COST Meeting IC 1208
University of Luxembourg
Luxembourg,
March 16-17, 2017

DAY 1 - 16/03/2017

TIME	№	SESSION	SPEAKER
8:30 - 9:00		**Registration**	
9:00 - 9:10		**Opening (welcome by FSTC dean and by Giusy Scalia)**	Local Organisers
9:10 - 10:00		**MC Meeting**	Action Chair/ Grant Holder
10:00 - 11:00		**Presentations**	
10:00-10:20	1	Training School: Photonics Integration: advanced materials, new technologies and applications (Erice)	Antonio D'Alessandro
10:20-10:40	2	Bent-Core Liquid Crystalline Dimers	Vladimira Novotna
10:40-11:00	3	Ferroelectricity and Helicity in the achiral bent-core Liquid crystals	Sithara Sreenilayam
11:00 - 11:30		**Coffee Break**	
11:30 - 13:00		**Presentations**	
11:30-12:00	4	Tutorial: Gravimetric biosensors: an overview	Enrique Iborra
12:00-12:20	5	STSM: Film Bulk Acoustic Resonators Based on Scandium Doped Aluminum Nitride	Michael Schneider
12:20-12:40	6	STSM: Biocompatible chromonic liquid crystals for photonic sensors:alignment studies and applications	Caterina Maria Tone
12:40-13:00	7	New liquid crystalline elastomers investigated by Deuterium NMR and X-ray diffraction measurements	Valentina Domenici
13:00 - 14:10		**Lunch**	
14:10 - 16:50		**Presentations**	
14:10-14:40	8	Tutorial: Introduction to synthesis of Liquid Crystals	Przemysław Kula
14:40-15:00	9	STSM: Study of electro-optical properties of liquid crystal devices by doping with titanium dioxide nanoparticles	Braulio Garcia-Camara
15:00-15:20	10	Experimental and numerical analysis of lattice plasmon modes in substrate-supported gratings of monomers & dimers	Joseph Marae Djouda
15:20-15:30		Short break (10 minutes, no coffee)	
15:30-15:50	11	Optoelectronic devices with liquid crystals and PDMS channels	Rita Asquini
15:50-16:10	12	Plasmonic nanogaps through 2 applications: nanolight sources and enhanced Raman sensing	Jean-Sebastien G Bouillard
16:10-16:30	13	Dielectric and phonon studies of cobolt ferrite doped lead zirconium titanate multiferroic composites	Robertas Grigalaitis
16:30-16:50	14	Dielectric properties of multiferroic ceramics of the Bi1-xLaxFe0.50Sc0.50O3 metastable solid solutions system	Juras Banys
16:50 - 17:10		**Coffee Break**	
17:10 - 18:30		**Presentations**	
17:10-17:30	15	The inversion phenomenon of the helical twist sense in antiferroelectric liquid crystal pure compounds	Michał Czerwiński
17:30-17:50	16	Temperature dependence on helical pitch in liquid crystalline mixtures of compounds differing in the length of chiral chain	Anna Drzewicz
17:50-18:10	17	Soft solution synthesis of Ga-doped ZnO nanostructures with controlled morphology	Pablo Gil Villanueva
18:10-18:30	18	Linear Electro-optic Response in non-Chiral Bent-Core Liquid Crystalline Systems	Yuri Panarin
20:00 h		**Dinner**	

DAY 2 - 17/03/2017

TIME	Nº	SESSION	SPEAKER
8:50- 9:00		**Signature Attendance List**	
9:00 - 10:50		**Presentations**	
9:00-9:30	19	Tutorial: The Active Plasmonics Paradigm	Roberto Caputo
9:30-9:50	20	STSM: The Effects of Area on The Performance of Solidly Mounted Resonators	Ngoc Nguyen
9:50-10:10	21	Narrowband terahertz transmission filters based on guided mode resonant gratings	Dimitrios Zografopoulos
10:10-10:30	22	STSM: Helical pitch, tilt angle & spontaneous polarization measurements of chosen ferroelectric liquid-crystalline mixtures	Katarzyna Kurp
10:30-10:50	23	STSM: Tunable Hybrid Liquid Crystal Metamaterial Systems for Photonic Applications	Oleksandr Buchnev
10:50 - 11:10		**Coffee Break**	
11:10 - 13:00		**Presentations**	
11:10-11:40	24	Tutorial: Tuning properties in electroceramics by composition and microstructural control	Lavinia Curecheriu
11:40-12:00	25	Planar nano-structured silicon lenses for optical manipulation	Georgiy Tkachenko
12:00-12:20	26	Design of new liquid crystalline materials with definite properties	Alexey Bubnov
12:20-12:40	27	Synthesis & properties of chosen 4-butyl-phenyltolane derivatives	Jakub Herman
12:40-13:00	28	Tamm plasmon modes on semi-infinite metallodielectric superlattices	Goran Isic
13:00 - 15:00		**Lunch**	
15:00 - 16:40		**Presentations**	
14:30-14:50	29	Investigation of dielectric properties of liquid crystals with the non-uniform structure	Vladimir Venediktov
14:50-15:10	30	Rotation of Light Polarization from Aligned Carbon Nanotube Sheets	Asiqur Rahman
15:10-15:30	31	Optical and magneto-optical sensors based on plasmon resonance	Volodymyr Tkachenko
15:30-15:50	32	Effect of porosity on nonlinear dielectric properties of BaTiO3 porous ceramics	Leontin Padurariu
15:50-16:10	33	Bismuth ferrite based single multiferroic materials	Nikola Ilic
16:40 - 17:30		**Closing**	
17:30		**Ending at Bernard Massard (optional)**	

COST IC1208 Meeting,
University of Luxembourg
Luxembourg

16 March 2017

COST IC1208 Training School on "Photonics Integration: advanced materials, new technologies and applications"

Antonio d'Alessandro
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The COST IC 1208 Training school was held in Erice, Italy from 25th September to 1st October, 2016 organized in collaboration with IEEE Photonics Society in the frame of the International School of Liquid Crystals of "E. Majorana" Center.In this talk I will report briefly on the school program and activities attended by more than 40 students, 15 of which were from the IC 1208 Cost Action (Fig. 1). Topics of the course encompassed advanced material properties, device design, technologies and applications of Photonics in different fields like telecom, sensing, interconnections, quantum information.

Photonic integration is the key issue of this first course, which involves novel design techniques and fabrication processes to make integrated optic devices and systems for novel industrial products. Industrial point of view will be also considered indeed.

Lectures were given by international first class scientists coming from prestigious Italian and foreign universities, research centers and industrial laboratories. A poster session was also organized where the Phd students and Post Docs participating to the School presented their recent results to the lecturers.

Figure. Participants of the IC 1208 COST Training School

Bent-Core Liquid Crystalline Dimers

Vladimíra Novotná,[1] Martin Horčic,[2] and Jiří Svoboda[2]
[1] Institute of Physics, Academy of Sciences of the Czech Republic, Prague, Czech Republic
[2] Department of Organic Chemistry, University of Chemistry and Technology, Prague, Czech Republic

Liquid-crystalline mesophases formed by bent-core molecules have attracted particular interest since the discovery of their polar switching in 1996 [1]. The aim of our work was to synthesize and study liquid crystalline properties of novel types of dimers based on bent-core molecules. Previously designed bent-core dimers are mostly based on side-to-side arrangement of cores. Only a few dimers with other geometry have been prepared up to now. Herein we present a structurally new type of core-to-core dimers. In the studied dimers, central cores of bent-core molecules are connected via an alkylene spacer, the length of which has been varied (Figure 1). Among diverse mesophases and structures, the antiferroelectric type of switching under applied electric field, which is typical for the SmC_AP_A phase, has been observed [2].

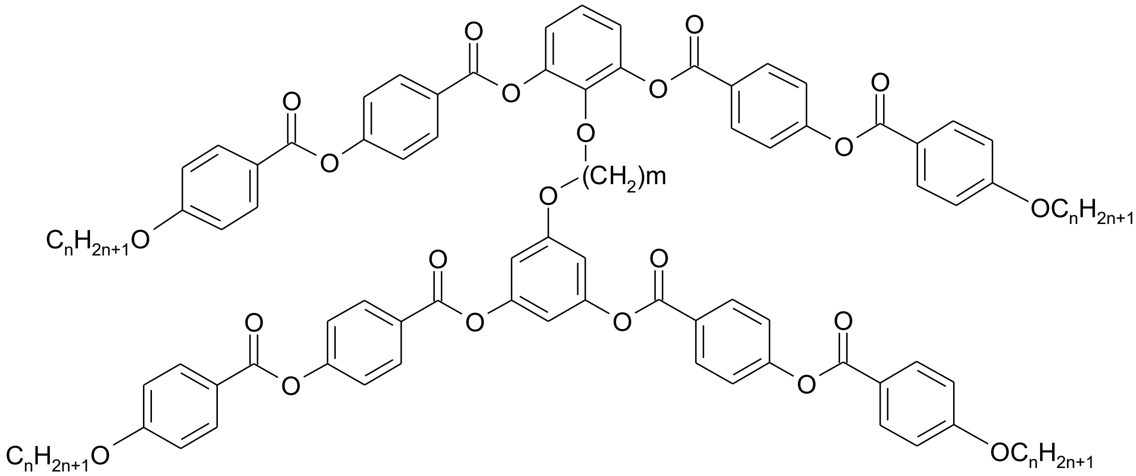

Figure 1. Chemical formula of new core-to-core dimers.

