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Shunsuke Murai,[1] Russell J. Holmes,[2] Jun Lin,[3] Miguel Anaya,[4,5] and Gabriel Lozano[6,a)]

AFFILIATIONS

[1]Department of Material Chemistry, Graduate School of Engineering, Kyoto University, Kyoto, Japan
[2]Department of Chemical Engineering and Materials Science, University of Minnesota, Minneapolis, Minnesota 55455, USA
[3]Changchun Institute of Applied Chemistry, Chinese Academy of Sciences, Changchun, People's Republic of China
[4]Department of Chemical Engineering and Biotechnology, University of Cambridge, Cambridge, United Kingdom
[5]Cavendish Laboratory, University of Cambridge, Cambridge, United Kingdom
[6]Instituto de Ciencia de Materiales de Sevilla, Consejo Superior de Investigaciones Científicas-Universidad de Sevilla, Américo Vespucio 49, 41092 Sevilla, Spain

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[a)]**Author to whom correspondence should be addressed:** g.lozano@csic.es

Our key physiological functions and economic activity depend on the constant driving force of light.[1] Over the last few decades, incandescent and fluorescent lamps have been surpassed by electroluminescent semiconductors, giving birth to a new technology, so-called Solid State Lighting (SSL). The energy-efficiency, versatility, accessibility, and cost-effectiveness of LED lamps have resulted in an overall rise in the global usage of artificial lighting. Thus, it is not surprising that illumination requires ~15% of the total electrical energy consumed on the planet and 5% of worldwide greenhouse gas emissions.[2] Therefore, the quest for novel photoluminescent and electroluminescent materials and the design of innovative device architectures are key for the realization of energy-efficient and environmentally friendly light generation.[3,4]

GaN-based LEDs have revolutionized how we light up the modern world, leading to the 2014 Nobel Prize recognizing the importance of the blue LED.[5] Indeed, GaN-based III–V compound semiconductors can cover the entire visible light spectrum from high energy (i.e., violet) to lower energy (i.e., red) emission.[6,7] However, the long-standing "green gap" issue arising from lattice mismatches between the GaN buffer layers and the InGaN quantum wells are exacerbated when the In content is increased to reach longer wavelengths. The search for a single material family spanning the entire visible spectrum is motivated by the tremendous advantages that a microLED display would have in terms of color stability with temperature changes and aging. In this context, emerging thin-film LEDs, including organic LEDs (OLEDs) and perovskite LEDs (PeLEDs), are taking the field into an era in which emitted light can be tuned *à la carte* while keeping fabrication processes low.[8–10]

Similarly, a blue GaN LED and a color converter traditionally based on yellow phosphors are the basis of today's commercial white SSL. However, this conversion has an associated Stokes' loss on the order of 25%,[11,12] and the color quality of standard devices is low since typical YAG:Ce phosphors present poor red emission.[13] Indeed, their high fraction of blue emission limits their integration into indoor applications, since they produce cold white light with poor color-rendering index, which increases light pollution.[14] If YAG:Ce is combined with a red phosphor (e.g., CaAlSiN3: Eu2+), it does result in more faithful colors but at the cost of reduced efficiency. Moreover, phosphors are traditionally synthesized as micro-sized particles, hindering their nanostructuring and, hence, the fine tuning of their spectral and angular emission. In this context, photonic engineering enables tailored light–matter interaction, allowing emitting devices with both enhanced performance and novel functionalities to tackle technological challenges ahead.[15]

Considering this scenario where market demands are constantly evolving, the research community seeks further advances, including lower cost, expanded color gamut, minimized electrical consumption, full control over the optical output, and adaptability to various emerging applications such as flexible, wearable, and transparent devices. The "Emerging Materials and Devices for Efficient Light Generation" Special Topic of the Journal of Applied Physics highlights new routes to synthesize and characterize emerging emitters in combination with resonant nanophotonic architectures for the development of light-emitting devices of improved efficiency and with new functionalities. We have covered advances in the understanding of the physical mechanisms behind light generation, light conversion, and light extraction, promoting new avenues for the flourishing of next-generation light sources.

In a Perspective, Hudson *et al.* present recent advances on organic radical doublet emitters as active layers in organic light-emitting diodes (OLEDs).[16] In contrast to standard organic emitters that have a singlet ground state, radical species feature a doublet ground state that enables surpassing spin statistics to achieve charge recombination with 100% efficiency. In particular, authors discuss the emission mechanisms of radical organic semiconductors, highlighting specific bright structures that allow reducing exciton quenching. They also elaborate on ongoing research efforts, which include improving charge balance to alleviate efficiency roll-off for high current densities, color tuning toward green and blue, and device stability. Finally, they comment on the main challenges radical emitters should overcome in the next years to become an alternative to OLEDs.

In another example of electroluminescent materials, Zahedi *et al.* report on a numerical design of InGaN/InN quantum wells for third harmonic generation.[17] The authors discuss the influences of different structural parameters on the third-order susceptibility of the nonlinear systems under study to develop optimized heterostructures that would operate within the far- to near-infrared spectral region.

