



Deliverable

WP5 – Dissemination and exploitation

D5.11 Project literature and posters (3)

Project Information

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Executive summary

The Project literature and posters (3) deliverable is related to Task 5.2 of PULSE-COM project and in particular to dissemination activities conducted during the final year of the project:

- Publications in scientific journals and conferences and workshops;
- Press releases;
- Posters display at conferences, workshops and seminars
- IPR

Deliverable report

This deliverable is the final update of a series of three deliverables started by the D5.9 - Project literature and posters (1) and followed by the D5.10 - Project literature and posters (2). To facilitate the reading, the information found in the former deliverable are not kept in this one. By consequence, to have the entire vision of the scientific dissemination activities, the three deliverables are needed.

1 Publication in scientific journals, conferences and workshops

1.1. Scientific journals

From M32 to M43, four new articles have been published in various journals:

- Ana Violeta Filip, Bogdan Alexandru Sava, Rares Victor Medianu, Lucica Boroica, Marius Catalin Dinca, Rovenca Pascu, Nicolae Tigau, Andreea Andrei, Antoniu Moldovan, Marius Dumitru, Mihai Oane, Mihai Eftimie, 2022, “[Ultrathin films of silver by Magnetron Sputtering](https://doi.org/10.3390/inorganics10120235)”, *Inorganics*, 10, 235, 1-14. <https://doi.org/10.3390/inorganics10120235>
- Domenico Sagnelli, Massimo Rippa, Amalia D’Avino, Ambra Vestri, Valentina Marchesano, Lucia Petti, 2022, “Development of LCEs with 100% Azobenzene Moieties: Thermo-Mechanical Phenomena and Behaviors”, *Micromachines*, 13, 1665. <https://doi.org/10.3390/mi13101665>
- Thomas Jalabert, Manojit Pusty, Mireille Mouis and Gustavo Ardila, 2023, “[Investigation of the diameter-dependent piezoelectric response of semiconducting ZnO nanowires by Piezoresponse Force Microscopy and FEM simulations](https://doi.org/10.1088/1361-6528/acac35)”, *Nanotechnology*, 34, 115402. <https://doi.org/10.1088/1361-6528/acac35>
- Andrés Jenaro Lopez Garcia, Mireille Mouis, Thomas Jalabert, Alessandro Cresti and Gustavo Ardila, 2023, “[Length and polarity dependent saturation of the electromechanical response of piezoelectric semiconducting nanowires](https://doi.org/10.1088/1361-6463/acbc86)”, *Journal of Physics D: Applied Physics*, 56, 125304. <https://doi.org/10.1088/1361-6463/acbc86>

Recently a new article has been submitted:

- Domenico Sagnelli, Amalia D’Avino, Massimo Rippa, Ambra Vestri, Valentina Marchesano, Giuseppe Nenna, Fulvia Villani, Gustavo Ardila, Sonia Centi, Fulvio Ratto, Lucia Petti, 2023, “[Enhancing Quantum Yield in Azobenzene Actuators for Solar Energy Harvesting](#)”, *ACS Applied Materials & Interfaces*, submitted.

1.2. Scientific conferences

The consortium attended seven conferences in which the PULSE-COM scientific advancements have been presented:

- [European Optical Society Annual Meeting 2022](#), 12th-16th September 2022, Porto (Portugal). Francesco Simoni has presented for CNR a presentation on “Heliconical Cholesterics: new opportunities for optofluidics?”.
- [Electronics for Sustainable Societies](#) – 13th-16th September 2022, Liverpool (UK). Gustavo Ardila has presented for UGA a presentation on the “Semiconducting Piezoelectric Transducers based on ZnO Nanowires”.
- [Notte dei Ricercatori](#), 30th September 2022, Napoli (Italy). Domenico Sagnelli (CNR) presented the PULSE-COM project with some general results and Amalia D'Avino (CNR) presented some more specific results in a poster entitled “Multiwavelength and mechanical improvement in doped azo-PMPs”.
- [Futuro Remoto](#), 22nd-27th November 2022, Napoli (Italy). A team coming from both CNR and ENEA (Fausta Loffredo, Giuseppe Nenna, Fulvia Villani, Anna De Girolamo Del Mauro, Tommaso Fasolino, Maria Montanino, Giuliano Sico, Riccardo Miscioscia, Lucia Petti, Domenico Sagnelli, Ambra Vestri, Valentina Marchesano, Amalia D'Avino, Massimo Rippa) have presented the PULSE-COM project through experiments (Figure 1).



