High Sensitivity Refractive Index Sensor Based on Highly Overcoupled Tapered Fiber-Optic Couplers

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***Abstract*— In this paper, a simple and compact fiber-optic sensor based on an overcoupled tapered fiber coupler is studied. The coupler is fabricated to be operated well beyond the initial coupling cycles, where the rapid exchange of energy between outputs ports enable the fabrication of a highly sensitive device. The suitability and sensitivity of the proposed scheme is demonstrated by measuring refractive index (RI) variations of sugar concentrations in water. The device presents a linear response in terms of power transmission or wavelength shift versus RI changes. The best achieved sensitivity is 0.442 units of normalized transmission per unit of sugar concentration, with a noise detection limit of 0.003 weight percentage of sugar concentration (wt %). From this result the minimum detectable RI change is estimated as 5×10^{-6} RI unit (RIU). The sensor can be also wavelength-encoded, exhibiting a sensitivity of 2171 nm/RIU, maintaining a linear response in a large range of RI. These experimental results are within the best results reported in the framework of fiber couplers and modal interferometer-based RI sensors.**

***Index Terms*— Biconical fiber coupler, refractive index sensor, spectral response.**

I. Introduction

FIBER-OPTIC sensors with high sensitivity and resolution have been the subject of extensive investigations for the measurement of diverse physical and chemical parameters; these parameters include temperature [1]–[3], stress [4]–[6], curvature [7]–[9], and refractive index (RI) [10]–[13]. Among them, we find that fiber coupler based sensors are promising structures since they do not require expensive and complex fabrication procedures, assuming they are fabricated using a standard fusion and pulling technique. Fiber couplers provide two complementary outputs ports that enable a straightforward normalization, i. e. the ratio between the difference and the addition, which compensates for power fluctuations, Beside this, also provide the advantages of compactness, high sensitivity, low-cost, *in situ* measurement and immunity to external electromagnetic interference. In this kind of sensors the coupler transmission response undergoes a shift in wavelength that it is strongly affected by the RI of the surrounding medium due to the evanescent field that is generated along the coupling region [14]. This effect was proposed and demonstrated in early works to develop fiber based refractometers [14], [15]. In recent years, optical sensors based on microfiber directional couplers have been proposed and demonstrated to perform high sensitivity measurements in many practical applications [16]–[23]. For the specific case of fiber coupler based RI sensors, these include fused biconical fibers [24]–[26], microfibers [16], [18], [27]–[30], photonic crystal fibers (PCF) [31]–[33], and specially designed two-core optical fibers [34], [35]. Most of these sensors are presented as wavelength codified and the achieved sensitivities are in the range from 1,125 to 30,100 nanometer (nm) per refractive index unit (RIU), with a detection limit in a range from 4×10^{-4} to 5×10^{-7} RIU, respectively. Amplitude codified sensors have been also reported to provide high resolution [31], [36], [37], with a detection limit between 2×10^{-5} and 4×10^{-6} RIU. However, the sensors with the highest sensitivities and best resolutions are based on PCF and require selective infiltration of holes with the liquid under test, which imposes severe limitations from a practical point of view.

For practical applications, amplitude codified sensors are of particular interest since they do not require special equipment to determine small variations of the RI. To date, several authors have exploited the power transmission dependence to develop a fiber coupler based refractometer [14], [15], [31], [37]. Nevertheless, in those works the authors did not study the conditions for an optimal performance of the reported device. In a previous publication we reported a fused biconical fiber coupler (FBFC) structure for the detection of small variations of RI [36]. In that scheme the coupler transmission was analyzed to find a power transmission response that allows a linear relation between RI changes and the output signal. The coupler was operated within the firsts coupling cycles, and the minimum detectable RI change was estimated as 2.4×10^{-5} RIU. Now in this paper our purpose is to report an improved FBFC scheme that is operated in a regime well beyond the initial coupling cycles; in order to improve the coupler sensitivity. The coupler is fabricated to reach the limits of the experimental implementation. Our study covers the analysis of the sensor in terms of normalized power variations and wavelength shifts; i. e., as amplitude and/or wavelength

Manuscript received October 14, 2016; accepted November 11, 2016. Date of publication November 15, 2016; date of current version December 20, 2016. This work was supported by CONACyT under Grant 222476. The associate editor coordinating the review of this paper and approving it for publication was Dr. Marco Petrovich.

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Digital Object Identifier 10.1109/JSEN.2016.2629281

Thin Solid Films 626 (2017) 55–59

Contents lists available at ScienceDirect

Thin Solid Films

journal homepage: www.elsevier.com/locate/tsf

Complex refractive index of $In_XGa_{1-X}N$ thin films grown on cubic (100) GaN/MgO

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ARTICLE INFO

Article history:
Received 8 October 2016
Received in revised form 14 January 2017
Accepted 7 February 2017
Available online 10 February 2017

Keywords:
Ellipsometry
III-nitrides
Molecular beam epitaxy

ABSTRACT

Spectroscopic ellipsometry measurements of $In_XGa_{1-X}N$ thin films were carried out in the photon energy range from 0.6 to 4.75 eV. The samples were grown on cubic GaN/MgO (100) template substrates by plasma assisted molecular beam epitaxy. Optical properties as the energy gap, refractive index (η) and extinction coefficient (κ) were obtained from the analysis of experimental data by a parametric dielectric function model. Our results show that the behavior of the optical band gap of cubic $In_XGa_{1-X}N$ fits $E_g(x) = 1.407x^2 - 3.662x + 3.2$ eV. The obtained bowing parameter of 1.4 ± 0.1 eV is in good agreement with reported calculated values around 1.37 eV. The complex index of refraction dispersion relations $\eta(\omega)$ and $\kappa(\omega)$ are obtained for the 85–99% mostly cubic $In_XGa_{1-X}N$ films for several In concentrations.

1. Introduction

During the last decade, $In_XGa_{1-X}N$ and $In_XGa_{1-X}N$/III-N heterostructures have attracted considerable attention due to their great potential in technological applications. Their properties such as peak electron velocity, absorption edge, and high thermal stability have been exploited for the manufacture of electronics, photonics and nanotechnology devices [1–3]. Furthermore, the $In_XGa_{1-X}N$ alloy system has the singular possibility of tuning its band gap energy from near UV to IR only by varying the In molar fraction [4,5]. Hence, $In_XGa_{1-X}N$ is specifically suitable in blue-green-red emitting devices, as well as photodetectors, laser and solar cell devices [6–9].

On the other hand, for the technological development of the above devices, it is key the study of vertical transport using basically the double-barrier (DB) formed by thin films. In these structures with stable hexagonal phase (h-$In_XGa_{1-X}N$ alloys), spontaneous and piezoelectric polarizations induce electric fields in the structure that are perpendicular to the growth direction, resulting in tilted energy bands [10]. These built-in fields are undesirable because they decrease the lifetime operation in optical devices. The growth of the meta-stable cubic phase of III-N and $In_XGa_{1-X}N$ alloys (c-$In_XGa_{1-X}N$) is a possibility to avoid these built-in fields, because the cubic crystal symmetry avoids spontaneous polarizations [11]. In addition, it is expected that cubic nitrides have superior electronic properties such as higher carrier mobilities, higher drift velocities, and better doping efficiencies [12,13]. So, several research groups have grown c-$In_XGa_{1-X}N$ films [1,14–21] with different x concentrations. Recently, homogenous c-$In_XGa_{1-X}N$ films with x up to 0.93 have been reported [18].

In the development of semiconductor devices for technological applications, as those mentioned above, the knowledge of key fundamental properties is essential for the design, modeling and understanding of the devices performance. So it is necessary to know the fundamental electrical and optical properties; in the case of c-$In_XGa_{1-X}N$ alloys their electrical properties have been extensively studied, however, optical properties have been barely investigated.