Also related to nonlinear processes, Yang *et al.* outline in another Perspective the state of the art of rare-earth-doped upconversion (UC) nano- and microparticles.[18] Specifically, authors provide the main keys that determine the luminescence efficiency of single UC systems. They highlight the importance of a careful analysis of the interplay between the crystal structure and photophysical properties at the nanoscale to develop UC nanomaterials showing enhanced performance for next-generation sensing, security, labeling, imaging, or super-resolution nanoscopy. As an example of the interest of rare-earth-doped microcrystals for temperature sensing, Chen *et al.* demonstrate anti-thermal quenching behavior in UC matrices based on materials with negative thermal expansion.[19]

Phosphors based on Eu-doped materials are among the most widely employed red-emitting color converters. In a Perspective, Quao *et al.* provide some keys related to the chemical composition of the host or the local environment of the luminescent center to design efficient Eu^{2+}/Eu^{3+} phosphors for white-light emission and displays.[20] In particular, the authors present a thorough analysis of the structural features that determine the efficiency of the luminescence in standard Eu phosphors. Also, they highlight new research pathways to demonstrate Eu-doped materials with improved chemical stability at lower cost, which turns out to be central to develop next-generation red emitters. In this context, Gao *et al.* demonstrate red-emitting Eu^{3+}-doped $BaLaLiTeO_6$ microparticles that are efficient and feature high color purity.[21] In another example of a red converter based on Eu^{3+}, Kitagawa *et al.* study the luminescent properties of different compounds with oxyhalide coordination using the Judd–Ofelt theory.[22] Authors perform a thorough analysis of the photophysical properties of the materials with temperature to attain relevant information on the interplay between structural properties and relaxation and quenching mechanisms, useful to design novel color-converters. On a similar note, Sabzevari *et al.* present colloidal quantum dots based on quaternary Zn–Ag–In–S as long-time stable green-to-red emitters.[23] In particular, authors demonstrate remarkable photoluminescence quantum yield values around 20% after more than 2 years of storage.

This Special Topic also includes articles that highlight results related to less conventional forms of light emission. Indeed, in a Perspective, Castaing *et al.* outline the main opportunities offered by persistent luminescent nanoparticles. These uncommon luminescent nanomaterials possess the unique ability to emit light long after being photoexcited, making them highly interesting for bioimaging, sensing, labeling, safety, or security.[24] Authors present main design strategies to develop persistent nanomaterials, most successful fabrication techniques to date, and discuss different applications, ranging from most established *in vivo* imaging to other more exploratory, where these nanomaterials may play a relevant role. They specifically address the physical mechanisms behind afterglow in the nanoscale and highlight that a precise understanding of the nature and the role of structural defects in connection to the photophysical properties of persistent nanomaterials is the key to push their integration into devices. In the same context, Liu *et al.* demonstrate Bi-doped $SrLaXO_4$ (X = Al, Ga, and In) powders that feature persistent luminescence from the UV to the visible spectral range upon x-ray excitation.[25] Besides, authors show that their UV-emitting persistent luminescent materials are interesting for therapy and real-time diagnosis.

In another example, Silva *et al.* analyze the effect of neutron irradiation in enriched $Zn^{82}Se$ used in scintillators.[26] Authors study the formation of point defects in such materials and conclude that irradiation with fast neutrons does not improve the scintillation properties of ZnSe for the detection of nuclear particles. On a related note, Yasar *et al.* investigate a photonic crystal design to improve the spatial resolution of a scintillator to detect x-ray radiation.[27] Specifically, they theoretically analyze some common scintillators and propose optimized structural parameters for the photonic crystals needed to guide scintillated light in the desired direction toward the detector.

Regarding the photonic design of light sources, this Special Topic also includes two articles that show the potential of nanophotonics for tuning the emission properties of luminescent materials. Indeed, Murai *et al.* show that the combination of periodic arrays of resonant scatterers allows for adjusting emission directionality of nearby emitters. In particular, the authors fabricate a dielectric metasurface on top of a YAG:Ce phosphor plate and demonstrate that the photoluminescence from the color converter is directionally enhanced in the forward direction as a result of the coupling of Ce^{3+} emission with the modes supported by the array of scatterers.[28] In another example, Murai *et al.* combine two different arrays that are resonant, respectively, at the absorption and emission frequencies of the sandwiched emitters.[29] As a result, 15-fold emission enhancement is attained, which originates from the product of the individual contribution of each metasurface.

Wan *et al.* develop Er^{3+}-doped tellurite–gallium oxyfluoride glass as gain material for infrared fiber lasers.[30] A careful analysis of the properties of the laser indicates that such materials feature high glass-transition temperature, large emission cross section, and longer photoluminescence lifetime compared to conventional Er-doped tellurite glasses. In another example, Kaur *et al.* report the fabrication of Sm^{3+}-doped ZnO phosphors that work both for downshifting and for upconversion.[31] The authors analyze energy transfer mechanisms involved in the color conversion process and suggest the potential of their findings for lighting and photovoltaics.

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AUTHOR DECLARATIONS

Conflict of Interest

The authors have no conflicts to disclose.

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