Figure 1: Some of the CNR/ENEA people involved in the Futuro Remoto event.

- [World congress of Nano science and technology - Nano-S&T](#) – 8th-10th February 2023, Sapporo (Japan). Gustavo Ardila has presented for UGA a presentation on the “Nanowire-based piezoelectric transducers: the impact of semiconducting properties”.
- [SPIE Optics + Optoelectronics](#), 24th-27th April 2023, Prague (Czech Republic). The whole consortium gathered within this conference. The final event of the project, called “PULSE-COM Workshop” had been organised the 27th within the Smart Materials for Opto-Electronic Applications conference (Figure 2).



Figure 2: PULSE-COM consortium gathered at the SPIE Conference for its final event.

It had been the occasion to produce ten articles to disseminate the results of the project. The complete list is described hereafter:

- Patrick Meneroud, Jolan Gauthier, Sylvain Duc, Mathieu Thomachot, Frank Claeysen, 2023, “[New range of light driven actuation devices](#)”, Proceedings Volume 12584, Smart Materials for Opto-Electronic Applications; 1258407 (2023) <https://doi.org/10.1117/12.2665171>.

- Amalia D'Avino, Domenico Sagnelli, Ambra Vestri, Massimo Rippla, Valentina Marchesano, Veronica Ambrogi, Anna De Girolamo, Fausta Loffredo, Fulvia Villani, Giuseppe Nenna, Lucia Petti, 2023, “[Optimization of PMP films' preparation and mechanical properties using ZnO nanoparticles as dopant](#)”, "Proceedings Volume 12584, Smart Materials for Opto-Electronic Applications; 1258405 (2023) <https://doi.org/10.1117/12.2665616>.

- M. Haras, M. Wlazło, W. Andrysiewicz, T. Skotnicki, 2023, “[ZnO nanorods as a piezoelectric energy harvester from light induced flexions](#)”, Proceedings Volume 12584, Smart Materials for Opto-Electronic Applications; 1258408 (2023) <https://doi.org/10.1117/12.2665540>.

- Fulvia Villani, Fausta Loffredo, Giuliano Sico, Maria Montanino, Anna De Girolamo Del Mauro, Maria Federica Caso, Manojit Pusty, Thomas Jalabert, Giuseppe Nenna, Gustavo Ardila, 2023, “[Printed ZnO nanoparticle seed layers to grow ZnO nanowires on flexible substrates](#)”, "Proceedings Volume 12584, Smart Materials for Opto-Electronic Applications; 125840A (2023) <https://doi.org/10.1117/12.2666645>.

- F. Loffredo, A. De Girolamo Del Mauro, F. Villani, M. F. Caso, T. Fasolino, R. Miscioscia, A. Vestri, D. Sagnelli, A. D'Avino, L. Petti, G. Nenna, 2023, “[Photomobile films based on liquid crystal polymer carbon black composites](#)”, "Proceedings Volume 12584, Smart Materials for Opto-Electronic Applications; 125840J (2023) <https://doi.org/10.1117/12.2673120>.

- Anna De Girolamo Del Mauro, Fausta Loffredo, Fulvia Villani, Maria Federica Caso, Tommaso Fasolino, Ambra Vestri, Domenico Sagnelli, Amalia D'Avino, Lucia Petti, Giuseppe Nenna, 2023, “[Visible photomobile response of azobenzene-based](#)”, "Proceedings Volume 12584, Smart Materials for Opto-Electronic Applications; 125840B (2023) <https://doi.org/10.1117/12.2666618>.