References

[1] T. Niori, T. Sekine, J. Watanabe, T. Furukawa and H. Takezoe, *J. Mater. Chem*. (1996) 6, 1231-1233.

[2] M. Horčic, J. Svoboda, V. Novotná, D. Pociecha, E. Gorecka, *Chem. Commun*., DOI: 10.1039/C6CC09983A.

Ferroelectricity and Helicity in the Achiral bent-core Liquid crystals

S. Sreenilayam[1], Yu. P. Panarin[1, 2], J. K. Vij[1], A. Lehmaan[3] and C. Tschierske[4]

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[2]School of Electrical and Electronic Engineering, Dublin Institute of Technology, Dublin 8, Ireland
[3]Institute of Chemistry, Martin-Luther-University Halle-Wittenberg, Germany

Liquid crystals (LCs) characterized by fluidity and long-range order [1, 2] belong to a fascinating branch of soft condensed matter science. The LCs built from bent-core molecules have recently been extensively investigated as these exhibits a large variety of phases with unique properties. Unlike calamitic LCs, bent-core materials even being achiral due to the C_{2v} symmetry may exhibit both spontaneous polarization and biaxiality in nematic phase (on microscopic level), in the orthogonal SmA–like and tilted SmC–like phases. In this study we present the polar smectic polymorphism of two achiral bent-core LCs (**n=16, 18**) involving 4-cyanoresorcinol bisbenzoate core terminated by alkyl chains on both ends (Figure 1).

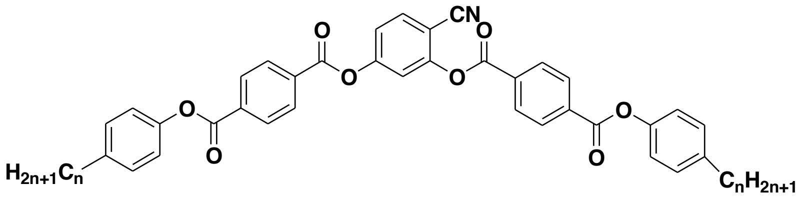

Figure 1. Molecular structure of homologue series of 4-cyanoresorcinol bisbenzoate with two terephthalate–based wings

The compound with the long alkyl chains (**n=18**) shows the phase sequence: Iso – SmA - SmC_SP_R - SmC_SP_X - SmC_SP_F/ $SmC_SP_F^{hel}$ - SmC_AP_A on cooling. In the macroscopically polarization randomized SmC_SP_R phase both polarization and the dielectric strength display critical behavior. The SmC_SP_X phase which observed over a narrow range of temperatures exhibits chirality flipping on the application of conventional AC field but it show an optical response by rotation on the tilt cone under a modified sequence of bipolar pulses. Fast electro-optical switching (~30 μs) with analog grey scale is achieved in the helical SmC_SP_F phase [3]. Therefore LCs under study are thus considered as promising materials for device applications.

References

[1] P. G. de Gennes and J. Prost, The Physics of Liquid Crystals, (Clarendon, Oxford, 1993).
[2] S. Chandrasekhar, Liquid Crystals, (Cambridge University Press 1992).
[3] S. P. Sreenilayam, Y. P. Panarin, J. K. Vij, A. Lehmann, M. Poppe, M. Prehm, and C. Tschierske, Nat. Comm., **7**, 11369 (1)-(8), 2016.

Gravimetric Biosensors: an overview

Enrique Iborra[1], Mario DeMiguel-Ramos[2], Teona Mirea[1], Jimena Olivares[1], José-Miguel Escolano[1], Jesús Sangrador[1], and Marta Clement[1]*

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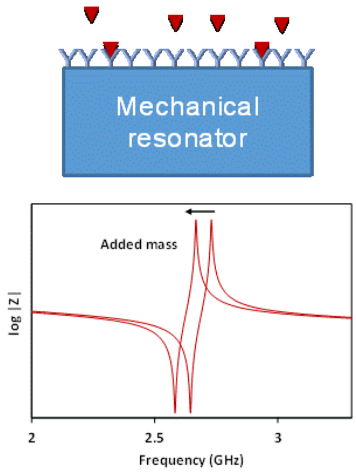
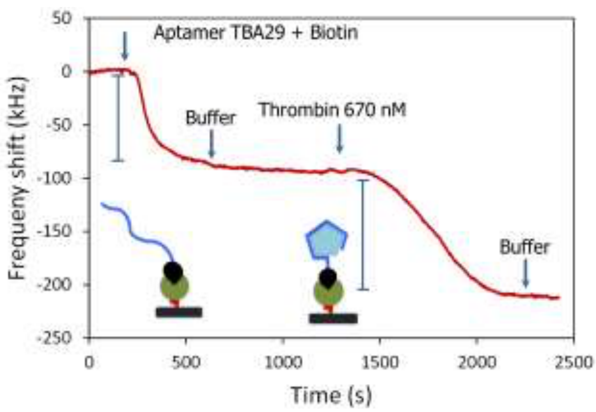
[2]EDM, Electrical Engineering Division, Department of Engineering, University of Cambridge, Cambridge, UK

Gravimetric biosensors based on piezoelectric resonators are briefly reviewed. The main characteristics of this kind of devices are highlighted showing the advantages and drawbacks of increasing the working frequency. Thin film resonators based on aluminium nitride films as piezoelectric material are presented as the future of these kind of biosensors. The most commonly-used resonator structure consists in an electrode/AlN/electrode piezoelectric capacitor acoustically isolated from the substrate by an air gap (suspended structures) or by an acoustic reflector (solidly mounted resonators). When the AlN is deposited with its c-axis (of the wurtzite crystal structure) perpendicular to the substrate surface, the propagating acoustic wave mode is longitudinal, that is, the movement of the material is parallel to the propagating direction, which is parallel to the c-axis. For biosensing applications, which require in-liquid operation, this mode is not suitable due to its high energy radiation to the medium, which gives rise to a reduction of the quality factor. For proper operation, shear mode resonators, where the movement of the material is perpendicular to the propagation direction and parallel to the surface, are need. To generate these modes, it is essential to create a component of the electric field perpendicular to the c-axis. The most straightforward way to do so is to deposit AlN films with grains whose c-axis is tilted with respect to the normal to the surface. To deposit such films, well-controlled directional deposition and well textured substrates are needed. After having this kind of resonator, the surface functionalization with specific receptors for the specie to be detected is a clue task to obtain well performing biosensors.



Gravimetric biosensor basis



Thrombin detection with BAW resonators

2 Week STSM to Cambridge

Film Bulk Acoustic Resonators Based on Scandium Doped Aluminum Nitride

Michael Schneider[1], Mario De Miguel Ramos[2], Andrew Flewitt[2], Enrique Iborra[3], Ulrich Schmid[1]

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Film bulk acoustic resonator (FBAR) devices are promising candidates to replace surface acoustic wave (SAW) devices as filters or delay lines, but also offer interesting and exciting opportunities as biological or gas sensors. In the scope of this STSM, advanced solidly mounted film bulk acoustic resonators (SMR) were manufactured by substituting commonly used pure aluminium nitride (AlN) by scandium doped aluminium nitride (ScAlN) thin films as the active layer. The ScAlN based resonators features a significant improvement of the electromechanical coupling factor compared to the pure AlN ones, which is clearly visible from the increased separation of the series and parallel resonances in figure 1. The decreased stiffness of ScAlN also resulted in a decrease of the quality factor due to increased damping losses in the piezoelectric material, which is shown in figure 2. With this trade-off in mind, these results encourage future cooperative efforts to improve the material properties of ScAlN towards highly efficient ScAlN based bulk acoustic resonators.

In addition, novel acoustic reflector structures have been developed and implemented into SMR devices. These reflectors are based on alternating layers of PECVD deposited stoichiometric amorphous hydrogenated silicon nitride (a-SiN:H) and amorphous hydrogenated carbon-rich silicon carbide (a-SiC:H) thin films.

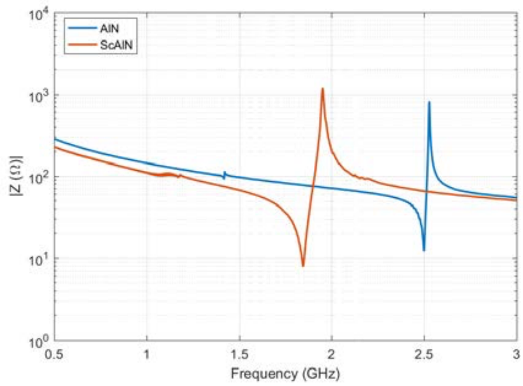

Figure 2: Impedance of AlN and ScAlN SMRs.