The refractive index for c-$In_XGa_{1-X}N$ was reported by Goldhan et al. in 2000 [14], their results showed the refractive index and the extinction coefficient in the range from 1 to 4 eV for relaxed films only for films with In concentration <0.2. Although different groups have contributed to the study of the optical properties of c-$In_XGa_{1-X}N$ [15,22,23], it has not been possible to define their characteristics for In concentrations >0.4 due to the difficulty to obtain homogenous alloys [24]. The dielectric function of GaN, $In_XGa_{1-X}N$, $Al_XGa_{1-X}N$ and $Al_{1-X}In_XN$ has been mainly reported for hexagonal phase films and the optical parameters reports of cubic nitride alloys are still scarce [25–29].

Therefore, the objective of this work is to determine the dispersion relations for the complex refraction index in the photon energy range from 0.6 to 4.75 eV of mostly cubic $In_XGa_{1-X}N$ films grown on cubic GaN/MgO template substrates for several In molar fractions up to $x = 1$. The complex refractive index, optical energy gap and crystalline quality of $In_XGa_{1-X}N$ were obtained from the experimental data using a multilayer parametric model for the dielectric function.

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http://dx.doi.org/10.1016/j.tsf.2017.02.016
0040-6090/

Deformation behavior of titanate nanotubes subjected to high pressure

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(Received 14 June 2016; accepted 24 December 2016; published online 12 January 2017)

Nano-sized titania (anatase) and sodium and potassium titanate nanotubes were studied via *in situ* Raman spectroscopy at hydrostatic pressures up to 6 GPa. Analysis by scanning electron microscopy shows a uniform dispersion of sodium and potassium cations in the nanotubes. The effect of the pressure was observed by significant shifts in the Raman band structure of nano-sized anatase crystals and nanotube titanate. In nano-particulate anatase, the phonon frequencies (143, 395, 517, and 639 cm^{-1}) increase linearly with pressure. In contrast, the upward frequency shifts in the sodium titanate nanotubes (NaTNT) and potassium-modified nanotubes (NaTNT+K) occur in a stepwise fashion. These stepwise changes occur in the nanotube samples between 2 and 4 GPa (ambient pressure phonon bands in NaTNT at 274, 444, 650, and 906 cm^{-1}) and between 4.5 and 5.5 GPa, (phonons 273 cm^{-1} and 436 cm^{-1} in NaTNT+K at an ambient pressure). Post-pressure high-resolution transmission electron microscopy analysis shows evidence of nanotube distortions and a 5% contraction in the interlaminar spacing of both NaTNT and NaTNT+K. *Published by AIP Publishing.*
[http://dx.doi.org/10.1063/1.4973735]

I. INTRODUCTION

Spectra of nanomaterials with Raman-active phonons yield detailed structural information at the molecular level. In this regard, Raman spectroscopy studies conducted *in situ* with a diamond anvil cell (DAC) is an effective strategy for probing the changes in molecular structure induced under pressure. The properties of nanometric materials can be altered by high pressures[1–4] as they undergo elastic deformation or phase modification. Carbon nanotubes (CNTs) have been extensively studied under high hydrostatic pressure, showing phonon shifts to higher frequency with increasing pressure, due to the high resistance to deformation of the single-wall structure. Structural changes have been reported to occur around a critical pressure of 2 GPa;[1] however, there is controversy on whether the new structure results from the transition of the hexagonal wall structure to a close-packed structure, or to the flattening of the tube walls, whose collapse pressure is diameter dependent.[1–11] In a previous study of single wall carbon nanotube (SWCNT),[12] the radial breathing mode phonon frequency ($\omega_{RBM} = 230\ cm^{-1}$), which provides information on tube diameter and chirality, did not show evidence of phase transitions in the pressure range studied. This led to the conclusion that the change of volume with pressure was consistent with the CNTs maintaining a circular cross section within the 0–4 GPa range.

Raman studies of titanium oxides have been conducted under high pressure with *in situ* Raman spectroscopy. Hearne *et al.*[13] contrasted the behavior at room temperature of bulk titania phases with nanophase material (12 nm grain size) in a DAC for pressures up to 40 GPa. Bulk anatase transforms from tetragonal to an orthorhombic α-PbO_2-type structure near 5 GPa, and then to monoclinic baddeleyite (TiO_2-B) phase at 15 GPa, which is then stable to 35 GPa. Nano-sized anatase crystals, in contrast, maintained their structure to 18 GPa before transforming directly to the baddeleyite structure. The pressure dependence of the four most prominent Raman bands is similar in both bulk and nano-sized anatase, implying a similar compressibility behavior. In heated studies to 1000 °C at an ambient pressure, the most intense E_g mode at 144 cm^{-1}, which arises from O-Ti-O bending-type vibrations[13] exhibited unusual stiffness during heating, in comparison with the other bands observed. In this regard, the other bands are more sensitive to dilatation effects. In anatase nanoparticles, the E_g mode decreases sharply when going from ambient to 2 GPa pressure. The 12 nm grain size is smaller than the critical size deemed necessary for nucleation and growth of the high-pressure α-PbO_2-type structure, explaining how this transition to the intermediate phase in bulk titania is inhibited in the nanomaterial. The authors indicate that one should thus anticipate the formation of new grain boundaries between compacted nanoparticles, a lower free-energy situation than nucleating the α-PbO_2-type structure at an anatase interface. At sufficiently high pressure, the interfacial free energy anatase-baddeleyite is offset by the free energy reduction (volume reduction) in forming the baddeleyite phase. During reduction from 35 GPa back to ambient pressure, both bulk and nanoparticles revert to the intermediate α-PbO_2-type structure. Raman modes specific to

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Growth of HfO_2/TiO_2 nanolaminates by atomic layer deposition and HfO_2-TiO_2 by atomic partial layer deposition

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(Received 9 August 2016; accepted 24 January 2017; published online 9 February 2017)

A novel growth technique, called atomic partial layer deposition (APLD), has been proposed to expand the applications of, and the research in, atomic layer deposition (ALD). This technique allows the possibility for the fabrication of well-controlled alloys on a single atomic layer scale. To demonstrate the capabilities of this technique, samples of HfO_2 and TiO_2 were prepared as conventional ALD nanolaminates through the repeated exposure of the separated metal-precursor and reactant. Subsequently, HfO_2-TiO_2 APLD growth mode samples were obtained by varying the precursor doses and exposure times to obtain a fractional coverage in the monolayer of Hf and Ti. The thickness and structure of the samples were studied by X-ray reflectivity. The surface topography was studied using atomic force microscopy along with Kelvin probe force microscopy for surface potential mapping. Clear differences on the surface, compared with the conventional HfO_2/TiO_2 ALD nanolaminates, were observed, which confirmed the HfO_2-TiO_2 APLD growth. The films were analyzed using X-ray photoelectron spectroscopy (XPS) depth profile scans and angle resolved XPS, where well-defined HfO_2 and TiO_2 contributions were found for both the conventional and APLD mode samples, and an additional contribution, assigned to a ternary phase Hf-Ti-O, in the APLD grown films was observed. This result confirms that Hf and Ti form an alloy in a monolayer by APLD mode growth. *Published by AIP Publishing.* [http://dx.doi.org/10.1063/1.4975676]

I. INTRODUCTION

The fabrication and implementation of alloys of various materials for improved or tunable features, such as optical, electrical, chemical, and structural characteristics, have been the areas of great interest. Various techniques, such as chemical vapor deposition (CVD), sputtering, thermal evaporation, submonolayer pulsed beam epitaxy (SPBE) and others, have resulted in alloys with applications in a variety of fields from semiconductors to medicine. SPBE can be used to tune ternary alloys, such as $Zn_{1-x}Cd_xSe$ quantum wells,[1] where a surface is exposed to Cd, Zn, and Se cycles and only one cell is open at a time followed by a dead time between cycles, which enables excellent control of the quantum well thickness and alloy composition.[2] Atomic layer deposition (ALD) for multilayer structures, such as ZnO/Al_2O_3 stacks, has also been used by adjusting the relative number of ZnO and Al_2O_3 ALD reaction cycles. The features of the structures, such as refractive index, roughness, and resistivity, could be tuned over a full range of values and may be useful in electrical applications.[3,4] Other reports have demonstrated the capability of creating a variety of combinations of metallic alloys, such as Ir-Pt,[5] Pt-Pd,[6] and Co-W,[7] using complete layer-by-layer growth, which suggests that the ALD metal alloy may have a wide range of applications in catalysis, chemical sensors, microelectronics, and various other fields.