- Dumitru Ulieru, Oana-Maria Ulieru, 2023, “[The comparative analysis of 2D photonic crystals applications based on specific modeling/simulation results](#)”, "Proceedings Volume 12584, Smart Materials for Opto-Electronic Applications; 125840C (2023) <https://doi.org/10.1117/12.2665488>.

- Wojciech Andrysiewicz, Dominik Wojcieszczak, Robert Socha, Domenico Sagnelli, Amalia D'Avino, Lucia Petti, 2023, "[Photo-mobile polymer in energy harvesting applications under simulated solar light](#)", "Proceedings Volume 12584, Smart Materials for Opto-Electronic Applications; 1258409 (2023) <https://doi.org/10.1117/12.2666931>."
- Thomas Jalabert, Manojit Pusty, Andrés Jenaro Lopez Garcia, A. Cresti, Mireille Mouis, Gustavo Ardila, 2023, "[ZnO nanowires based piezoelectric energy transducers: the role of size and semiconducting properties](#)", "Proceedings Volume 12584, Smart Materials for Opto-Electronic Applications; 1258406 (2023) <https://doi.org/10.1117/12.2665500>."
- Bogdan Alexandru Sava, Ion Sandu, Bogdan Stefanita Calin, Lucica Boroica, Ana Violeta Filip, Marius Cătălin Dincă, Alexandra Maria Isabel Trefilov, Claudiu Teodor Fleacă, Marius Dumitru, Marian Zamfirescu, Dumitru Ulieru, 2023, "[Optical effects by opal/reverse opal structures, laser polymerizing and plasmonic Ag ultra-thin films](#)", "Proceedings Volume 12584, Smart Materials for Opto-Electronic Applications; 125840K (2023) <https://doi.org/10.1117/12.2682701>."

- [Materials Research Society Spring Meeting 2023](#), 25th-27th April 2023, Virtual event. Gustavo Ardila has presented for UGA a presentation on "Probing the Local Piezoelectric Response of Semiconducting ZnO Nanowires by Piezoresponse Force Microscopy and Finite Element Modeling."

Even if the project ends by the end of June 2023, some communication and dissemination actions will take place in the near future. It is for example the case for two joints communications by CNR and ENEA:

- [109th National Congress of the Società Italiana di Fisica \(SIF\)](#), 11th-15th September 2023, Fisciano (Italy), "Effect of carbon black on the photomobile properties of liquid crystal polymers with or without azobenzene moieties by F. Loffredo, A. De Girolamo Del Mauro, F. Villani, M. F. Caso, T. Fasolino, R. Miscioscia, A. Vestri, D. Sagnelli, A. D'Avino, L. Petti, G. Nenna. And "Optimization of photomobile polymer films' production by ZnO nanoparticles and silver nanocuboids doping by A. D'Avino, D. Sagnelli, A. Vestri, M. Rippa, V. Marchesano, A. De Girolamo Del Mauro, F. Loffredo, F. Villani, G. Nenna, F. Ratto, V. Ambrogi and L. Petti.

Or for a joint communication by SITEX 45 and INFLPR:

- [The 46th International Semiconductor Conference CAS an IEEE event](#), 11th-13th October 2023, Sinaia (Romania), "The spectral analysis instrumentation based on the optical effects generated by hybrid structures on Photomobile Polymer substrate". Authors: Bogdan Alexandru Sava, Dumitru Ulieru, Ion Sandu, Bogdan Stefanita Calin, Oana Maria Ulieru, Lucica Boroica, Ana Violeta Filip, Marius Cătălin Dincă, Alexandra Maria Isabel Trefilov, Claudiu Teodor Fleacă, Marius Dumitru, Marian Zamfirescu.

