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Feature issue introduction: colloidal systems

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Abstract: This feature issue on "Colloidal Systems" of *Optical Materials Express* highlights recent advances in a broad scope of colloidal particles and structures. It consists of seven papers primarily in the areas of metal colloids, polymer composites and quantum dots in colloidal solutions. It is hoped that this special theme issue can urge and stimulate further research endeavors into novel colloidal materials with improved optical or photonic properties to accelerate scientific discoveries in the field of optical colloids, thereby promoting their structural and device performance for potential photonic applications.

OCIS codes: (160.2540) Fluorescent and luminescent materials; (160.3918) Metamaterials; (160.4236) Nanomaterials; (160.6000) Semiconductor materials; (160.5298) Photonic crystals; (250.5403) Plasmonics.

References and links

1. S. S. Savchenko, A. S. Vokhmintsev, and I. A. Weinstein, "Temperature-induced shift of the exciton absorption band in InP/ZnS quantum dots," Opt. Mater. Express **7**(2), 354–359 (2017).
2. H. P. S. Castro, M. K. Pereira, V. C. Ferreira, J. M. Hickmann, and R. R. B. Correia, "Optical characterization of carbon quantum dots in colloidal suspensions," Opt. Mater. Express **7**(2), 401–408 (2017).
3. T.-C. Chiang, C.-Y. Chiu, T.-F. Dai, Y.-J. Hung, and H.-C. Hsu, "Surface-plasmon-enhanced band-edge emission and lasing behaviors of Au-decorated ZnO microstructures," Opt. Mater. Express **7**(2), 313–319 (2017).
4. V. S. Gerasimov, A. E. Ershov, S. V. Karpov, A. P. Gavrilyuk, V. I. Zakomirnyi, I. L. Rasskazov, H. Ågren, and S. P. Polyutov, "Thermal effects in systems of colloidal plasmonic nanoparticles in high-intensity pulsed laser fields [Invited]," Opt. Mater. Express **7**(2), 555–568 (2017).
5. J.-G. Park, W. B. Rogers, S. Magkiriadou, T. Kodger, S.-H. Kim, Y.-S. Kim, and V. N. Manoharan, "Photonic-crystal hydrogels with a rapidly tunable stop band and high reflectivity across the visible," Opt. Mater. Express **7**(1), 253–263 (2017).
6. W. Gao, M. Rigout, and H. Owens, "Optical properties of cotton and nylon fabrics coated with silica photonic crystals," Opt. Mater. Express **7**(2), 341–353 (2017).
7. V. Yu. Reshetnyak, I. P. Pinkevych, A. M. Urbas, and D. R. Evans, "Controlling hyperbolic metamaterials with a core-shell nanowire array [Invited]," Opt. Mater. Express **7**(2), 542–554 (2017).

A colloid or colloidal material is a mixture that has particle sizes spanning one to 1,000 nanometers in diameter, yet being still able to remain evenly distributed throughout the dispersion medium. Based on the dispersed phase and the continuous phase; i.e., what phase the dispersed substance is suspended in, colloidal systems can be classified into five groups: sol, gel, emulsion, foam, and aerosol. In recent years the rapid development of a good variety of new materials in the form of colloids has permitted many interesting optical, topological, and interface-science phenomena as well as their applications in optical and photonic devices such as photovoltaic cells, light-emitting diodes, lasers, displays, and photodetectors. The implications in chemistry, physics, biology, and technology should not go unnoticed.