In this work, we propose a novel growth technique based on ALD principles that we have called atomic partial layer deposition (APLD) to create well-controlled monolayer alloys. This technique involves (i) varying the doses of metal precursors flowing into the ALD reaction chamber and (ii) varying the exposure times to deposit two or more species on the same surface. In this study, the conventional HfO_2/TiO_2 ALD mode sample and HfO_2-TiO_2 deposited by the APLD mode were compared. This technique is proposed to create well-controlled alloys of oxides by APLD on ALD systems. Chemical states and compositions were studied using X-ray photoelectron spectroscopy (XPS) depth-profile and angle-resolved XPS (ARXPS) measurements. Morphology and surface potential features were studied by atomic force microscopy and Kelvin probe force microscopy (AFM-KPFM), while thickness, density, and the roughness of the different samples were studied by X-ray reflectivity (XRR) measurements.

II. EXPERIMENTAL

The experiments were performed in an automated ALD system that has been conditioned to accommodate up to four precursors. Tetrakis(dimethylamido)titanium(IV) (TDMAT-99.999% purity from Sigma-Aldrich) and Tetrakis (dimethylamido) hafnium(IV) (TDMAHf-99.99% purity from Sigma-Aldrich) were used as precursors, and high purity deionized water was used as an oxidant. The nitrogen used as carrier gas had a purity of 99.999%. p-type (100) Si wafers with ~2.3 nm SiO_2 native oxide were used as the substrate. Prior to deposition, wafers were degreased with acetone in an ultrasonic cleaner and with boiling

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Cite this: *Phys. Chem. Chem. Phys.*, 2017, **19**, 7215

Raman spectra of single walled carbon nanotubes at high temperatures: pretreating samples in a nitrogen atmosphere improves their thermal stability in air

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Received 13th January 2017,
Accepted 17th February 2017

DOI: 10.1039/c7cp00289k

rsc.li/pccp

We present a combined experimental and theoretical study dedicated to analyzing the structural stability and chemical reactivity of single walled carbon nanotubes (SWCNTs) in the presence of air and nitrogen atmospheres in the temperature interval of 300–1000 K. The temperature dependence of the radial breathing mode (RBM) region of the Raman spectra is irreversible in the presence of air, but it is reversible up to 1000 K in a nitrogen atmosphere. Our density functional theory (DFT) calculations reveal that irreversibility is due to partial degradation of SWCNTs produced by dissociative chemical adsorption of molecular oxygen on intrinsic defects of the nanotube surface. Oxygen partially opens the nanotubes forming semi-tubes with a non-uniform diameter distribution observed by Raman scattering. In contrast, heating CNTs in a nitrogen atmosphere seems to lead to the formation of nitrogen-doped SWCNTs. Our DFT calculations indicate that in general the most common types of nitrogen doping (*e.g.*, pyridinic, pyrrolic, and substitutional) modify the location of the RBM frequency, leading also to frequency shifts and intensity changes of the surrounding modes. However, by performing a systematic comparison between calculated and measured spectra we have been able to infer the possible adsorbed configurations adopted by N species on the nanotube surface. Interestingly, by allowing previously nitrogen-exposed SWCNTs to interact with air at different temperatures (up to 1000 K) we note that the RBM region remains nearly unperturbed, defining thus our nitrogen-pretreated SWCNTs as more appropriate carbon nanostructures for high temperature applications in realistic environments. We believe that we have implemented a post-growth heat-treatment process that improves the stability of carbon nanotubes preserving their diameter and inducing a defect-healing process of the carbon wall.

1. Introduction

Given the widespread applications of carbon nanotubes (CNTs) it is very important to understand their behavior under extreme physical conditions.[1–7] In particular, if a heat treatment is needed for the fabrication of a CNT composite, the thermal decomposition behavior of the samples is a key aspect in the integration process. As is well known, due to their high curvature, nanotubes pick up impurities from just standing in different atmospheres or in a solvent. In the case of an air atmosphere, partial opening of carbon nanotubes has been shown to occur due to an oxidation reaction with an activation energy barrier of about 225 kJ mol^{-1}.[8] In addition, thermal annealing of oxidized nanotube samples in the presence of air induces large atomic relaxations together with additional chemical adsorption of O_2 molecules, breaking up new C–C bonds of the tube and leading to a notable degradation of the carbon material.

The changes in the chemical reactivity of CNTs as well as the variation of their electronic and structural properties due to oxidative treatments have been extensively analyzed in the literature. However, we would like to emphasize the following studies. In the infrared reflection and absorption spectroscopic measurements of Bermúdez and Ericson[9] the irreversible effects in the spectra upon oxygen exposure were interpreted in terms of enhanced chemisorption at or near regions of the nanotube wall. Fan *et al.*[10] showed that hole opening in single walled carbon nanotubes (SWCNTs) is dependent on the oxygen environment and the heating process. They suggested that, in slow combustion, the defects in the nanotubes were ignited gradually and that the defects as well as their surroundings burnt slowly reducing the contamination of the nanotubes with carbonaceous dust.

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Thin Solid Films 626 (2017) 55–59

Contents lists available at ScienceDirect

Thin Solid Films

journal homepage: www.elsevier.com/locate/tsf

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ARTICLE INFO

Article history:
Received 8 October 2016
Received in revised form 14 January 2017
Accepted 7 February 2017
Available online 10 February 2017

Keywords:
Ellipsometry
III-nitrides
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http://dx.doi.org/10.1016/j.tsf.2017.02.016
0040-6090/

Growth of HfO_2/TiO_2 nanolaminates by atomic layer deposition and HfO_2-TiO_2 by atomic partial layer deposition

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(Received 9 August 2016; accepted 24 January 2017; published online 9 February 2017)

A novel growth technique, called atomic partial layer deposition (APLD), has been proposed to expand the applications of, and the research in, atomic layer deposition (ALD). This technique allows the possibility for the fabrication of well-controlled alloys on a single atomic layer scale. To demonstrate the capabilities of this technique, samples of HfO_2 and TiO_2 were prepared as conventional ALD nanolaminates through the repeated exposure of the separated metal-precursor and reactant. Subsequently, HfO_2-TiO_2 APLD growth mode samples were obtained by varying the precursor doses and exposure times to obtain a fractional coverage in the monolayer of Hf and Ti. The thickness and structure of the samples were studied by X-ray reflectivity. The surface topography was studied using atomic force microscopy along with Kelvin probe force microscopy for surface potential mapping. Clear differences on the surface, compared with the conventional HfO_2/TiO_2 ALD nanolaminates, were observed, which confirmed the HfO_2-TiO_2 APLD growth. The films were analyzed using X-ray photoelectron spectroscopy (XPS) depth profile scans and angle resolved XPS, where well-defined HfO_2 and TiO_2 contributions were found for both the conventional and APLD mode samples, and an additional contribution, assigned to a ternary phase Hf-Ti-O, in the APLD grown films was observed. This result confirms that Hf and Ti form an alloy in a monolayer by APLD mode growth. *Published by AIP Publishing.* [http://dx.doi.org/10.1063/1.4975676]

I. INTRODUCTION

The fabrication and implementation of alloys of various materials for improved or tunable features, such as optical, electrical, chemical, and structural characteristics, have been the areas of great interest. Various techniques, such as chemical vapor deposition (CVD), sputtering, thermal evaporation, submonolayer pulsed beam epitaxy (SPBE) and others, have resulted in alloys with applications in a variety of fields from semiconductors to medicine. SPBE can be used to tune ternary alloys, such as $Zn_{1-x}Cd_xSe$ quantum wells,[1] where a surface is exposed to Cd, Zn, and Se cycles and only one cell is open at a time followed by a dead time between cycles, which enables excellent control of the quantum well thickness and alloy composition.[2] Atomic layer deposition (ALD) for multilayer structures, such as ZnO/Al_2O_3 stacks, has also been used by adjusting the relative number of ZnO and Al_2O_3 ALD reaction cycles. The features of the structures, such as refractive index, roughness, and resistivity, could be tuned over a full range of values and may be useful in electrical applications.[3,4] Other reports have demonstrated the capability of creating a variety of combinations of metallic alloys, such as Ir-Pt,[5] Pt-Pd,[6] and Co-W,[7] using complete layer-by-layer growth, which suggests that the ALD metal alloy may have a wide range of applications in catalysis, chemical sensors, microelectronics, and various other fields.