1.3. Scientific workshops

Thomas Jalabert from UGA has assisted to two workshops:

- [Journées nationales des nanofils semiconducteurs](#), 28th September 2022, Nice (France). Thomas Jalabert made an oral presentation on "Probing the local piezoelectric response of semiconducting ZnO nanowires by Piezoresponse Force Microscopy".
- [Forum des microscopies à sonde locale](#), 3rd-7th April 2023, Obernai (France), Thomas Jalabert made an oral presentation on "The impact of free carriers and surface traps on semiconducting piezoelectric structures and related devices".

1.4. Books

Some of the members of the consortium have been invited to contribute to a book entitled “Optical Materials and Applications: Volume 1 – Novel Optical Materials” edited by Iam Choon Khoo (The Pennsylvania State University, USA), Francesco Simoni (Università Politecnica delle Marche, Italy), and Cesare Umeton (Università della Calabria, Italy) (<https://doi.org/10.1142/13523>). The authors, D. Sagnelli, A. Vestri, A. D'Avino, M. Rippa, V. Marchesano, F. Ratto, A. De Girolamo Del Mauro, F. Loffredo, F. Villani, G. Nenna, G. Ardila, P. Meneroud, J. Gauthier, S. Duc, M. Thomachot, F. Claeysen, L. Petti have produced the final chapter on “Novel photosensitive materials for microengineering and energy harvesting”.

2 Press releases

No press releases had been produced during that period of the project.

3 Posters

As already introduced in the previous sections, the PULSE-COM partners had the opportunity to make some posters dedicated to various events.

For example, Dumitru Ulieru from SITEX 45 have been involved in the preparation of a poster entitled “Advanced sol-gel IV-VI quantum dots-doped thin films for temperature sensing systems” that has been presented to the 26th International Congress on Glass at Berlin (Germany) from the 3rd to the 8th of July 2022. From the 19th to the 21st of August 2022, Dumitru Ulieru was also involved in another poster with Xavier Vila (from SITEX 45 too) on “Complex sol-gel IV-VI quantum dots-doped inorganic thin films for temperature sensing instrumentation”. This poster had been presented at the 24th International Conference Materials, Methods & Technologies in Burgas (Bulgaria).

In September 2022, Amalia D'Avino made on poster for the “Notte dei Ricercatori” (Figure 3).

Also, for the SPIE Conference conducted in Prague in April 2023, two partners of the consortium have presented some posters. The first one, presented by Fausta Loffredo (ENEA) is about the “Photomobile films based on liquid crystal polymer-carbon black composites” (Figure 4). The second one, presented by Bogdan Sava (INFLPR), is about the “Optical effects by opal/reverse opal structures, laser polymerizing and plasmonic Ag ultra-thin films” (Figure 5).



PULSE-COM
PHOTO-PIEZO-ACTUATORS BASED
ON LIGHT SENSITIVE COMPOSITE

Multiwavelength and mechanical improvement in doped azo-PMPs

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Photo-mobile polymer (PMP) films are an important class of materials used to develop new applications in energy harvesting and sensoristic fields during the EU-project PULSE-COM n.863227. Usually, PMPs are realized with a mixture [1] of liquid crystals (LCs) including azobenzene moieties (6 mol%) that play a fundamental role in converting light into mechanical work thanks to a photoisomerization reaction. The aim of this work is to expand the absorption band of PMPs by doping these films with novel silver nanoparticles. The easy, solvent free and reproducible approach used to synthesize the doped films is explained. Optical and thermic properties are investigated to prove the multiwavelength behavior of doped films and show improvement in bending compared to undoped ones.

[1] Markus Labiladie, Hao Zeng & Art Primragl. Reconfigurable photobacter through synergistic use of photochemical and photothermal effects.

Realization of PMPs films

Sequence for PMPs film realization

- Cell Fabricration:** an elvamide (ELV) solution is spinned and rubbed on two glass slides later glued by Kapton strips (~ 50 μm);
- Loading Phase:** the isotropic LCs are inserted by capillary action into a cell;
- Polymerization phase:** the LCs mixture is placed under UV light (405 nm) for 30 minutes on each side;
- Collecting phase:** at the end of the irradiation and after 16h at nematic temperature the film is ready.