In an effort to solicit original papers on recent advances in a wide spectrum of colloidal materials and systems, including but not limited to colloidal crystals, metal colloids, quantum-dot colloids, core–shell colloids, liquid-crystal and polymeric colloids, dye-doped composites, organic–inorganic hybrid materials, ferrofluids or colloids with magnetic nanoparticles, nanoparticle dispersions, surfactants, and biocolloids, we decided to include research works on furtherance in fabrication, characterization and, especially, the optical properties of all

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kinds of colloidal materials or structures. Specifically, this special theme issue comprises seven papers on "Colloidal Systems," of which two are invited articles. The collection can be divided into four categories. There are two papers related to luminescent colloidal quantum dots (Savchenko, Vokhmintsev, and Weinstein [1] as well as Castro *et al.* [2]). Two papers involve systems of metallic nanoparticles (Chiang *et al.* [3] and Gerasimov *et al.* [4]). There are two in the area of photonic crystalline structures (Park *et al.* [5] and Gao, Rigout, and Owens [6]). Finally, there is one article focusing on a system of a core-shell nanowire array in liquid crystal (Reshetnyak *et al*. [7]).

The Russian Team Savchenko, Vokhmintsev, and Weinstein report on an experimental study of the variation of the bandgap exciton energy with temperature in InP/ZnS colloidal quantum dots [1]. The presented work brings an interesting set of experimental data, showing the temperature dependence of the first excitonic peak. It is found that the optical transition energy, corresponding to the first exciton absorption peak of the InP core, is equal to 2.60 ± 0.02 eV at room temperature and that its variation with temperature in a range of 6.5–296 K originates mainly from the interaction between excitons and longitudinal acoustic phonons. The second paper on colloidal quantum dots is contributed by Castro *et al.* [2]. This Brazilian group led by Correia and Hickmann use laser ablation to prepare suspensions containing carbon dots from graphite powder. The colloidal systems are studied by means of UV-VIS-NIR spectroscopy and the authors describe the absorbance at 300 nm as a function of the filling factor. By performing photoluminescence and fluorescence studies, they observe tunable broad-band fluorescence, which is typical for carbon dots. Their fluorescence lifetime measurements with excitation at 310 nm and probing at 480 nm reveal a bi-exponential behavior contributed by different processes. Finally by employment of a thermally managed eclipsed Z-scan the nonlinear optical response is studied in an effort to separate the thermal from the electronic contribution of the systems. These studies have been performed using 100 fs, 800 nm laser excitation.

In the study of band-edge emission and lasing from ZnO microstructures [3], Chiang and colleagues in southern Taiwan explore the surface plasmon effect in Au-decorated ZnO. They demonstrate that the intensity of the band edge emission and lasing threshold from ZnO microstructures can be improved via surface plasmon resonance by Au nanoparticles in the hybrid Au/ZnO structures. Indeed, the near-band-edge emission intensity is found to be 11 times higher and the defect-related emission completely suppressed, in comparison with those from a pristine counterpart, due to the electron transfer between the conduction band and defect level of ZnO via the localized surface plasmon resonance by the incident light. The invited paper by Gerasimov *et al.* comes from an international research group teamed with eight members from Russia, Sweden, and USA [4]. This work studies thermal effects in colloidal Au and Ag nanoparticle systems under strong heating provided by a high-intensity laser pulse. The major contribution is their development of a physical model incorporating the mechanical, electrodynamical and thermal interactions in systems of nanoparticles under pulsed laser illumination, by which the phenomena observed during and after a pulse are elucidated. Experimental results are also shown to verify numerical ones of surface plasmon resonance.

In the nice paper entitled "Photonic-crystal hydrogels with a rapidly tunable stop band and high reflectivity across the visible," Park and associates present a new type of hydrogel photonic crystal with a stop band that can be rapidly varied across the entire visible spectrum [5]. The authors fabricate the photonic crystals by inducing depletion interaction between polystyrene (PS)-poly(Nisopropylacrylamide-co-bisacrylamide-co-acrylic acid) core-shell nanoparticles using a high-molecular-weight, non-adsorbing polymer (PAm) at high concentration. The hydrogel photonic crystals exhibit a thermally tunable stop band at visible wavelengths. By altering the temperature from 20 °C to 40 °C, the bandgap can be tuned from 650 nm to 440 nm at a rate of 60 nm/s. The response rate of the bandgap of the core-shell photonic crystals is three orders of magnitude faster than that of other similar photonic

