the production of epitaxial films of other complex oxides (Table 1). The search for new functionality and control (and enhancement) of the parameters of known bulk materials forced the development of methods for obtaining layers of simple oxides (Table 2) used for interfacial engineering. Furthermore, the deposition of wide-bandgap semiconductors based films and their doping became an independent task.

Superlattices: An improvement in magnetic and transport properties of functional oxides by a layer-by-layer selection of the atomic scale composition in special complex oxide superlattices has been proposed. The MAD technology makes it possible to prepare such superlattices based on complex oxides $Pr_{1-x}Ca_xMnO_3$-SrTiO3[1], $La_{1-x}Sr_xMnO_3$-$SrTiO_3$, $La_{1-x}Ca_xMnO_3$-$BaTiO_3$, $Ca_3Co_4O_9$-$Sr_3Co_4O_9$.

Nanocomposites: An alternative approach to properties control is the design of composite two-phase systems, which consists of the controllable modification of properties by strain engineering in epitaxially coupled nanocrystals. Examples of such nanocomposite systems manufactured using MAD technology are $La_{1-x}Sr_xMnO_3$:MgO [2], ZnO: $La_{1-x}Sr_xMnO_3$, VO_2:TiO_2.

Table 1

Complex oxides thin films synthesized by MAD technology

compound	substrate	Electronic properties
Manganites		
$La_{1-x}Ca_xMnO_3$	MgO, $SrTiO_3$	ferromagnetic, metal MIT@260K x=0.3
$La_{1-x}Sr_xMnO_3$	MgO, $SrTiO_3$	metal, ferromagnetic MIT@360K x=0.3
$(La_{1-y}Pr_y)_{1-x}Ca_xMnO_3$	MgO, $SrTiO_3$	ferromagnetic, metal MIT@200K x=0.3, y=0.5
$Pr_{1-x}Ca_xMnO_3$		charge-ordering x=0.5
Cobaltates		
$Ca_3Co_4O_9$	Al_2O_3, $SrTiO_3$	metal
$Ca_2Co_2O_5$	$SrTiO_3$	insulator
$PdCoO_2$	Al_2O_3	metal
Titanates		
$SrTiO_3$	$SrTiO_3$	insulator
$BaTiO_3$	$SrTiO_3$	ferroelectric
Rutinate		
$SrRuO_3$	$SrTiO_3$	metal, ferromagnetic MIT@160K

Table 2

Thin films and monolayers synthesized by MAD technology

Simple oxide	structure	substrates	Electronic property	
ZnO, ZnO:Ga	wurtzite	Al_2O_3, SiO_2/Si	semiconductor	epitaxial, polycrystalline
TiO_2, TiO_2:Nb	rutile, anatase	$SrTiO_3$, $LaAlO_3$	semiconductor	epitaxial, polycrystalline
MgO	cubic		insulator	nanocrystals
SrO, CaO	cubic	$SrTiO_3$	insulator	monolayer
VO_2	rutile	Al_2O_3, SiO_2/Si, fused quartz	metal (T > 340 K)	epitaxial, polycrystalline

Interface engineering and artificial materials: The atomic precision of layer deposition allows MAD technology to solve the problems of AO or BO_2 termination in bulk films with a perovskite ABO_3 structure. Epitaxial films were fabricated from bulk $La_{0.7}Sr_{0.3}MnO_3$ and $La_{0.7}Sr_{0.3}Mn_{0.9}Ru_{0.1}O_3$ decoupled by single SrO_2 or SrO_2-TiO_2-SrO_2 sequence Ruddlesden-Popper layers [3]. The growth of artificial $A_{n+1}B_nO_{3n+1}$ Ruddlesden-Popper structures, which conventional solid-state reaction techniques fail to synthesize for intermediate n-values, so is also a subject of MAD technology.

The issues that are being investigated within the framework of MAD technology today are the study of the control of the epitaxial layers' functional properties by stresses, the preparation of oxygen-deficient compounds, and the effective doping of wide-gap semiconductor oxides.

Referinţe:

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