Optimization ✓

The coating of ELV is realized with a spin coater (4000 rpm for 30s). Two concentration of ELV (1% and 6%) are tested to understand if the layer thickness would influence the depth of rubbing and so alignment of LCs.

1% Elvamide

- ELV thickness 25 nm
- Torision
- NO Vibration

6% Elvamide

- ELV thickness 200 nm
- NO Torision
- Vibration

Doping with Silver nanoparticles

Preparation of doped PMPs

Dry Silver nanocuboids (NCs), that resonate at 774nm, are mixed with isotropic LCs until homogeneity. This mixture is injected in the cell at isotropic temperature. After, the PMPs are polymerized at the nematic temperature as for undoped film.

There are no changes in absorbance spectra of doped and undoped films. Possibly, 1% of NCs absorbance is not enough to be detected with our set-up. However, as shown below, such low concentration makes the differential

Characterization

The bending for doped film is better than undoped ones; Moreover, higher concentration leads to higher bending at the same power density; Doped PMP films can move under a wider range of wavelength.

Doped PMP films show also self-vibration during a constant irradiation with RED light.

Thermography

At wavelength near to resonance of the silver nanocuboids the doped film heats up while the undoped one does not. The silver NCs seems to dissipate heat at 457 nm.

Conclusions

- New elvamide solution allows to obtain films that have better and reproducible behavior in bending and in vibration;
- Our method is solvent free, nevertheless the dispersion of nanoparticles in the film is homogeneous;
- The silver NCs improves mechanical properties of material. Moreover, the light absorption band is broadened allowing PMP movement in a wider range of wavelength. Although the absorbance spectra of doped and undoped films are the same, the thermographic measurements prove that the performance improvements in doped azo-PMPs are due to the silver NCs presence.



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Figure 3: Poster presented by Amalia D'Avino (CNR) for the 'Notte dei Ricercatori' in Napoli (Italy).



Photomobile films based on liquid crystal polymer-carbon black composites



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INTRODUCTION

Liquid crystalline polymers (LC-POLs) are smart materials based on crosslinked elastic polymers chemically bounded to rigid, anisotropic units (mesogens). They combine elasticity, durability, light weight and mechanical strength with reversible actuation. For this reason, they have attracted a lot of attention as smart actuators in different fields [1-3]. The underlying mechanism of actuation of LC-POLs is the switching between LC/isotropic phases that produces a variation in orientational ordering of the mesogens and changes the macroscopic polymer shape [4]. In principle any external source that could activate the phase transition can be used to trigger the actuation. In order of sensitizing LC-POLs to light different routes can be investigated as for example incorporation of photochromic groups and/or nanoparticles [4-5]. In this work, the effect of low concentration of carbon black (CB) in a LC-POL with acrylic backbone was studied. CB was chosen as filler to induce phototactic properties in the polymer because it is a low cost, commercially available filler having high absorption of the solar spectra [6] and good thermal conductivity [7]. The morphology, the optical and photomobile properties of LC-POL/CB were studied and compared with that ones of pristine LC-POL.

MATERIAL AND METHODS

Table 1. Structures and mol% amount of LC monomers

LC MONOMERS	mol% in LC polymer
	18
	53
	28
	1



Fig.1 - General structure of LC-POL with acrylate backbone. R represents one of four possible pendent LC groups

Carbon Black Filler Powder

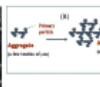
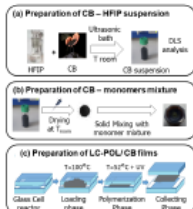


Fig. 2. SEM image (A) and schematic representation (B) of CB powder

Fabrication Process



Composites based on LC monomers (Table 1) and CB (Fig. 2) were prepared by UV-photopolymerization ($T < T_{LC}$, isotropic; $\lambda = 405\text{nm}$) of LC acrylic monomers and 0.1 wt% of CB filler. The reaction mixture was obtained by solid mixing of the components

Fig.3. Schema of fabrication process used to prepare LC-POL/CB films

RESULTS

OPTIMIZATION OF CB-HFIP SUSPENSION

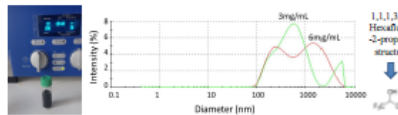


Fig. 4. DLS measurements of different suspensions of CB in HFIP

Table 2: Z-average (Zeq) and Polydispersity Index (PDI) measured by DLS.