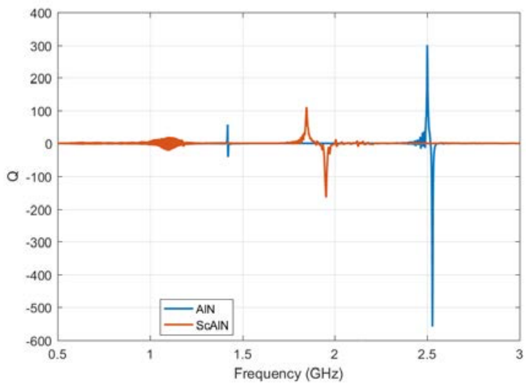

Figure 1: Q-factor of AlN and ScAlN SMRs.

Biocompatible chromonic liquid crystals for photonic sensors: alignment studies and applications

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Lyotropic Chromonic Liquid Crystals (LCLC) are materials characterized by the ability to self-assemble in ordered structure according to their concentration in solution. Although their fascinating properties have been object of study for years they are still poorly understood. There are no clear information about the driving forces in aggregation phenomena or about the general rules that guide the alignment of their liquid crystal phases. Nevertheless, LCLC represent the preferred option –often the only one– for applications where hydrophilic targets or biocompatible materials must be employed. Chromonic liquid crystals hold great promises to useful applications, especially as optical materials and devices in both high industrial and biological technology. One of the main goal in the production of devices based on these water soluble compounds is represented by the possibility to achieve a suitable surface-induced alignment of LCLC liquid crystals phases.

It has been already demonstrated that it is possible to align the LCLC solution modifying the surface energy of the alignment layers used to assemble the optical devices [1, 3]. A particular attention has been focused to the alignment of nematic phase of both cromolyn and sunset yellow (SSY) chromonic liquid crystals.
In this contribution we will report the alignment results obtained using both conventional and non-conventional alignment layers, together with some tests of patterned surfaces, which possess either hydrophilic or hydrophobic nature, to study the behaviour of the LCLC sandwiched between these structures.

References

[1] C.M. Tone et al, Colloids Surf. B: Biointerfaces, 119 99 (2014)
[2] C.M. Tone et al. Soft Matter, 8 8478 (2012)
[3] E. Otón, et al, Liquid Crystals, 42:8, 1069-1075 (2015)

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New liquid crystalline elastomers investigated by Deuterium NMR and X-ray diffraction measurements

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[b] Department of Solid State Physics, Jozef Stefan Institute, Jamova 39, SI-1000, Ljubljana, Slovenia.
[c] University of Warsaw, Department of Chemistry, ˙Zwirki i Wigury 101, 02-089 Warszawa, Poland.
[d] Institute of Physics, The Czech Academy of Sciences, Na Slovance 2, 18221 Prague, Czech Republic.

New side-chain liquid crystal elastomers have been prepared by using a smectic crosslinker. Monodomain films were prepared showing isotropic-nematic or isotropic-smectic phase transitions, depending on the relative crosslinker/monomers concentrations. Detailed physical-chemical investigations based on Deuterium NMR spectroscopy and X-ray diffraction measurements will be here shown and relevant results discussed in view of practical applications.

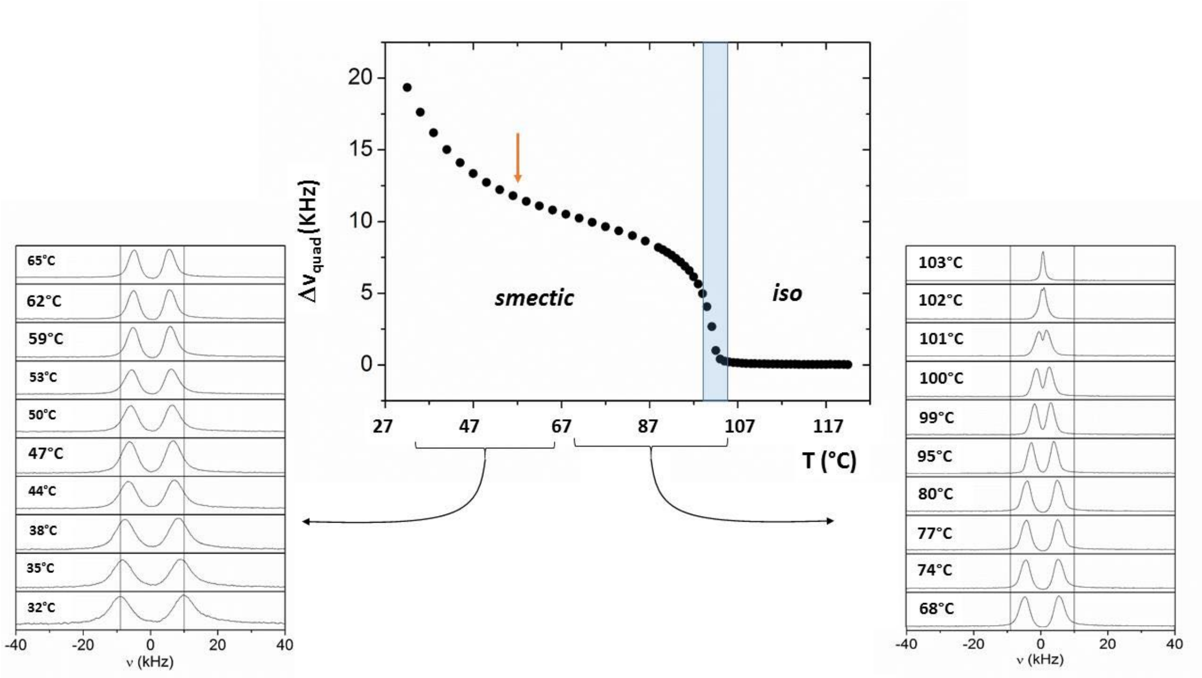

Figure 1. Deuterium NMR spectra and trend of the quadrupolar splitting ($\Delta\nu_{quad}$) as a function of temperature (°C) of a new liquid crystal elastomer showing direct isotropic-smectic phase transition.

Acknowledgements:

Authors thank the bilateral Italian-Polish project "Canaletto"2013–2015", the COST ACTION IC1208 and the Polish National Science Centre grant 2013/08/M/ST5/00781.

Introduction to synthesis of LCs

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Organic synthesis of liquid crystalline materials has always been covered by nimbus of secret. The aim of the lecture is to dispel the secretiveness of organic synthesis of liquid crystals by giving several examples of evolution of synthetic strategy of well-known liquid crystalline materials. Additionally synthetic methods that revolutionized synthesis of liquid crystals will be described and new possibilities discussed. Typical molecular design of dielectrically positive and negative nematics will be presented and its synthesis explained on the strategy of the typical building block synthesis and its conjunction using state of the art cross-coupling reactions discussed. Bypassing the problematic synthetic stage will be given as an example of optimization process in synthesis path, which is additional very important matter of liquid crystal synthesis, especially in bigger scale. Last but not the least issue discussed during the lecture will be related to the synthesis of chiral smectic materials, where challenges of long, multistep synthesis will be presented and main differences with nematics will be pointed out as well.

Study of electro-optical properties of liquid crystal devices doped with titanium dioxide nanoparticles

J. C. Torres[1], *W. Piecek*[2], *V. Marzal*[1], *I. Pérez*[1] *and J. M. Sánchez-Pena*[1] and *B. García-Cámara*[1]
[1]Group of Displays and Photonic Applications. Carlos III University of Madrid, 28911, Leganés, Spain
[2]Institute of Applied Physics, Military University of Technology, Warsaw, Poland.

Inspired by previous researches, a series of cells filled with a dispersion of TiO_2 nanoparticles in a liquid crystal (LC) have been fabricated and investigated [1]. Changing the concentration and the size of nanoparticles, physical properties of the liquid crystals can be established [2]. Specifically, a certain concentration of TiO_2 nanoparticles into a liquid crystal E7 led to a decrease of the isotropic phase temperature (aprox. 10°C). In addition, as shown in Figure 1a, the cell filled with dispersed nanoparticles in similar volume with LC E7 produces smaller phase retardation, resulting of a decrease in the birefringence. The effective birefringence of the LC + TiO_2 nanoparticle is lesser than ~15% in the worst case. In samples with different concentration dopant, we observed a non-lineal effect, with a resonant profile. A voltage around 3V produces a substantial increase of the birrefringence of the mixture. In particular, it changes from ~0.007 to ~0.13 (Figure 1b). Therefore, doped LC offer a method of modifying the properties of existing liquid crystals.