In this work, we propose a novel growth technique based on ALD principles that we have called atomic partial layer deposition (APLD) to create well-controlled monolayer alloys. This technique involves (i) varying the doses of metal precursors flowing into the ALD reaction chamber and (ii) varying the exposure times to deposit two or more species on the same surface. In this study, the conventional HfO_2/TiO_2 ALD mode sample and HfO_2-TiO_2 deposited by the APLD mode were compared. This technique is proposed to create well-controlled alloys of oxides by APLD on ALD systems. Chemical states and compositions were studied using X-ray photoelectron spectroscopy (XPS) depth-profile and angle-resolved XPS (ARXPS) measurements. Morphology and surface potential features were studied by atomic force microscopy and Kelvin probe force microscopy (AFM-KPFM), while thickness, density, and the roughness of the different samples were studied by X-ray reflectivity (XRR) measurements.

II. EXPERIMENTAL

The experiments were performed in an automated ALD system that has been conditioned to accommodate up to four precursors. Tetrakis(dimethylamido)titanium(IV) (TDMAT-99.999% purity from Sigma-Aldrich) and Tetrakis (dimethylamido) hafnium(IV) (TDMAHf-99.99% purity from Sigma-Aldrich) were used as precursors, and high purity deionized water was used as an oxidant. The nitrogen used as carrier gas had a purity of 99.999%. p-type (100) Si wafers with ~2.3 nm SiO_2 native oxide were used as the substrate. Prior to deposition, wafers were degreased with acetone in an ultrasonic cleaner and with boiling

Wigner crystallization in quantum wires within the Yukawa approximation

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(Received 21 September 2016; revised manuscript received 6 January 2017; published 28 February 2017)

One crucial and important aspect to account for the nature of the quantum wires is the understanding of the effects associated to many-body interactions between confined electrons. The inclusion of such many-body forces in any theoretical framework is a difficult and computationally demanding task. Then one has to make use of coarse-grained descriptions that allow one to incorporate the contribution of all the electrons. In a simple physical picture, the interaction between two electrons can be considered screened due to the presence of the other ones. If the latter are homogeneously distributed inside the wire, the interaction between the former can then be assumed of the Yukawa form. In this contribution, we report on the lower energy states of n-doped GaAs circular-quantum wires with two electrons in the conduction band interacting through a repulsive Yukawa potential. By varying the length and the electronic density of the wire, quite different trends in the electronic distribution are observed. By changing the material parameters to InSb and InAs nanowires, we found that our results are consistent with available experimental data that have reported the formation of Wigner crystals.

DOI: 10.1103/PhysRevB.95.085437

I. INTRODUCTION

Technological progress in the epitaxial fabrication of semiconductor quantum wires (QWRs) by diverse growth techniques, such as molecular beam epitaxy (MBE) and metal-organic chemical-vapor deposition, have allowed the synthesis of high-quality QWRs of different materials and geometries [1,2]. QWRs possess unique one-dimensional (1D) quantum confinement properties and have emerged as promising structures for the next generation of electronic and optoelectronic devices, for example, photodetectors, solar cells, field-effect transistors, light-emitting diodes, or low-threshold lasers [3–7]. In addition, the strong 1D confinement of electrical carriers, photons, and phonons makes the QWRs very attractive laboratory systems for probing 1D physics of great interest both experimentally and theoretically [8–13] in condensed matter.

Parallel to the experimental advance in the fabrication and characterization of QWRs, a vigorous theoretical modeling area has been developed with an increasing level of sophistication that, nowadays, allows us to gain a deeper understanding of the physical properties of QWRs. Theoretical predictions have shown that the electron-electron (e-e) interactions in 1D electron systems are unique and of importance to account for interesting phenomena. For example, Wigner crystallization is one of the most remarkable many-body effects in 1D systems where electrons spontaneously form a self-organized lattice [14]. The formation of such 1D electronic structure has been predicted by using some complex models, see, e.g., Refs. [13,15–17], and, recently, some experimental signatures of a Wigner crystal have been reported [8–10].

Several studies addressing the single-electron confinement in QWRs of different geometries have been investigated using tight-binding and effective bond-orbital models, as well as classical envelope function schemes like the parabolic band approximation (PBA), the Luttinger model, and the eight-band k-p model [18–21]. On the other hand, the many-body correlations that emerge due to e-e interactions in QWRs have been reported during the last few years within the effective field theory, Hartree-Fock, and the density functional theory approaches [8,12,22–26]. In general, such approaches involve large computational times and complex mathematical calculations when many-body forces are explicitly included and only short wires [elongated quantum dots (QDs)], containing a small number of electrons, have been considered. Furthermore, due to the inherent difficulty of these models to address the many-body effects and to deal with long QWRs, critical values for the electronic concentration and QWR length required to observe the Wigner crystallization phenomenon remains unclear.

One way to overcome the inherent difficulties that arise when many-body interactions are incorporated into the description of QWRs is the use of coarse-grained potentials that are able to capture the effects of many-body forces. In particular, the use of Yukawa-like potentials to address the many-body problem has been extensively used in other branches of physics, such as soft matter [27] and nuclear physics [7]. Surprisingly, the problem of two electrons in a QWR, as far as we know, has not been systematically studied by using a repulsive Yukawa potential even when, at least qualitatively, many experimentally observed trends can be reproduced with this potential model that considers a pair of pointlike particles interacting via a screened Coulomb potential. For instance, in a recent contribution, the screening effects on the binding energy of a neutral donor in parabolic QWRs were studied and authors derived a modified Yukawa potential that takes into account the contribution of the parabolic confining potential [28]. Furthermore, it has been recently shown that the interaction between a pair of electrons in a quasi-one-dimensional electron gas embedded in a semiconductor cylindrical QWR has a Yukawa functional form [29].

The aim of this work is to numerically solve the Schrödinger equation for two nonrelativistic electrons without spin con-

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RSC Advances

PAPER

View Article Online
View Journal | View Issue

Cite this: *RSC Adv.*, 2017, **7**, 17813

Nanowire Y-junction formation during self-faceting on high-index GaAs substrates

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Received 16th February 2017
Accepted 11th March 2017

DOI: 10.1039/c7ra01972f

rsc.li/rsc-advances

A major current focus in nanotechnology is the precise control of the self-assembling of semiconductor structures at the nanometric level. Highly uniform structures such as quantum wires can now be fabricated from the self-assembly of nanometric facet arrays produced using high-index substrates and epitaxial techniques. However, the self-assembling of more complex nanostructures such as Y-junctions is a more involved problem, hindering potential technological applications and one-dimensional physics exploration. In this contribution, we report on the observation of high-order and two-dimensional mechanisms in the Molecular Beam Epitaxy growth of GaAs on (6 3 1) oriented GaAs substrates. These mechanisms allow the formation of a regular alternating pattern of bifurcated nanowires, the Y-junctions. The Y-junction/nanowire arrays have suitable dimensions to form a one-dimensional electron gas device by use of a modulation doping structure with a source, a drain, and gate electrodes. Finally, the potential use of the bifurcated structures for the exploration of one-dimensional transport and as a viable alternative to carbon nanotube Y-junctions is discussed.