CB concentration in HFIP (mg/mL)	Zeq (nm)	PDI
6	484±18	0.59±0.07
3	476±6	0.41±0.010

The Z average and the polydispersity index decrease with concentration suggesting a reduction of equivalent hydrodynamic radius of the CB structures and a more homogeneous and narrow distribution of the aggregate sizes.

OPTICAL AND MORPHOLOGICAL CHARACTERIZATION OF LC-POL/0.1CB FILMS

Thanks to the high absorption of CB, a low amount of this filler already enough to make the LC-POL/0.1CB dark (Fig.5b) and strongly reduces the transmittance of the LC-POL (Fig.6) in the range 300-900nm. For example, by comparing the transmittance values of two samples measured at 400nm and 700nm, a reduction of transmittance of 69% and 55% is observed for $\lambda=400\text{nm}$ and 800nm, respectively. The films do not present birefringence under polarized light (Fig.5c,d). This suggests that the filler disturbs the mesogen groups' orientation.

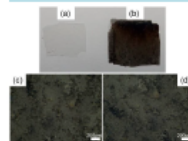


Fig. 5. Photos of LC-POL (a) and LC-POL/0.1CB (b) films; optical images of a LC-POL/0.1CB film obtained by polarized light microscope measured by putting the respective samples parallel to one of the two polarizers (c) or at 45 degrees (d)

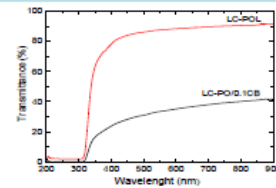


Fig.6 The transmittance of the LC-POL films reduced of about 60% by introducing only 0.1wt% of CB

PHOTOMOBILE BEHAVIOR AT 457 nm

Fig.7. Images of LC-POL (a) and LC-POL/0.1CB (b) obtained before (left) and after (right) irradiation with laser at 457nm at different powers

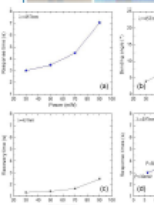
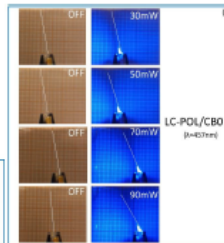


Fig.8. Response times (a) and bending angles (b) measured during laser irradiation at different powers; recovery times (c) measured after laser irradiation at different powers; response times (d) versus bending angles measured at different laser powers

Unlike the LC-POL film, a rapid bending of LC-POL/0.1CB film is observed ($3s < t_{response} < 7s$, Fig.8) for all the investigated powers (from 30mW to 90mW, Fig.7). By increasing the power the bending angle increases up to about 22°. The process is reversible with $t_{recovery} < 2.5s$ (Fig. 8c).

CONCLUSIONS

1. The inclusion of suitable amount of CB filler in LC polymer can induce photomobile behavior under visible light
2. Bending of 3° is observed for LC-POL/0.1CB films already at a 30mW irradiation by 457nm-laser. This bending angle increases up to 25° with the power (Pmax=90mW)
3. The process is rapid and reversible

Further work will be made to deeply investigate the working mechanism of this class of composites up to now attributed to a potential thermal effect induced by the absorbed irradiation.