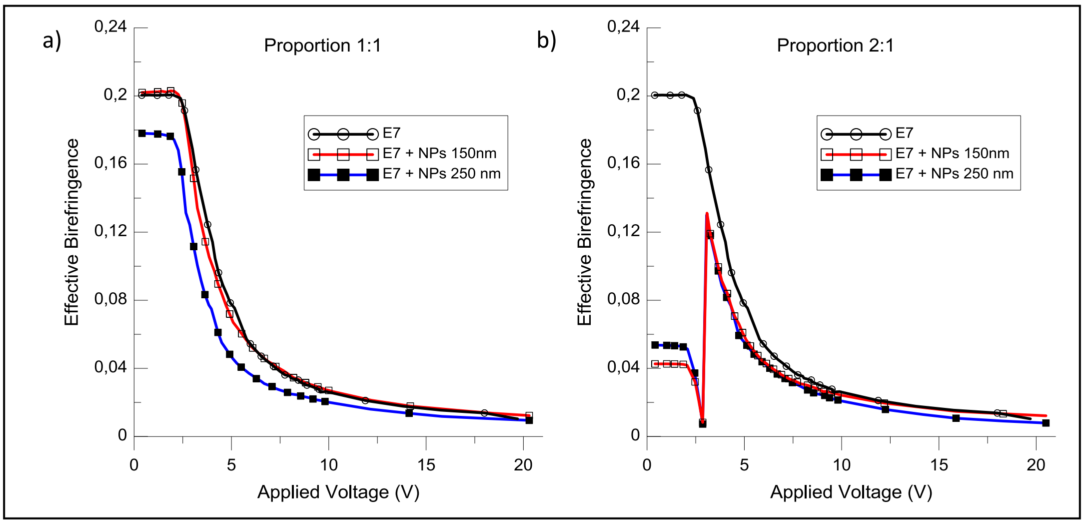

Figure 1. Birrefringence of a TiO_2+ E7 mixture as a function of the applied voltage. Samples considered a similar volume of LC and the dispersion ofTiO_2 (a) or when the volume of LC is double than NPs solution. Data of a pure E7 LC cell is also included for comparison.

References

[1] V. Marzal, J.C. Torres, I. Pérez, J.M. Sánchez-Pena, B. García-Cámara, Induced Magnetic Anisotropy in Liquid Crystals Doped with Resonant Semiconductor Nanoparticles, J. Nanoparterials, 2016, 1-9, 2016

[2] I. Abdulhalim; Liquid crystal active nanophotonics and plasmonics: from science to devices. J. Nanophoton. 0001;6(1):061001-061001, 2012.

Experimental and numerical analyzed of lattice plasmon modes in substrate-supported gratings of monomers and dimers

J. Marae-Djouda[1,2], A. Gontier[1], R. Caputo[1,3], G. Lévêque[4], P.-M. Adam[1] and T. Maurer[1]*

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The optical properties of bidimensional gratings of metal nanoparticles are very attracting due to their great scientific and technological potential. Technological devices in diverse fields are based on the use of optical properties of metal nanoparticles (Maurer et al. 2015; Caputo et al. 2015; Marae- Djouda et al. 2016). To improve existing devices and design news one, the good comprehension of the coupling of bidimensional gratings of gold nanoparticles (AuNPs) is necessary. In this study, gratings in arrangement of monomers and dimers are investigated experimentally and numerically. The influence of the effect of the edge diffraction, corresponding to the grazing propagation of a particular diffracted orders, and the parameters of the gratings on the lattice plasmon modes (LPM) supported by the gratings are studied. The pitch of the grating modifies the position the Rayleigh wavelength linked to the grazing diffraction in air or glass. The extinction measurements with different incidence angles are conducted in order to deeply investigate the effect of the diffraction and the play of the Rayleigh wavelength. For an incidence angle up to 20°, quadrupolar and vertical modes appears, very narrow dips are also observed in the spectra like depicted in Figure 1. All these features are explained in the light of numerical calculations obtained with two different methods; the Green's tensor method and the coupled-dipole approximation. The comparisons of the results obtained by the two methods are very useful for the understanding of certain features observed in the spectra. The comparison between experimental and numerical results is also presented

a) b)

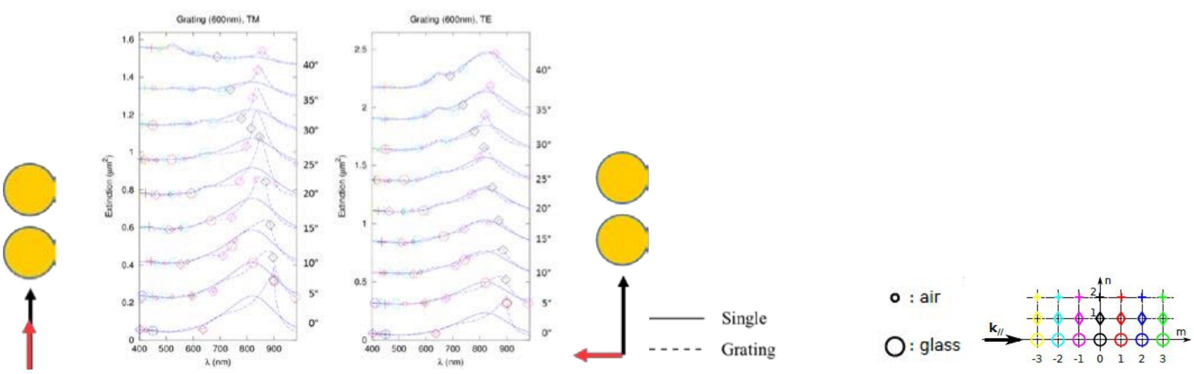

Figure 1: Extinction spectra of grating of dimers with Px=Py=600 nm and the gap is 40 nm deposited by EBL on top of glass substrate in TM (left) and TE (rigth) polarizations (a). The spectra are recorded for different incident angles in silica from 0° to 40°. The diffraction order at the glass and air influenced the spectra and are superimposed on the spectra (b).

References

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Optoelectronic devices with liquid crystals and PDMS channels

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[1]Department of Information Engineering, Electronics and Telecommunications, Sapienza University of Rome, Via Eudossiana, 18 - 00184 Rome, Italy

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We present optoelectronic tunable and switchable devices for integrated optics based on easy-to-build optical waveguides. The devices take advantage of the spontaneous homeotropically alignment of liquid crystals (LC) molecules to the surface of a polydimethylsiloxane (PDMS) microfluidic channel (LC:PDMS) [1]. This behaviour was investigated by means of Monte Carlo simulations, which allowed to evaluate the molecular organization and ordering inside the cell. A set of rectangular PDMS waveguides, filled with LC were designed and the calculations were performed using a Lebwhol-Lasher (LL) lattice spin model to emulate the LC cell, imposing homeotropic boundary conditions on each wall of the channel. Simulations confirmed that the aligning surfaces affects the ordering, being this ordering constant along the channel [2]. Samples of the structure were made using cast and moulding techniques to build the PDMS rectangular microchannel waveguides, which were infiltrated with LC in its isotropic phase at 80 °C under vacuum by capillarity. As forecasted, no alignment was needed to obtain LC molecule orientation on the PDMS inner surfaces. Characterization, performed at a wavelength of 1550 nm, confirmed a substantial insensibility to polarization despite liquid crystal anisotropy, being the variation of the transmitted light power with polarization angle less than 0.3 dB [3]. Based on this simple structure, we demonstrated LC:PDMS optical directional couplers with a coupling length of 45 μm and 300 nm waveguide gap. Switching capabilities of the device were confirmed, with an extinction ratio of the output power level higher than 20 dB [4]. To obtain the electro-optical control of the directional couplers we fabricated flexible electrodes by sputtering ITO on the PDMS, with different deposition times of 30 s, 60 s, and 90 s, both at 100 °C and 150 °C. Preliminary conductive ITO layers with a thickness of about 27.5 nm were obtained.

References

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Plasmonic nanogaps for enhanced light-matter interactions – applications to nano-light sources and SERS

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Plasmonic technology, referring to the study of specific surface electromagnetic waves resulting from the coupling of photons and collective electron oscillations in metals, has seen a rapidly increasing interest over the past two decades. Combining key advantages directly linked to their nature, such as high field confinement, strong field enhancement, with polarisation and spectral selectivity, plasmonic systems promise many applications encompassing bio- and chemical sensing, signal guiding and manipulation on subwavelength scales, and extend to include photonic devices with enhanced performances, such as photodetectors, solar cells and light emitting diodes.

Plasmonic nano-gaps, arising from the strong coupling of a metal nanoparticle and metal film, offer a surprisingly powerful way to control and enhance light-matter interactions at the nanoscale despite their simple fabrication. Here we present an in-depth study of the plasmonic nano-gap optical properties, highlighting different spectral regimes corresponding to different mode hybridisations within the plasmonic cavity, leading to increased control over the optical properties of the system. We then present potential applications of such nano-gaps through their coupling with quantum emitters for applications in nanolight sources, energy transfer, and SERS (Surface Enhanced Raman Spectroscopy) potential. Experimental results are supported by FDTD calculations allowing to fully characterise and gauge the potential of such nano-systems.