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crystals reported previously in the literature. The short response time is attributable to the large collective diffusion coefficient ($D = 8.0 \times 10^{-3}$ cm^2s^{-1}) of the sparse hydrogel shells and the depletion forces. The high-refractive-index PS cores dominate the scattering of light from the core-shell particles. Since their size and index of refraction are independent of temperature (only the shells swell and de-swell as a function of temperature), the intensity and width of the measured peak of the reflected light from the crystals remain constant. The high refractive index of the PS cores also gives rise to high reflectivity of the crystals compared with that of previously reported pure microgel crystals. The authors use high concentration of depletant polymers so that the resulting crystals remain stable and do not melt at high temperatures above the volume phase transition temperature of the shell polymers. The approach is truly elegant, technically sound, and the interpretations of the data are rooted in the firm foundations of colloid and polymer physics/chemistry, indeed.

In addition to the above-mentioned work, another paper focusing on photonic crystals is also compiled in this special-issue collection [6]. Gao, Rigout, and Owens, in their paper entitled "The optical properties of cotton and nylon fabrics coated with silica photonic crystals," report colorant-free colored textile fabrics made by coating self-assembled silica nanoparticles (SNPs) on fabrics by means of a natural sedimentation method. The optical properties of various SNP-coated fabrics are investigated with the aid of reflectance spectroscopy, chromaticity coordinates (and CIE L*a*b* values), and scanning electron microscopy. The authors claim that the particle size of SNPs, fabric structure (woven and knitted), and inherent fabric colors (black and white) all have influence on the optical properties of the SNP-coated fabrics.

The last paper on the colloidal systems, which is an invited one, is written by Reshetnyak and coauthors [7]. This is a theoretical study of optical response of an anisotropic core (Ag or Au)-shell nanowire array embedded in a liquid crystal medium (a single compound known as 5CB), assuming that the nanowire shell's permittivity is anisotropic with radially-power-law-dependent components. Through the formulation of the problem, mathematical treatments, and analysis of the calculated results, the authors show that the system can possess two hyperbolic metamaterial (HMM) areas and the HMM properties can become significant in a desired visible or infrared spectral region by choosing the parameters of the core-shell nanowires.

We intend for this feature issue on "Colloidal Systems" of *Optical Materials Express* to render a timely topical and highly interesting overview in recent advances in a broad spectrum of colloidal science and technology. We have given a brief summary for each paper to portray the flavor and scope.

We are thankful to all of authors who have effortlessly prepared their contributed or invited papers to make this feature issue possible. All the peer reviewers deserve our many thanks for their invaluable time to provide professional and constructive comments, which definitely helped promote the scientific content of each published paper. Considering a special issue on this theme to be timely enough, we successfully formed the internationally editorial team back in April 2015, and later learned of our hit of a "snag" with this proposed feature in that *Optics Express* quite independently came up with a very similar feature entitled "Colloidal Nanophotonics." After ensuring their emphasis to be on colloidal nanophotonic physics, devices, and functions rather than the synthesis, whereas our emphasis would be on the fabrication, characterization and, especially, the optical properties of the colloidal materials rather than the device design, we decided to postpone this feature issue. For this sake, our thanks are due, in addition to Alexandra Boltasseva, present Editor-in-Chief of *Optical Materials Express*, to David Hagan, who stepped down from his founding Editor-in-Chief position in December 2015, for his support on this feature issue. W. Lee has pleasantly served as Associate Editor on the editorial board of *Optical Materials Express* for two terms since it was launched in 2011. This feature issue concludes his editorial service to this express journal. He has enjoyed working with the OSA staff members through the years. His personal

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gratitude is thus extended to the OSA journal staff for their hard work and considerate coordination throughout the entire review and production processes for not only this very feature issue but also every regular issue.