REFERENCES

1. Sung, H. et al, Smart Mater. Struct. 29, 055032 (2020).
2. Da Cunha, et al, Chem. Soc. Rev. 49, 6568-6578, (2020).
3. Shen, Z. et al, J. Mater. Chem. B, 8, 8972-8991 (2020).
4. Yi, J. et al, Polymers 4(1), 316-340 (2012).
5. Sagnelli, D. et al, Nanomaterials 11, 3320 (2021)
6. Han, D. et al; Nanoscale Res. Lett. 6 (1) 1-7 (2011).
7. Song, J.-P. et al, International Journal of Heat and Mass Transfer 137, 184-191 (2019).



Optical effects by opal/reverse opal structures, laser polymerizing and plasmonic Ag ultra-thin films

SPIE.

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INTRODUCTION

The optical effects were obtained by three different ways, which are opal structures, laser polymerising and plasmonic ultrathin Ag films deposition.

METHODS

I. Opal structures were realised by deposition of a thin layer composed of sub-micron spheres of polystyrene on the surface of an optical fiber using drop-drying method and capillary method. Polystyrene spheres with a diameter of 0.5 μm and 20 μm were tested.

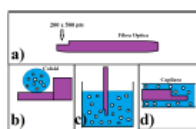


Fig. 1. Schematic: a) the morphology of the optical fiber used, b) the deposition of the colloidal solution by the "drop drying" method, c) the deposition of the colloidal solution by the "vertical deposition" method, d) the deposition of the colloidal solution by the "capillary" method

II. Multiple diffraction gratings have been designed and obtained on mechanically processed optical fiber, through means of Two-Photon Polymerization via laser direct writing (3D Lithography - 3DL). Optimal structures were obtained through variation of the tilt, power, writing speed, structure height. These structure were obtained for a writing speed of 80 $\mu\text{m/s}$, an average laser power of 28.8 mW with a size of the grating of 100 x 100 x 2.5 μm .

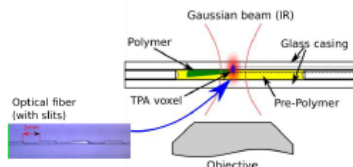


Fig. 2. Sandwich-like sample setup for writing diffraction gratings on the surface of a mechanically processed optical fiber via 3DL

III. Ultrathin Ag films of 1 to 9 nm thickness were deposited by RF Magnetron Sputtering onto different substrates. The samples were morphologically analyzed by atomic force microscopy (AFM) showing roughness of several nm.

RESULTS

I. The SEM electron microscopy shows well organized films in which the sub-micron spheres form crystalline monodomains with a size of 5x5 μm if microspheres with a diameter of 0.5 μm are used (approximately 10 x 10 spheres).

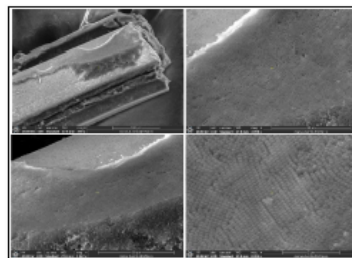


Fig. 3. SEM images of ordered thin films composed of sub-micron spheres with a diameter of 0.5 μm deposited in the pre-fabricated flat area of the optical fiber by the "capillary" method.

II. the height of the core surface varies above 5 μm . The tilt was determined with 3 points in this case (corners of the grating). The grating has a step of 5 μm (2 μm polymer, 3 μm space).

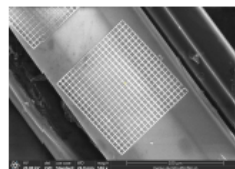


Fig. 4. Optimal diffraction grating fabricated via 3DL on the surface of mechanically produced slits in an optical fiber.

III. Ultrathin Ag films of 1 to 9 nm thickness were deposited by RF Magnetron Sputtering onto different substrates. The samples were morphologically analyzed by atomic force microscopy (AFM) showing roughness of several nm. SEM investigation showed the smoothness and homogeneity of the deposited ultrathin films. The films with the thickness between 5 and 9 nm combine low roughness with potential electrical conductivity, because they are continuous films with surface plasmonic properties.