Dielectric and Phonon Studies of Cobalt Ferrite doped Lead Zirconium Titanate Multiferroic Composites

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Multiferroics belongs to class of materials in which the ferroelectric and ferromagnetic ordering occurs simultaneously in the same temperature range. Some of them can show a coupling between these orders and are promising as multifunctional materials for various applications [1]. The most interesting multiferroics are two-phase multiferroic composites due to the possibility to realize the "product property". Lead zirconate titanate $PbZr_xTi_{1-x}O_3$ is the well known perovskite ferroelectric with excellent electromechanical properties while cobalt ferrite $CoFe_2O_4$ exhibit good ferromagnetic and magnetostrictive properties. These properties allow combining them together to form composite exhibiting multiferroic behaviour. Because of the lack of high frequency dielectric data the applicability of such multiferroics in microwaves is still limited and this work is dedicated to the broadband dielectric spectroscopy results of $Pb_{0.988}(Zr_{0.52}Ti_{0.48})_{0.976}Nb_{0.024}O_3$ (PZTN) and $CoFe_2O_4$ (CF) composite ceramics.

CF-PZTN composite ceramics with CF ratio of 10%, 20 % and 30% were prepared in situ by citrate–nitrate combustion by using PZTN-based template powders as described in [2]. Various devices and broadband dielectric spectroscopy methods were used to cover frequencies from 20 Hz to 50 GHz. Time domain THz spectroscopy was used in measurements of complex dielectric response in the range of 5 – 50 cm^{-1}. IR reflectivity spectra were collected with Bruker IFS 113v Fourier-transform IR spectrometer in the range of 30 – 700 cm^{-1}.

The obtained results show a broad dielectric anomaly around the temperature of 630 K. The peak of permittivity in the temperature dependencies can be associated with the paraelectric-ferroelectric phase transition in the morphotropic phase boundary (MPB) PZT material, in accordance to the phase diagram of lead zirconate-lead titanate system. Comparing ε' and ε'' temperature dependencies at a fixed frequency one can conclude that permittivity values decrease with an increase of cobalt ferrite concentration, as can be explained by a sum rule. In IR spectra characteristic phonons of ferroelectric morphotropic phase boundary PZT are dominated in all (1-x)PZTN-xCF composites. The softening of central mode around 45 cm^{-1} is observed.

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Dielectric properties of Multiferroic Ceramics of the $Bi_{1-x}La_xFe_{0.50}Sc_{0.50}O_3$ Metastable Solid Solutions System

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Single-phase perovskite ceramics of the $Bi_{1-x}La_xFe_{0.50}Sc_{0.50}O_3$ system can be prepared using the conventional ceramic route, only when the lanthanum substitution rate (x) is at least 80 at.%, while application of the high-pressure synthesis is needed if $x<0.80$. The $Bi_{1-x}La_xFe_{0.50}Sc_{0.50}O_3$ ceramics ($0 \le x \le 0.80$) were prepared at 6 GPa and 1370-1470 K from the pre-synthesized (10 min at 1140 K at ambient pressure) stoichiometric oxide mixtures. Three structural phases were found in the $Bi_{1-x}La_xFe_{0.50}Sc_{0.50}O_3$ system. The as-prepared phase at $x \le 0.05$ is an antipolar Pnma with the $\sqrt{2}a_p \times 4a_p \times 2\sqrt{2}a_p$ superstructure. An incommensurately modulated structural phase with the Imma(00γ)s00 superspace group is observed for $0.10 \le x \le 0.33$, while a non-polar Pnma phase ($\sqrt{2}a_p \times 2a_p \times 2\sqrt{2}a_p$) forms at $x \ge 0.34$. Below TN ~220 K, all the obtained phases exhibit the same long-range G-type antiferromagnetic order with a weak-ferromagnetic component. The very narrow compositional range of $0.33 \le x \le 0.34$ is of a great interest since it corresponds to solid solutions with T_C close to T_N and, therefore, with the maximal lattice-magnetic coupling effect expected.

The $Bi_{1-x}La_xFe_{0.50}Sc_{0.50}O_3$ ceramics synthesized under high-pressure from the oxide mixtures were rather inhomogeneous and porous. Although quality of those ceramics was satisfactory for structural and magnetic studies, dielectric measurements were hardly possible because of high electrical conductivity. In this work, the advanced preparation methods were applied. The powders corresponding to the compositions with x=0.33 and 0.34 were prepared using a sol-gel method followed by calcination at 870 K. The calcined product was found to be a single phase perovskite although poorly crystallized. The powders were then sonicated in ethanol media at 4 kW for 10 min. It was found that such a treatment results in further crystallization. Then the powders were compacted and subjected to a quasi-hydrostatic pressure of 8 GPa for 5 min at room temperature. Single-phase dense ceramics were obtained as a result of sintering of the compacts at 800 K for 48 h in air. We report on structure, microstructure characterization and measurements of dielectric response of these ceramics in comparison with those synthesized under high pressure.

The inversion phenomenon of the helical twist sense in antiferroelectric liquid crystal pure compounds

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In some compounds with chiral smectic liquid crystalline phases (SmC* or SmC_A*) the change of the helix handedness may be observed within one phase [1]. Still new compounds are being discovered having inversion of the helical twist sense. In our institute it was also found that orthoconic antiferroelectric compounds, being members of homologues series 3FmX1PhX2 [2] may have an increasing or decreasing dependence of a helical pitch upon temperature and different sign of a helical twist sense in SmC_A* phase, although they have the same chiral terminal chain [3]. Electronic circular dichroic (ECD) and vibrational circular dichroic (VCD) spectroscopy (see figure 1) have proved the existence of unwound helical structure in antiferroelctric phase of such compounds. Obtained results may confirm the assumption connected inversion phenomena in liquid crystalline chiral phase with the change of the concentration of different conformers promoting opposite handedness. Two examples of such conformers, obtain by conformational analysis, will be shown.

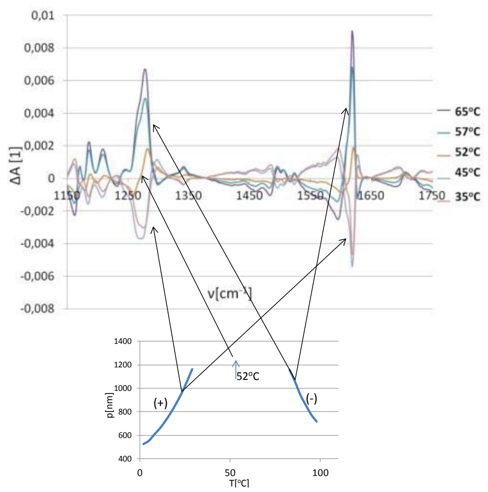

Figure1. VCD spectra at different temperatures for compound with the helical twist sense inversion phenomena

Acknowledgment: This work has been done under grant UMO-2015/19/D/ST5/02730

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Temperature dependence on helical pitch in liquid crystalline mixtures of compounds differing in the length of chiral chain

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One of the most important parameter for liquid crystalline materials is the helical pitch which should be long for easier unwinding of the macroscopic helix in liquid crystalline cells [1-2]. The helical pitch depends on the temperature in different way for different materials in the ferroelectric as well as antiferroelectric phases [3-4]. Also the helical structure of the chiral smectic phases in the same substance have opposite handedness [5-6].

New antiferroelectric compounds were synthesized at the Military University of Technology in Warsaw to improve the usefulness of mixtures in display applications [7]. The aim of this work was to determine the temperature dependence of parameters of helicoidal structure in mixtures composed of chiral liquid crystalline esters differing in the length of chiral chain. The helical pitch was measured by a spectrophotometric method based on the selective light reflection phenomenon. The polarymetry technique was used to measure the helical twist sense. It was found that the value of helical pitch strongly depends on the temperature in the antiferroelectric phase and does not change in the ferroelectric phase. The helical twist inversion phenomenon appears for phase tranistion between ferroelectric and antiferroelectric phase, but it was also observed for few compounds and their mixtures within the antiferroelectric phase.

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Soft solution synthesis of Ga-doped ZnO nanostructures with controlled morphology

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Semiconductor ZnO gathers a set of unique physicochemical characteristics that fairly depend on the degree of crystallinity, the crystallographic orientation, the crystallite size and the morphology of the constituting particles. A strict control is therefore required during the synthesis stage of the ceramic powder, and in view of that different processing strategies are currently being explored to successfully manipulate the crystallization engineering of ZnO. In this contribution we analyse the possibilities of a soft solution microwave assisted hydrothermal processing to prepare Ga-doped ZnO nanostructures with tailored shape and crystallinity. Initially postulated as a suitable dopant candidate for introducing more carrier concentration into the wide band gap of ZnO, trivalent gallium may also act as an inorganic surfactant, so altering the morphology and size of the as-synthesized ZnO nanocrystals. Our results indicate that an extensive Ga:ZnO solid solution is not easily obtained, and confirm that the presence of this dopant during the (MW-assisted) nucleation and crystallization processes, produces a strong effect on the material´s morphological development which eventually governs its crystal growth habit and its optical response.