1 Introduction

Among the number of growth techniques available to achieve the challenging task of precisely controlling the self-assembling of semiconductor nanostructures such as quantum dots or quantum wires (QWRs), Molecular Beam Epitaxy (MBE) is especially able to produce the ordered formation of crystalline nanostructures. This control can be achieved using tactics, such as the structural stress from dissimilar materials to form quantum dots,[1,2] or by growing on high-index substrates to grow uniform one-dimensional facet (1DF) arrays, which are useful as nano-templates to form QWRs.[3–5] In MBE the growth process is carried out under non-equilibrium conditions, then nonlinear evolution processes, such as step-bunching,[6] meandering instabilities,[7] and coarsening,[8] produce a very rich variety of surface morphologies, which in turn must be understood to precisely control the self-assembly of complex nanostructures.

In previous work, in the homoepitaxy of 1 μm thick layers on GaAs(631)A substrates grown by MBE, at a slow growth rate of 0.3 μm h^{-1}, a high T_g of 700 °C, an optimal As/Ga ratio, and a long deposition time, a quasi-stationary state was established to induce the formation of almost perfect 1DF nanometric arrays in areas of up to 1 × 1 μm^2. Furthermore, a high uniformity in 5 × 5 μm^2 areas presenting 1DF coherent lengths up to 3.6 μm was also achieved,[9] ensuring a one-dimensional (1D) electronic transport length larger than the electronic quantum coherence.[10] Similar results have been reported by other groups by using substrates oriented in different high-index directions.[3,4] However, for areas larger than 1 μm^2 a loss of uniformity is frequently observed, indicating that unknown long-range mechanisms play an important role in the 1DF growth process.

In this work, using long-range mechanisms that are present in the 1DF MBE synthesis on high-index substrates, a method to self-assemble an alternating array of Y-junctions and nanowires is presented.

2 Experimental

In order to induce the formation of uniform nanometric arrays of 1DFs, homoepitaxial layers on GaAs (631)A semi-insulating substrates were grown by MBE, following similar experimental conditions published elsewhere.[9] Prior to the layers' growth, the GaAs wafers were degreased, etched, and then loaded in a Riber 32 MBE system. Once transferred to the growth chamber, the oxide desorption process was carried out at 580 °C for 15 min under As_4 overpressure. Next, a smoothing 100 nm thick GaAs layer was deposited at Ga and As beam equivalent pressures (BEPs) of 4 × 10^{-7} Torr and 5.5 × 10^{-6} Torr, respectively, at a growth temperature (T_g) of 600 °C. Finally, T_g was increased to

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Estimation of the instable composition areas and its dependence on the thickness of GaInAsSb layers grown on different substrates

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Abstract. In this work we inform about the results of estimations of the changes of the spinodal decomposition areas and its dependence on the thickness of epitaxial layers. The calculations have been performed using the CALPHAD method and the SGTE data taking into account the elastic energy generated by the lattice mismatch between forming solid solutions and substrate. We have shown that in thin layers the elastic energy may serve both as a stabilizing factor for compositions inside the immiscibility region but lattice matched, or close, to the substrate and, on the contrary, as a reason of instability for the compositions laying in the periphery of the miscible regions.

1. Introduction

In different III-V solid solutions systems, growth within decomposition spinodal areas can produce layers with composition modulated regions [1-3] of the order of several tens of nanometers [4,5]. Such layers can serve to form low-dimensional heterostructures in the fabrication of advanced optoelectronic devices [1]. However, the instability of the solid phase inside the spinodal decomposition area can impose restrictions on the growth of alloys with certain compositions. These restrictions limit the wavelengths in which photovoltaic devices, lasers or photodetectors could be fabricated. This is clearly seen on the example of the III-V solid solutions containing Sb [2,3]. At different times, different authors have calculated spinodal decomposition areas [4-6]. However, the results of experimental studies show some disagreement with the calculated data. In addition, it was shown experimentally that instability of layers grown within the miscibility gap depend on their thickness [7].

The object of this work is to estimate the variation of the miscibility gaps when the thickness of the grown layers change, taking into account their mismatch with the substrate. The calculations have been performed for the GaInAsSb quaternary system, as an example. GaAs, InAs, InP and InSb were chosen as substrates for the formation of the layers.

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Materials Research.
DOI: http://dx.doi.org/10.1590/1980-5373-MR-2016-0181

Structural Characterization of ZnTe Grown by Atomic-Layer-Deposition Regime on GaAs and GaSb (100) Oriented Substrates

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Received: February 29, 2016; Revised: October 21, 2016; Accepted: November 21, 2016

This work presents the characterization of ZnTe nanolayers grown on GaAs and GaSb (100) substrates by the Atomic Layer Deposition (ALD) regime. Under certain conditions, the alternating exposition of a substrate surface to the element vapours makes possible the growth of atomic layers in a reactor where the atmosphere is high-purity hydrogen. ZnTe was grown simultaneously on GaAs and GaSb at the same run, allowing, a comparison between the effects produced by the superficial processes due to the different used substrates, thereby eliminating possible unintended changes of growth parameters. Nanolayers on GaSb maintained their shiny appearance even at temperatures near 420°C. It was found that for exposure times below 2.5 s there was not growth on GaAs, while for GaSb the shortest time was 1.5 s at 385°C. By HRXRD the peak corresponding to (004) diffraction plane of ZnTe was identified and investigated, the FWHM resulted very wide (600-800 arcsec) indicating a highly distorted lattice mainly due to mosaicity. Raman scattering shows the peak corresponding to LO-ZnTe, which is weak and slightly shifted in comparison with the reported for the bulk ZnTe at 210 cm^{-1}. Additionally, the measurements suggest that the crystalline quality have a dependence with the growth temperature.

Keywords: *Atomic Layer Deposition, nanolayers, X-ray diffraction, Raman scattering*

1. Introduction

Nowadays, most of the modern electronic devices are based on the growth of nanometric layers, strained or not; superlattices, quantum wells, optical modulators, hot-electron transistors, are only a few examples of the wide field of application of them[1-4]. Among the most successful semiconductor materials for the radiation detection, ZnTe has excellent optical properties as its quantum efficiency. ZnTe has proved to be a very successful material for the radiation detection in its bulk form although is a promising material for radiation detection in its nanolayers form[5,6]. The layer by layer growth regime can be implemented by a precise control of the precursor flows in systems as CVD, MOCVD, MBE, Radical-Enhanced ALD[7,10]. Normally, this is done by exposing the substrate, in an alternating way to the vapour of each one of the constituent elements of the layer, followed by a purge or dead period between exposures in order to evacuate adequately the growth chamber. An important characteristic of ALD is its self-regulated nature[7-10]. In this work are presented the results obtained of the growth and characterization of ZnTe epitaxial layers on GaSb and GaAs by ALD regime under an ambiance of high purity hydrogen at atmospheric pressure.

2. Experimental Procedure

The growth system used in the experiments is depicted in Figure 1, which has a horizontal geometry; the body of the reactor is made of a quartz tube while the suceptor is made of high purity graphite. The experiments were performed using a high purity Pd-Ag diffused hydrogen flow of 300 ml/min.