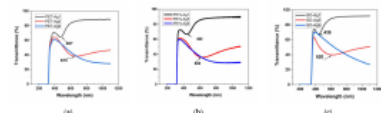


Fig. 5. Optical properties of as-deposited ultrathin films, transmittance, (a) on thick PET, (b) on thin PETs, (c) on optical glass, absorbance

CONCLUSIONS

- Using the capillary forces induced by the interfaces between a colloidal solution of spheres of 300 nm of polystyrene, it was possible to deposit ordered films of opal type, homogeneous, compact, with crystal dimensions of about five micrometers on a predetermined surface on the surface of an optical fiber.
- Diffraction gratings with a step of 5 μm were deposited on optical fiber slits using laser polymerizing.
- The films between 5 and 9 nm combine low roughness with potential electrical conductivity because they are continuous films with SPR properties, which make them valuable candidates for future photonic application.

REFERENCES

- Sandu, I.; Fleaca, C.T.; Dumitrache, F.; Sava, B.A.; Urzica, I.; Antoche, I.; Brajnicov, S.; Dumitru, M.; Shaping in the Third Direction; Fabrication of Hemispherical Micro-Concavity Array by Using Large Size Polystyrene Spheres as Template for Direct Self-Assembly of Small Size Silica Spheres, *Polymers* 2022, 14, 2158. <https://doi.org/10.3390/polym14112158>
- Ana Violeta Filip, Bogdan Alexandru Sava*, Rares Victor Medaniu, Lucica Boroica, Marius Catalin Dinca, Rovena Pasou, Nicolae Tigau, Andreea Andrei, Antoniu Moldovan, Marius Dumitru, Mihal Oane, Mihai ETime: Ultrathin films of silver by Magnetron Sputtering, *Inorganics*, 10, 235, 1-14. <https://doi.org/10.3390/inorganics10120235>

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Figure 5: Poster presented by Bogdan Sava (INFLPR) in the SPIE Conference, Prague (Czech Republic).

4 IPR

Within the project, one patent has been accepted (already presented in the deliverable D5.10). A new one has been submitted to cover the harvesting application.

4.1. Patents pending

- **Photo-piezoelectric device**

Applicants: ENEA, CNR, UGA

Authors: Giuseppe Nenna, Riccardo Miscioscia, Giuliano Sico, Maria Montanino, Gustavo Ardila, Tommaso Fasolino, Lucia Petti, Domenico Sagnelli

Filing date: N/A

European patent application number: N/A

- The portable high integration degree spectrometer/wavesector for spectral analysis in optical networks

Applicants: SITEX 45 SRL

Authors: Dumitru Ulieru, Oana-Maria Ulieru, Lorandt Szolga, Xavier Vila Gelli

Filing date: May 20th, 2023

National patent OSIM application number: A 2023 00925

4.2. Accepted patent

Photo-piezoelectric generator of electrical energy from light energy

Applicants: Centrum Badan i Rozwoju Technologii dla Przemyslu S.A.; Italian National Council of Research - CNR; ENEA; UGA

Authors: M Haras, T Skotnicki, M Wlazło, G Kołodziej, G Ardila-Rodriguez, L Petti, G Nenna

Filing date: 21st September 2021

European patent application number: EP21461595.7

Energy Conversion Device And Production Method

Application/Publication/Patent Number: EP3782258A1

Publication Date: 2021-02-24

European patent application number: EP19717981.5

Filing Date: 2019-04-11

Authors: Castagna Riccardo, Rippa Massimo, Petti, Lucia, De Girolamo Del Mauro Anna, Nenna Giuseppe, Diletto Claudia, Ardila Rodriguez Gustavo

5 Communication documents

For the final event of the project two documents have been produced (Figure 6): the first one is a leaflet gathering the main elements and results of the project. All the content is compacted in one page. The other one is an extended brochure of 36 pages presenting in detail the main results of the project. The two documents are accessible on the PULSE-COM project website (<https://www.pulsecom-h2020.eu/project-results/posters/>).



Figure 6: Visual of the first pages of the leaflet (on the left) and of the extended brochure (on the right).