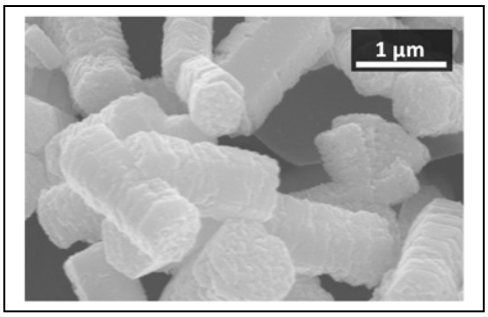

Figure. Rod-like self-assembled nanostructures of Ga-doped ZnO

Linear Electro-optic Response in non-Chiral Bent-Core Liquid Crystalline Systems

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For long time since the discovery of ferroelectricity in LCs the formation of polar and/or helical structures was associated with chiral molecules. Nevertheless, another class of LCs built from the achiral bent-core (BC) molecules, may form microscopically/macroscopically polar and biaxial structures in the nematic, orthogonal (SmA–like) and tilted (SmC–like) smectic phases. These phases exhibit a linear EO response due to the interaction of spontaneous polarization with an electric field. Here we report on the properties of EO effects in different BC LC phases.

The nematic phase of the BC LCs suggests the appearance of microscopically polar and biaxial "cybotactic" (smectic-like) clusters. An application of electric field aligned the short axes of clusters in the direction of applied field causing the appearance of field–induced macroscopic biaxiality and corresponding EO response in homeotropic cells.

The orthogonal BC SmA LCs may form both microscopically ($SmAP_R$) and macroscopically ($SmAP_A$, etc…) biaxial phases. The EO effect in SmAPR phase is similar to that in the BC nematics, showing higher value of induced biaxiality, contrast ratio and faster switching. The macroscopically biaxial SmAPA phase show several EO modes [1] with sub–millisecond switching time and very high contrast ratio.

The non–orthogonal BC LCs show a rich polymorphism (B1–B8), where B2 are the tiled and polar (SmCP) with different synclinic/anticlinic and ferro–/antiferroelectric order in neighboring layers. Among them SmC_SP_F forms very short helical pitch superstructure [2]. The application of electric field below the threshold EU causes a deformation of helix and fast electro-optic response and V-shape switching [2]. The amplitude of EO response initially increases with electric field and then saturates at E > EU. A further increase of electric field results in the drop of EO response amplitude due to the appearance of the domains show non–optical chiral flipping. The transformations in EO response with temperature and electric field are explained with modified model [3] of two coupled partial dynamic differential equations.

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COST IC1208 Meeting,
University of Luxembourg
Luxembourg

17 March 2017

The Active Plasmonics Paradigm

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Remarkable properties are devised in systems exploiting plasmonic functionalities. After years of research in this direction, great results have been achieved in Photonics, Sensoristics, Bio-systems, Theragnostics and Metamaterials. Very often, despite the awesome functionality reported, these systems comprise an intrinsic limit in their "single use" applicability. The active plasmonics paradigm predicts, in a given plasmonic system, the presence of a tunable medium thus enabling the tunability of aforementioned functionalities. Following this design rule, a much wider scenario of possibilities is unveiled that breaks the gap between research, fundamental and/or applied, and realization of tangible "everyday use" devices.

Effects of Area on the Performance of Solidly Mounted Resonators

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Solidly Mounted Resonators (SMR) is one type of Bulk Acoustic Wave (BAW) resonators that implement half-wavelength resonance of longitudinal wave (TE1 mode) for their operation. In BAW resonators, the confinement of acoustic energy in the resonator is critical as it decides the performance of the resonators. In the SMR, an acoustic mirror is placed in between the resonator and the substrate to trap the acoustic energy within the resonator area. In the bulk, besides TE1, there also exist shear modes which can transmit through the mirror into the substrate if they are not taken into account. Even for a small amount of acoustic energy associated with these modes, this transmission can cause the quality factor of the SMR greatly deteriorate [1]. For such reason, in this work, the SMRs are designed so that the mirrors are able to confine both TE1 and shear waves. Various designs of the SMR with different mirrors, i.e. mirrors with different layer materials and thicknesses, are carried out. Various arrays of these SMRs with different sizes and shapes are fabricated(*). The results show that the quality factors of these resonators also strongly depend on their areas. The quality factor at resonance frequency decreases with the resonator area whereas it is of opposite trend for the quality factor at anti-resonance frequency. These results prove that there has to be a compromise between the quality factors of the SMRs and the size of the resonators in term of the scale of integration for such applications as multichannel RF filters.

(*) This work was done with the help of Prof. Enrique Iborra and his group at Technical University of Madrid (UPM), Spain.

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Narrowband terahertz transmission filters based on guided mode resonant gratings

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Guided-mode resonances (GMR) manifest as narrow-linewidth transmission or reflection bands when waves diffracted from a grating couple to propagating modes in an adjacent dielectric substrate [1]. Recently, such structures were proposed for the design of narrowband filters operating at terahertz (THz) frequencies, suitable for applications in telecommunications, radar science, or imaging [2].

Here, we investigate, both theoretically and experimentally, the properties of GMR in terahertz filters based on metallic frequency-selective surfaces (FSS), as shown in Fig. 1(a), which are patterned via photolithography on thin films of the low-loss cyclo-olefin polymer Zeonor. Filters with very high quality factors are designed and their spectral response is studied under different conditions, such as oblique incidence, rotation of the polarization plane, and bent configurations. Contrary to the filtering response of standard free-standing FSS-THz filters, we observe extensive tunability of the GMR frequencies by means of mechanically rotation, as well their suppression by bending the flexible substrate, as demonstrated in Fig. 1(b).

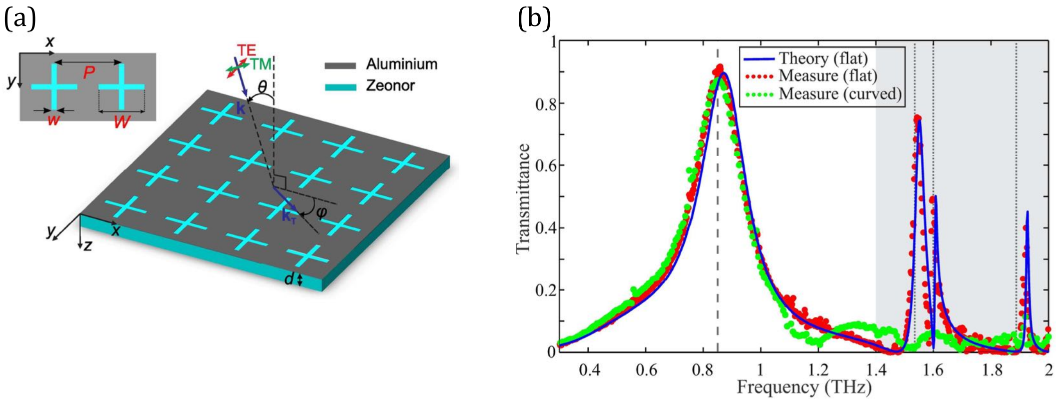

Figure 1. (a) Schematic layout of the investigated FSS-THz filter. (b) Filter power transmittance in both flat and bent configurations.

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Helical pitch, tilt angle and spontaneous polarization measurements of chosen ferroelectric liquid-crystalline mixtures

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Ferroelectric liquid-crystalline (FLC) mixtures are used in many electrooptical effects. Crucial parameters of such mixtures, besides proper temperature range of SmC* phase, are: length of helical pitch, tilt angle and spontaneous polarization value. Among the most used electro-optic modes *deformed helix ferroelectric* – DHF-FLC [1], *surface stabilized* – SSFLC [2] and *polymer stabilized V-shaped ferroelectric* – PSV FLC [3] effects should be distinguished.

Multicomponent FLC mixtures can be prepared by three methods. The first involves mixing of chiral compounds, which form SmC* phase [4]. The second method is preparation of non chiral base, which forms SmC phase in wide temperature range, and dopping it by optically active compounds with high value of helical twisting power (HTP) [5]. The third method is preparation of the so-called ferroelectric frustrated phase by mixing ferro- and antiferroelectric liquid crystal compounds, and selection of concentration in which antiferroelectric phase is not formed [6]. Preparation of multicomponent mixture by each method should be preceded by miscibility studies in bicomponent systems.