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Available online at www.sciencedirect.com

Journal of Applied Research and Technology

Journal of Applied Research and Technology 15 (2017) 140–142

www.jart.ccadet.unam.mx

Original

Vision-aided system for obtaining a required weight by efficient choice of irregular fragments

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Received 27 June 2016; accepted 23 January 2017
Available online 15 March 2017

Abstract

There are some situations when it is necessary to weigh, with high accuracy and high precision, a required amount of material using heterogeneous and irregular pieces. As an example, in the laboratory, when preparing a liquid phase epitaxial growth, each of the materials that constitute the liquid phase must have an exact weight, within micrograms, given by the phase diagrams. The sources of the materials usually are small polycrystalline pieces of irregular shapes and random weights. Normally the weighing is done by interchanging the small irregular pieces of different sizes according to the criteria of the operator until the given weight is obtained. This is a long and tedious process and since each liquid solution requires several components, and a different liquid phase is needed for each layer, very often weighing it takes several hours. This operative process is prone to errors. To ease this kind of processes, a vision-assisted system has been developed. It consists of a webcam, an analytical balance and a PC. To use this assembly the operator only needs to put sequentially the pieces of the material in the analytical balance. When the required weight can be obtained by a combination of some of the pieces added to the analytic balance, the PC notifies the operator and signals the selected pieces in the screen. With the help of this system, the weighing accuracy has been improved and the time required to accomplish the process has been dramatically reduced.

Keywords: Arrays; Data acquisition; Data visualization; Image recognition; Machine vision

1. Introduction

The exact weighing of a required amount of certain materials can be a frustrating and tedious task if the material is given in irregular pieces of different weights and shapes. Such is the case in the preparation of experiments for the growth of semiconductor heterostructures using the liquid phase epitaxial (LPE) technique (Mishournyi, Hernández, Gorbatchev, & Lastras, 2002).

In this kind of experiments each layer is grown from a specific multicomponent liquid solution. To prepare the solution with an exact composition, given by the phase diagrams, it is necessary to weigh each component with high accuracy.

A further complication arises because a large number of pieces of each component increases the risk of losing one piece during the following steps of the growth experiment and so the maximum number of pieces allowed of each component of the solution is usually limited to 3–4.

Normally this process is carried out by an operator that judiciously changes the weighed pieces according to his own experience until the required weight is reached.

Since each liquid solution can have up to five components and normally several liquid solutions are required for one heterostructure, the weighing process can take several hours and thus it is prone to errors committed by the operator.

To facilitate the weighing process, and to reduce the weighing time, a system has been built which consists of an analytic balance, a webcam and a PC (Sánchez Niño, 2009).

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Peer Review under the responsibility of Universidad Nacional Autónoma de México.

http://dx.doi.org/10.1016/j.jart.2017.01.003

Sensors and Actuators B 238 (2017) 880–887

Contents lists available at ScienceDirect

Sensors and Actuators B: Chemical

journal homepage: www.elsevier.com/locate/snb

High sensitivity bolometers from thymine functionalized multi-walled carbon nanotubes

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ARTICLE INFO

Article history:
Received 18 April 2016
Received in revised form 27 June 2016
Accepted 16 July 2016
Available online 25 July 2016

Keywords:
Bolometer
Thymine
Carbon nanotube
TCR

ABSTRACT

In this work, thin films of thymine functionalized MWNT (t-MWNT) were prepared and systematically characterized in their thermal and electrical response in order to determine the proper conditions for them to have optimum bolometric properties. It was found that t-MWNT, deposited in dried layers 5×6 mm and 0.53 ± 0.05 μm in thickness, on top of silicon wafers, provided the best characteristics to function as bolometric materials. One of the key resultant figures of merit, the Temperature Coefficient of Resistance (TCR or α), which is measured in percent change of resistance per degree Kelvin was found to be -5.6 ± 0.1%/K. Typical measured response times of these thermal devices ranged from 0.8 to 1.6 ms. This indicates that these bolometer materials can be modulated at frequencies above 1 kHz. The responsivity (R_v) and specific detectivity (D^*) at the optimal bias voltage of 1 V and at 100 Hz were $R_v = 252 \pm 4$ V/W, and $D^* = (2 \pm 0.2) \times 10^6$ cmHz$^{1/2}$/W. Both results are among the largest for MWNT based bolometer devices; however the specific detectivity observed is smaller than that for bolometric devices prepared with SWNT. The t-MWNT's have their optimal specific detectivity response for 0.75 and 1.0 V bias voltages examined, in the frequency range above 1 kHz.

1. Introduction

The detection of terahertz (THz) and infrared radiation (IR) is of great relevance for a growing list of imaging, biomedical and industrial applications. Several examples are early detection of biological abnormalities in humans as well as in animals and living tissue samples, night vision sensors, early warning fire detection systems, and search and rescue equipment. Bolometric detectors are primarily used for the detection of FIR and THz radiation. These devices operate by absorbing incident radiation, which results in a small change of its temperature, which in turn produces a change in its electrical resistance. The resistance can increase or decrease depending on the Temperature Coefficient of Resistance (TCR) of the active material, which can be subsequently transduced, amplified, electronically processed and digitally recorded.

In general, bolometers have smaller specific detectivities than optoelectronic devices, photoconductive or photovoltaic, however these last typically require cooling to operate efficiently. Therefore for many every day applications bolometers are the best practical option to detect electromagnetic FIR and THz radiation [1], where uncooled detectors are necessary.

Researchers have previously reported that carbon nanotubes (CNT) have promising bolometric properties [2–4]. An excellent review of the state of the art of CNT uncooled photodetectors and bolometers, may be found in Ref. [5].

One wall CNT or SWNTs constitute quasi-one dimensional structures with remarkable electric properties resulting from their fully conjugated pi network along with optical and mechanical characteristics advantageous for sensor technologies [3,4]. CNTs possess a large surface to volume ratio, chemical stability, tensile strength, and concomitantly large elastic response, making them attractive materials for many technological applications. The work reported herein takes advantage of the fact that CNTs have very large IR absorption coefficients, (larger than 70% in CNT layers of 100 nm in

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http://dx.doi.org/10.1016/j.snb.2016.07.081
0925-4005/

Organic Electronics 45 (2017) 159–168

Contents lists available at ScienceDirect

Organic Electronics

journal homepage: www.elsevier.com/locate/orgel

Flexible rewritable organic memory devices using nitrogen-doped CNTs/PEDOT:PSS composites

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ARTICLE INFO

Article history:
Received 30 December 2016
Received in revised form
8 March 2017
Accepted 9 March 2017
Available online 10 March 2017

Keywords:
N-MWCNTs
Resistive organic memory devices
Al oxide
PEDOT:PSS
Flexible substrates

ABSTRACT

Nonvolatile rewritable organic memory devices based on poly(3,4-ethylene dioxythiophene):poly(styrenesulfonate) (PEDOT:PSS) and nitrogen doped multi-walled carbon nanotube (NCNT) nanocomposites were fabricated on glass and PET substrates.

Organic memory devices with bistable resistive switching were obtained using very low NCTN concentration (~0.002 wt%) in the polymeric matrix. The memory devices exhibited a good ON/OFF ratio of approximately three orders of magnitude, a good retention time of 10^4 s under operating voltages $\leq |4V|$ and a few hundredths of write-read-erase-read cycles. The bistable resistive switching is mainly attributed to the creation of oxygen vacancies. These defects are introduced into the thin native Al oxide (AlOx) layer on the bottom electrode during the first voltage sweep. The well-dispersed NCNTs immersed in PEDOT:PSS play a key role as conductive channels for the electronic transport, hindering the electron trapping at the AlOx-polymer interface and inducing a soft dielectric breakdown of the AlOx layer. These PEDOT:PSS + NCNTs memory devices are to easy to apply in flexible low-cost technology and provide the possibility of large-scale integration.

1. Introduction

Currently, flexible electronics has become very attractive for the next generation of electronic devices, particularly wearable and foldable applications due to their bendable properties [1]. Nonvolatile memory devices [2–7], field effect transistors [8,9], light-emitting diodes [10,11], logic circuits [12], static random access memories [13] and other devices using organic materials have been fabricated onto flexible substrates, allowing their application in large area electronics [14] and in the Internet of Things [15]. In particular, polyethylene terephthalate (PET) has been used as a substrate in various electronic applications because of its low cost, good thermal stability, excellent transparency in the visible range and good mechanical flexibility [2,3,5,7–9,16].