Results of helical pitch, tilt angle and spontaneous polarization measurements for bi- and multicomponent FLC mixtres will be presented. Significant differences in the values of these parameters (as shown in Figure, for dependence of tilt angle upon temperature reffered to phase transition) are associated with the choice of the method of preparation of multicomponent FLC mixture.

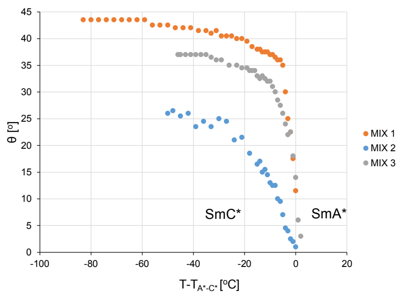

Figure. Dependence of tilt angle upon temperature reffered to phase transition in MIX 1, MIX 2 and MIX 3

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Tunable Hybrid Liquid Crystal Metamaterial Systems for Photonic Applications

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Metamaterials (MMs) in optics represent a large class of nano-structured artificial media with optical characteristics not found, or superior, to those exhibited by natural materials. They have rapidly advanced over the past decade and are now expected to have major impact across the entire range of photonic technologies. The current effort in the field is focused on implementing the idea of active and tunable MMs, a generation of artificial photonic media with dynamically controlled optical properties [1, 2].

Developing an efficient technology for active control over MM exotic optical response is an essential step towards their practical application. One of the methods to achieve tunable MMs if to functionalise the fabric of these man-made photonic materials with liquid crystals (LCs), where the MM properties are tuned by changing the LC optical anisotropy with external voltage or light/temperature [3, 4]. Recently we demonstrated efficient spectral tuning of the hybrid LC-MM system in the optical part of the spectrum, which so far has been challenging due to a strong anchoring of LC molecules to the surface of nano-structures [5]. Nevertheless, the tuning range of these hybrid systems is still limited by the value of LC optical birefringence, leading to the maximum change in the spectral shift up to 10%.

In order to increase hybrid LC MM tunability we also employed elastic properties of LCs creating the first tunable elastic LC photonic MMs based on nano-electro-mechanical systems (NEMS)[6]. In our work we experimentally demonstrated the full potential of electrical tuning of the elastic LC photonic MM, where we combined mechanical properties of NEMS with elastic and optical features of LCs. The robust control of nano-scopic actuations in such systems was achieved for the entire range of structurally allowed displacements. The new approach also enabled on-demand, fully reversible transitions between different regimes of NEMS operation upon changing phase of LC materials.

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Tuning properties in electroceramics by composition and microstructural control

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One of the most important properties of ferroelectric and of polar non-linear dielectrics is the ability to change their permittivity with field – tunability- which makes them promising candidates for microwave components and microelectronic circuits. The main requirements for such materials in applications are: lake of hysteresis, high level of tunability of $n = \varepsilon(E)/\varepsilon(0) \geq 1.5$, moderate permittivity below 1000 and losses below 3% in microwaves range. In the present paper, I will present the most used methods to fulfill these technological requirements: making composites based on ferroelectrics close to Curie temperature (T_C) as $(Ba,Sr)TiO_3$ (*BST*) or $Ba(Zr,Ti)O_3$ (*BZT*) mixed with low permittivity linear dielectrics as: MgO, Al_2O_3, Mg_2BO_6, etc. , doping of these materials with different ions and our approach of using the concept of local field engineering in order to propose new configurations of ferroelectric composites with improved tunable properties. Based on Finite Element Method (FEM) calculations we proposed some new tunable materials: porous ferroelectrics with controlled connectivity between the pores, nanostructurated $BaTiO_3$ ceramics and polymer based composites and the obtained results will be presented and discussed in relation with their peculiar microstructures.

Acknowledgements: This paper was financial supported by Romanian CNCS-UEFISCDI PNII-RU-TE-2014-4-1494 project EXPOFER.

Planar Nano-structured Silicon Lenses for Optical Manipulation

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We report on design, fabrication, and characterization of planar nano-structured metalenses made of silicon. Individual structures consist of high contrast gratings (see Figure) produced by means of electron beam lithography. Alternating ridges and groves are arranged on a layer of amorphous silicon with nanometer precision in order to shape the wavefront of a reflected or transmitted light. In this work we create planar structures which mimic the phase profile of a parabolic reflector. The gratings are simulated using rigorous coupled-wave analysis. We demonstrate experimentally that such a planar metalens can be applied for 3D optical trapping of microscopic particles in a microfluidic environment.

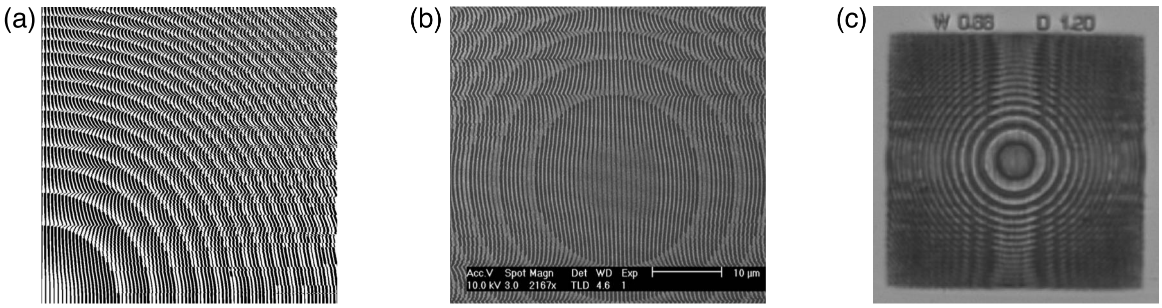

Figure. Planar metalens: (a) simulated quarter-lens design where white denotes silicon grating ridges and black denotes grooves; (b) zoomed in scanning electron micrograph of a fabricated structure; (c) metalens under a white light optical microscope.

Design of new liquid crystalline materials with definite properties

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A specific class of self-assembling materials, the liquid crystals, attracts considerable attention in our days. Liquid crystalline materials with a chiral part based on lactic acid have been intensively studied for the last decades [1-2] due to their rich liquid crystalline properties potentially attractive for applications [3] but also due to a reasonably low synthetic costs with respect to a commonly used self-assembling materials with commercially available chiral part derived from (S)-2-octanol.

While searching for new materials the main mechanisms to reach the desirable liquid crystalline properties are: (i) tuning the molecular architecture, specifically changing the type and the structure of the molecular core, length of the terminal chains, type and the position of the lateral substituents [2, 4], (ii) attaching different polymerisable groups for further design of the macromolecular materials that increase the stability of the self-assembling behaviour [5] and (iii) incorporation of various functional groups (like photosensitive azo group, etc.) in the molecular core [6]. However, it is still almost impossible to achieve the desired properties for a pure single liquid crystalline compound. Design of binary and multicomponent mixtures is also a common and widely used approach to reach the anticipated liquid crystalline properties [2, 7] that gives these materials a chance to be utilised in future for various applications. Mixing of structurally similar or structurally different materials [7-8] is a powerful tool for tuning the mesomorphic, electro-optic, structural and dielectric properties of the resulting mixture.

This presentation will be devoted to the results obtained recently on a large variety of lactic acid derivatives with different molecular architecture. The uncommon mesophases and their properties will be highlighted and a potential usefulness of such materials will be discussed.

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Synthesis and properties of chosen 4-butyl-phenyltolane derivatives – on the influence of core substitution on mesomorphic, optical and dielectric properties

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The synthesis and characterization of new liquid crystal (LC) compounds based on 4-[(4-butyl-2,6-difluorophenyl)ethynyl]biphenyl core are described. New family of dielectrically positive compounds presents alternative molecular approach to the conventional LC design. Correlations between molecular structure and mesomorphic properties for compounds being isothiocyanato, cyano, trifluoromethoxy, chloro and fluoro terminated analogues as well as other known from the literature have been drawn. Additionally, the experimentally determined physical properties (birefringence, dielectric anisotropy) for presented derivatives of phenyl tolane are compared with DFT calculation's results. Compounds are characterized by 1H NMR spectroscopy and mass spectrometry (electron ionization) analysis. They show an enantiotropic nematic behavior in broad temperature range, confirmed by a polarizing thermomicroscopy, differential scanning calorimetry and dielectric spectroscopy. Detailed synthetic procedures are attached. Synthesized compounds stand as promising components of medium to highly birefringent liquid crystalline mixtures.

Tamm plasmon modes on semi-infinite metallodielectric superlattices

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Interest in superlattices of ultrathin metallodielectric layers has recently experienced an extensive expansion [1] as these systems have been found to support Bloch surface plasmon polaritons (SPPs) far outside the dielectric light cone with important implications for nano-optics and photonics in general.

Bloch SPPs are formed by the hybridization of SPPs appearing on individual metal-dielectric interfaces and are delocalized across an infinite superlattice, but characterized by finite lifetime and propagation length due to unavoidable absorption lossess associated with intraband electron scattering in the metal [2]. The distinct character of Bloch SPPs originates from their large in-plane wavenumber, reaching values an order of magnitude above the dielectric wavenumber and hinting towards a potential for optical nanoimaging and radiative decay engineering applications [3].

Here we investigate the fundamental properties of interface Tamm plasmon modes (TPM) in order to identify their contribution to the local photonic density of states (PDOS) at the interface of a semi-infinite metallodielectric superlattice [4]. We find that superlattice interfaces can be classified into homo- and hetero- types. The former corresponds to the case when the surrounding medium is one of the superlattice constituents. We show that the homo-interface TPM existence, fields and confinement are governed by ω_T, while its dispersion must partly overlap the single-interface SPP dispersion. In contrast, the hetero-interface TPM exhibit a more complex behavior as a result of hybridization between the homo-interface SPP and single-interface SPPs at the interface between the surrounding medium and the superlattice. The TPM contribution to PDOS is found to range from negligible to dominant, suggesting ways to manage photons generated by adjacent nanoemitters by tailoring the superlattice termination.

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Investigation of dielectric properties of liquid crystals with the non-uniform structure

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We have investigated in theory and in experiment the re-orientation of the nematic liquid crystal under the action of the electric field in the cells with the planary helicoidal and with the homeoplanary structure of the director field. We have measured in the experiment the dependence of electric capacity of such system in the external electric field below the Fréedericksz threshold and over it. The same dependencies were calculated numerically. In our calculations we have used the director distribution across the volume for the various values of the voltage, which was estimated by the direct minimization of the free energy. The inhomogeneity of the electric field inside the cell was taken into account. There was shown the correlation of the numerical results with the experimental data.

Rotation of Light Polarization from Aligned Carbon Nanotube Sheets

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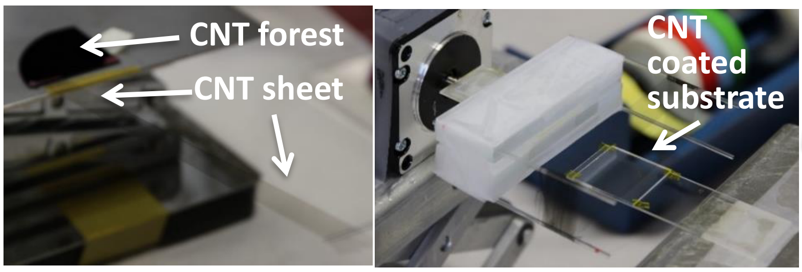
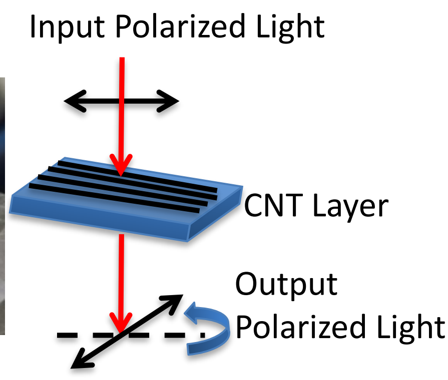
Free standing sheets of carbon nanotubes (CNTs), drawn from vertically-grown multi-walled CNT forests (shown in Fig. 1a), have the nanotube bundles mostly oriented in the drawing direction and can be deposited on glass substrates [1], see Figure 1b. We have observed an effect on the polarization of light propagating through CNT coated substrates and studied it for varying number of layers. The polarization of the output light results changed, as sketched in Fig. 1c, and this is likely due to the anisotropic optical absorption of nanotubes. We have measured the optical absorption of the CNT layers with light polarized parallel and perpendicular with respect to the CNT aligning direction. The value of transmission was also monitored while azimuthally rotating the alignment direction of CNTs. Optical studies of the stack of CNT layers help to understanding the role of the structure of those layers (i.e. density, thickness and assembling). The results are relevant for producing optical elements based on CNTs but are also useful for optimizing liquid crystal devices since the uniformly oriented CNT sheets can be used as multifunctional layers for LC displays (i. e. for the alignment [2] but also reorientation of LC molecules [3]).



(a) (b)



(c)

Figure. a) Realization of CNT sheets: b) Substrate coated with one layer of aligned CNTs c) Sketch of the effect of CNT layer on the polarization of light.

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Optical and Magneto-Optical Sensors Based on Plasmon Resonance

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Optical sensors, based on surface plasmon resonances (SPR), have attracted much attention in recent years. They benefit from the local electomagnetic field enhancement and high sensitivity of the resonances to the surrounding media. We report on localized SPR sensors based on periodic [1,2] and aperiodic [3] plasmonic nanostructures. Figure depicts the nanostructure based on the Thue Morse sequence of Au nanopillars (NP). The design of a magneto-optical sensor, enhanced by propagating surface plasmon polariton, will be discussed.

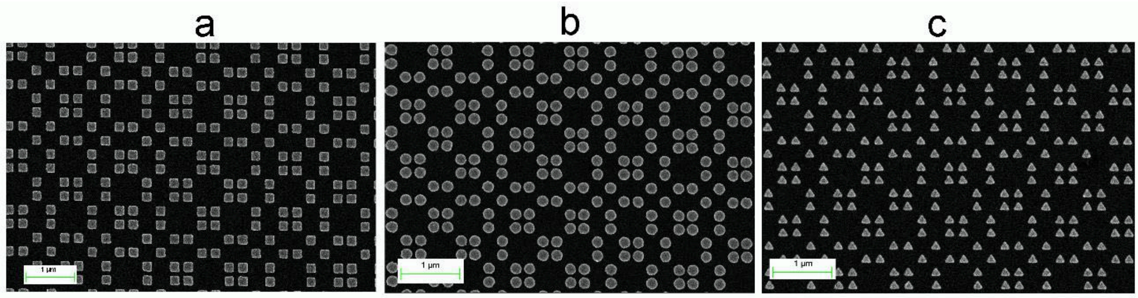

Figure. SEM images of Thue Morse nanopatterns with square (a), circular (b) and triangular (c) gold NPs. Characteristic NP size is 180nm.

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Effect of porosity on nonlinear dielectric properties of $BaTiO_3$ porous ceramics

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The tunability properties make ferroelectrics interesting for wireless communications, for voltage tunable microwave devices, such as oscillators, phase shifters, varactors, lens antennas, etc [1]. However, the main requirements as moderate permittivity (few hundreds), high tunability and low losses (tanδ<3%) are very difficult to obtain in single phase ferroelectrics. The proposed solution was to develop composites based on ferroelectrics close to Curie temperature (T_C) as $(Ba,Sr)TiO_3$ (*BST*) or $Ba(Zr,Ti)O_3$ (*BZT*) mixed with low permittivity linear dielectrics as: *MgO*, Al_2O_3, Mg_2BO_6, etc. [2,3]. The obtained results were a reduction of permittivity together a reduction of tunability.

Recently, we have proposed the original concept of *local field engineering* as a new tool to control the macroscopic properties of ferroelectric composites, based on Finite Element Method (FEM) calculations of local fields in composites. Using this approach, we proved that the case of porous ferroelectrics with closed porosity is the best solution to fulfill the tunability requirements, because the tunability is very sensitive to the dielectric constituents permittivity [4]. For this reason the highest contrast between dielectric phase permittivities (1 for pores) and permittivity of regions (thousands in case of paraelectric/ferroelectric matrix) ensures highest local field inhomogeneity and strongly enhance the nonlinear dielectric response.

The aim of the present work was to investigate in a systematic way the role of the pores concentration and phase interconnectivity (0-3, 3-3 and 1-3) on the nonlinear properties of $BaTiO_3$ porous ceramics. The obtained results show that by increasing porosity a systematic reduction of permittivity was obtain, while the tunability is almost constant. The results were explained using the concept of local field engineering, in order to propose new porous configurations with improved tunable properties.

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Bismuth ferrite based single multiferroic materials

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Bismuth ferrite is one of the most promising single multiferroic materials, but problems with low electrical resistivity and unexpressed magnetisation prevent its application. Substitution of Bi^{3+} and Fe^{3+} ions with ions of different size and/or valence is one of the ways of overcoming the drawbacks by modifying the structure and the mechanism of conduction [1]. Other potentially beneficial improvements could be introduced through synthesis. Chemical solution methods make the system homogeneous and help in sustaining the homogeneity during the synthesis process [2].

For these reasons, we have chosen to synthesize $BiFeO_3$ powders and ceramics doped with ions of different valences. Auto-combustion synthesis route with glycine as a fuel has proved to be successful in obtaining $BiFeO_3$ powder with small amount of secondary phases at low temperatures. Cations with valences from +1 to +6 were introduced in places of Bi^{3+} and Fe^{3+}, and their influence on phase composition, structure, microstructure, dielectric, ferroelectric and magnetic properties was investigated. The doping level of 5 mole % was too high for some of the added cations to completely incorporate into structure, so the secondary phases were formed and densification process was disturbed in ceramics processing. Others haven't changed the structure significantly, but had notable impact on properties.

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