Among the various organic electronic devices, one of the most studied is the resistive memory [15,17,18]. Organic rewritable resistive memories consist of a polymer layer or a polymer composite sandwiched between two metal electrodes, which can be switched several times between two different conductive states using voltage pulses or voltage sweeps [19,20]. These organic resistive devices are becoming an alternative to the conventional memory technology due to the possibility of device miniaturization using scalable cross-bar array architecture, good operation speed and low energy consumption [15,17,18]. In addition, the fabrication of organic memories is easy and inexpensive, and the flexibility of the organic materials allows their deposition on either polymeric substrates or other unconventional substrates [2,5,7]. A variety of organic materials have been used for the fabrication of resistive organic memories [15,17,18], of which the most interesting are the carbon nanostructures [3,21–27]. In some cases, these carbon nanostructures, such as graphene oxide, reduced graphene oxide and graphene grown by CVD, are used as the resistive switching layer [3,21,22]. In other cases, these nanostructures are embedded in polymer matrices [23–27]. In some of these works the presence of native Al oxide layer (AlOx) is crucial for the resistive switching [18,20,22,27]. Nanocomposites of carbon nanostructures in a polymer matrix sandwiched between two metal electrodes have

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http://dx.doi.org/10.1016/j.orgel.2017.03.014
1566-1199/

Experimental multi-scroll attractor driven by switched systems

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Received 18 May 2016; accepted 6 December 2016

This article deals with an electronic implementation of a 3-D dynamical system that comprises multiple scrolls and is regarded as unstable dissipative system. Such a system is dissipative in one of its components but unstable in the other two. The proposed electronic circuit is implemented with resistors, capacitors and comparators and has the capability to generate two or three scrolls

Keywords: Phase portrait; Analog electronic; Differential equations; Operational Amplifier.

Este artículo trata de la instrumentación de un sistema dinámico 3-D que puede presentar múltiples enroscados, cual se ha denominado sistema disipativo inestable. Este sistema es disipativo en uno de sus componenets pero inestable en los otros dos. El circuito eléctrico propuesto esta constituido por resistencias, capacitores y comparadores. Este circuito es capaz de generar dos y tres enroscados.

Descriptores: Retrato de fase; electrónica analógica; ecuaciones diferenciales; amplificadores operacionales.

PACS: 02.10.Yn; 02.30.Hq; 02.10.Ab; 84.30.Sk; 84.30.Le

1. Introduction

In the last two decades, theoretical design of different kind of electronic circuits based on chaos have been a central subject. In this regard, the design of multi-scroll chaotic attractor is a challenging issue. Therefore, there are different choices concerning the implementation of chaotic circuits and one of them is the synthesis of electronic circuits with the capability of generating multi-scroll chaotic attractors. One idea is to modify a system that originally produces double-scroll attractors in such a way that multi-scrolls arise; as for example in the Chua and Lorenz systems [1-4]. As a matter of fact, Suykens and Vandewalle introduced several methods for generating n-scroll chaotic attractors using simple circuits [5,6]. Likewise, Yalcin and his colleagues [7] also reported work on multi-scroll chaotic attractors. Therefore, one of the main goals of chaotic systems is the search for alternatives to manipulate the number of scrolls in attractors without losing its dynamical behavior. Hitherto, different techniques are well established in the design of such systems, such as the modification of a simple sinusoidal oscillator [8], the improvement of existing chaotic systems [9-12] and through multi-fractal processes [13], among others.

In addition, new mechanisms of chaotic system generation have been reported from a theoretical viewpoint [14-17]. A simple technique is carried out in controlled systems by a switching control law [14], aimed at changing the switching control law in order to add further equilibria to the system, where each equilibrium point generates a scroll around it.

In this work, we propose an electronic implementation of a class of 3-D dynamical systems as already reported in Ref. 14. This class of systems is termed unstable dissipative systems (UDS) because it is dissipative in one of its components while unstable in the other two. The UDS are constructed with a switching law in order to accomplish several multi-scroll strange attractors. The strange multi-scroll attractors appear as a result of the combination of several unstable "one-spiral" trajectories. Each of these trajectories lie around a saddle hyperbolic stationary point.

This work is organized as follows. In Sec. 1, both the UDS and the switching law are presented in order to produce multi-scroll chaotic attractors. The proposed electronic circuit of multi-scroll chaotic attractors using this approach is given in Sec. 2. Experimental results are given in Sec. 3, and conclusions are outlined in Sec. 4.

2. Unstable Dissipative Systems

We consider a linear system given by:

$$\dot{X} = AX, \tag{1}$$

where $X = [x_1, \cdots, x_n] \in \mathbb{R}^n$ is a state vector and $A \in \mathbb{R}^{n\times n}$ is a linear operator. The equilibrium point of this system is located at the origin which is a saddle hyperbolic stationary point. Thus, one feature of matrix A relies on two generated manifolds, one stable E^s and another unstable E^u.

If the system given by Eq. 1 has a saddle equilibrium point responsible for unstable and stable manifolds and the sum of its eigenvalues is negative, then the system is called unstable dissipative system (UDS). In [14,15] two types of UDS in $\mathbb{R}^3$ and two types of corresponding equilibria are defined.

Definition 2.1 *A system given by Eq. 1 in $\mathbb{R}^3$ with eigenvalues λ_i, $i = 1, 2, 3$, is said to be an UDS Type I,* if

Metrol. Meas. Syst., Vol. 24 (2017), No. 1, pp. 19–26.

PAN POLSKA AKADEMIA NAUK

METROLOGY AND MEASUREMENT SYSTEMS

Index 330930, ISSN 0860-8229

www.metrology.pg.gda.pl

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MEASUREMENTS OF CONCENTRATION DIFFERENCES BETWEEN LIQUID MIXTURES USING DIGITAL HOLOGRAPHIC INTERFEROMETRY

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Abstract

We present an alternative method to detect and measure the concentration changes in liquid solutions. The method uses *Digital Holographic Interferometry* (DHI) and is based on measuring refractive index variations. The first hologram is recorded when a wavefront from light comes across an ordinary cylindrical glass container filled with a liquid solution. The second hologram is recorded after slight changing the liquid's concentration. Differences in phase obtained from the correlation of the first hologram with the second one provide information about the refractive index variation, which is directly related to the changes in physical properties related to the concentration. The method can be used – with high sensitivity, accuracy, and speed – either to detect adulterations or to measure a slight change of concentration in the order of 0.001 moles which is equivalent to a difference of 0.003 g of sodium chloride in solutions. The method also enables to measure and calculate the phase difference among each pixel of two samples. This makes it possible to generate a global measurement of the phase difference of the entire sensed region.

Keywords: Digital Holographic Interferometry, refractive index measurements, phase difference, full-field measurements.

1. Introduction

Liquid mixtures can be classified based on their physical properties such as concentration, weight, colour, and boiling temperature, among others [1]. The concentration of a liquid solution refers to the amount of solute (in moles or mass) dissolved in a certain quantity of solvent [2]. Methods and tools for accurate measurements that can detect slight concentration variations are greatly important for science, regulatory agencies, food processors, and consumers. Expensive liquids , including olive oil, fruit juices, honey, alcoholic drinks, and gasoline, are especially vulnerable to adulteration. For this reason, a fast and accurate technique is required to validate the concentrations of products or liquid mixtures. Optical techniques are non-destructive and are generally preferred for this purpose.

The index of refraction is one of the most important optical properties of an object [3]. In liquid solutions, this parameter is unique and proportional to the concentration of a substance [4]. Commonly, the refractive index is determined using Snell's law, which involves the displacement of the angle of an incident beam with respect to a refracted beam by a phase object. Some methods based on this law use prisms [5–8], squares [9, 10], and special containers [11]. However, these methods require a good estimation of the angles, which reduces their accuracy. Other disadvantages are that they use only a small region (scarcely a point) to obtain

Article history: received on Dec. 03, 2015; accepted on Aug. 28, 2016; available online on Mar., 10, 2017; DOI: 10.1515/mms-2017-0002.

Hindawi Publishing Corporation
Complexity
Volume 2017, Article ID 7157943, 10 pages
https://doi.org/10.1155/2017/7157943

Research Article

On the Emergence of Islands in Complex Networks

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Received 6 July 2016; Revised 9 November 2016; Accepted 12 December 2016; Published 16 January 2017

Academic Editor: Pietro De Lellis

Most growth models for complex networks consider networks comprising a single connected block or island, which contains all the nodes in the network. However, it has been demonstrated that some large complex networks have more than one island, with an *island size distribution* (I_s) obeying a power-law function $I_s \sim s^{-\alpha}$. This paper introduces a growth model that considers the emergence of islands as the network grows. The proposed model addresses the following two features: (i) the probability that a new island is generated decreases as the network grows and (ii) new islands are created with a constant probability at any stage of the growth. In the first case, the model produces an *island size distribution* that decays as a power-law $I_s \sim s^{-\alpha}$ with a fixed exponent $\alpha = 1$ and in-degree distribution that decays as a power-law $Q_i \sim i^{-\gamma}$ with $\gamma = 2$. When the second case is considered, the model describes island size and in-degree distributions that decay as a power-law with $2 < \alpha < \infty$ and $2 < \gamma < \infty$, respectively.

1. Introduction

Research in complex networks (CN) has risen in interest and importance given that many natural and artificial systems can be abstracted, modeled, and analyzed using this type of networks. Examples of such systems are numerous: neuron connectivity [1], the plant pollination process [2], gene inheritance [3], metabolic interactions [4, 5], highway and road networks [6], emails [7], sexual partners [8], and many others.

Before 1998, most networks were studied using the random network model, which assumes that each node randomly chooses other nodes to get connected. This random selection process produces certain topological properties [9]. For example, both the in-degree and out-degree distributions may approximate either a Poisson or an exponential function [9].

Random models were employed before real data became available which allowed to verify the properties and characteristics obtained from this model. Still, it was difficult to emulate the behavior of real networks because many of the factors needed to perform these simulations were unknown. It is under this context that Paxon and Floyd published an article where they described the main difficulties in simulating the Internet [10].

A new insight was provided by Redner in 1998, when he published a study about the distribution of citations in scientific publications [11]. In his study, publications are described as a network, where an article is represented as a node and the citations between papers are represented as a network edge. Redner discovered that the tail of the citation distribution decays as a power-law with an exponent $\gamma = 3$.

In 1999, Faloutsos et al. published important topological properties occurring in the Internet [12]. Among the most interesting ones is the conclusion that the Internet's out-degree and in-degree distributions at the autonomous system scale follow a power-law distribution [12]. In that same year, Adamic et al. showed that the WWW also follows a power-law distribution in some of its topological properties [13].

Device, Circuit, And Module Fabrication

Efficiency of broadband terahertz rectennas based on self-switching nanodiodes

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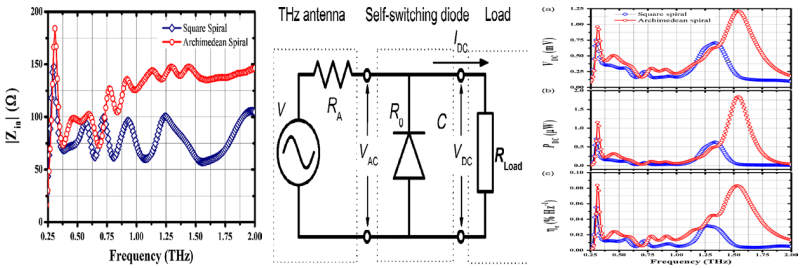
J. Photon. Energy. 7(2), 025001 (Apr 27, 2017). doi:10.1117/1.JPE.7.025001

History: Received December 16, 2016; Accepted March 31, 2017

Abstract

Abstract | Introduction | Self-switching Diodes for Square Law-Rectification |Rectennas Based on Self-switching Diodes | Rectennas Frequency Response |Conclusion | Acknowledgments | References

Abstract. The authors investigate the efficiency of a series of broadband rectennas designed to harvest the free-propagating electromagnetic energy at terahertz frequencies. We analyze by simulations the case of self-complementary square- and Archimedean-spiral antennas coupled to L-shaped self-switching diodes (L-SSDs). First, the geometry (i.e., the width and length of the channel) of the L-SSD was optimized to obtain a remarkable diode-like I–V response. Subsequently, the optimized L-SSD geometry was coupled to both types of spiral antennas and their characteristic impedance was studied. Finally, the energy conversion efficiency was evaluated for both rectenna architectures.



Journal of Crystal Growth xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Journal of Crystal Growth

journal homepage: www.elsevier.com/locate/crys

Strain and anisotropy effects studied in InAs/GaAs(221) quantum dashes by Raman spectroscopy

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ARTICLE INFO

Article history:
Available online xxxx
Communicated by Jean-Baptiste Rodriguez

Keywords:
A1. Nanostructures
A1. Stresses
A1. Crystal structure
A1. Characterization
A3. Molecular beam epitaxy
B2. Semiconducting III-V materials

ABSTRACT

Quantum dashes were synthesized in the molecular beam epitaxial growth of InAs on GaAs(221). By changing the arsenic pressure it was possible to obtain highly ordered one-dimensional InAs arrays as demonstrated by autocorrelation function analysis. Polarized Raman spectroscopy was utilized in order to characterize the samples and to estimate the stress at the InAs/GaAs interface as well as the surface anisotropy imposed by the quasi one-dimensional character of the quantum dashes. The most ordered surface, showed the lowest correlation length, and for this sample the Raman spectra exhibits small shift of the GaAs resonance modes indicating likewise small GaAs tensile strain.

1. Introduction

During the last two decades, the semiconductor nanostructures have been the subject of diverse studies since they are expected to improve the properties of laser diodes, solar cells, low dimensional transistors, etc. As a particular kind of nanostructure, the InAs/GaAs quantum dots (QDs) are the most studied nanostructures due to their potential applications in optoelectronic devices [1–3]. Usually, the formation of self-assembled QDs has been strain driven by employing the Stranski–Krastanov growth mode in the molecular beam epitaxial (MBE) growth of InAs on GaAs(100). The strain force causes transition from two-dimensional growth mode to the formation of islands, which is expected nominally after the deposition of 1.7 InAs monolayers (ML). Furthermore, it has been demonstrated that additional order during the self-assemblage of the nanostructures can be propitiated with the use of high-index substrates allowing the synthesis of one-dimensional InAs systems, like quantum wires (QWRs) and quantum dashes (QDHs) [3,4]. This particular 1D arrangement involves also different mechanisms of strain distribution, quantum confinement effects, and surface anisotropy. All of these effects are of great interest, with the aim to eventually tailor the nucleation of the semiconductor nanostructures. On the other hand, Raman spectroscopy (RS) has been used for the study of a wide variety of nanostructures since it is a powerful technique used to provide valuable information about the characteristic phonon modes and structural properties of semiconductors such as strain and confinement parameters [5,6]. It is worth commenting that RS is very sensitive to the topmost layers, which make it a valuable tool for the study of surface 1D systems like QWRs and QDHs.

In this work InAs quantum dashes were synthesized during the molecular beam epitaxial growth on GaAs(221)-oriented substrates. The geometry of the quantum dashes was tailored by changing the As-beam equivalent pressure during the GaAs and InAs growth. After the growth, polarized Raman spectroscopy was utilized in order to evaluate both, the strain status near surface and the surface anisotropy imposed by the quasi one-dimensional character of the quantum dashes.

2. Experimental

Before being loaded into the MBE system semi-insulating GaAs (221)B substrates were etched in a "Semico Clean" (Furuuchi Chemical Corp., Japan) solution and then pre-degassed at 380 °C under UHV environment for 15 min. Once transferred to the growth chamber, the oxide desorption process was carried out at 640 °C for 20 min under As_4 flux. A half micrometer thick GaAs

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http://dx.doi.org/10.1016/j.jcrysgro.2017.04.004
0022-0248/