Review Article

# In the Beginning there was Darkness, Today there are Lighting Systems

SHRINE PUBLISHERS
Crafting your Achievement

Shrine Journal of Research and Sciences (SJRS)

ISSN: 3069-2032

Volume 3 Issue 1, 2026

Article Information
Received date: January 14, 2026
Published date: January 27, 2026

**R Martínez Martínez[1*], M García Hipólito[2], G Juárez López[1], F Ramos Brito[3] and R M Calderón Olvera[2]**

[1]*Technological University of the Mixteca, Oaxaca, Mexico*
[2]*Institute of Materials Research, National Autonomous University of Mexico, Mexico*
[3]*Materials Synthesis Laboratory, Faculty of Physical and Mathematical Sciences, Autonomous University of Sinaloa, University City, Mexico*

*Corresponding author
Rafael Martínez Martínez, Institute of Industrial and Automotive Engineering. Technological University of the Mixteca. Av. Dr. Modesto Seara Vázquez, Mexico

DOI: 10.65070/SJRS.2026.819

Keywords
History; Lighting; Light sources; Solid state lighting; LEDs



## Abstract

An overview of the evolution of artificial lighting is presented, tracing its development from the simple systems used by ancient civilizations such as torches and oil lamps to today's advanced technologies, including LEDs. This popular article highlights the work of a collaborative research group, focusing on their studies of photoluminescent materials produced using an economical deposition technique. These materials show promising potential for use in modern solid-state lighting applications, which are increasingly important in everyday life.

## Introduction

The evolution of lighting systems has been a fundamental aspect of the development of human civilization, shaping the way we live, work, and relate to our surroundings. From the rudimentary torches and oil lamps used in antiquity to today's advanced LED lighting, each technological advance in illumination has marked a significant milestone in human history [1].

A lighting system is a set of light sources, designed using specific technologies to provide artificial illumination. The primary purpose of a lighting system is to deliver an appropriate quantity of light for a variety of activities and needs, such as general, task, or decorative lighting. In addition, modern lighting systems place strong emphasis on energy efficiency, durability, and the capacity for customization, allowing them to adapt to different environments and user preferences [2].

The earliest lighting systems, such as torches and candles, provided limited and inefficient light, yet they enabled human activities to extend beyond sunset (Figure 1). With the advent of the Industrial Revolution, the introduction of gas street lighting and, later, the invention of the incandescent light bulb radically transformed both public and private spaces. These developments had a profound influence on quality of life and played a key role in fostering economic progress [1].

In recent decades, we have witnessed a new revolution in illumination with the emergence of solid-state lighting systems, particularly light-emitting diodes (LEDs). These technologies have surpassed their predecessors in terms of energy efficiency, durability, and light quality. LEDs not only consume less energy and last significantly longer but also offer unprecedented flexibility in the design and application of lighting systems, adapting to a wide range of needs and environments [3].

Considering the above, the aim of this popular science essay is to outline, through selected historical elements, the transition towards solid-state lighting systems - a transition that represents a paradigmatic shift in how we conceive and use light. Within this context, understanding the history and advantages of these systems is essential to fully appreciate their impact and future potential. The essay also presents some of the contributions achieved by our research and collaborative group.

**Figure 1:** Candle and torch lighting.
Source: Courtesy of photograph https://stocksnap.io/search/Candles+and+torches

## Timeline of Artificial Lighting

In 2015, UNESCO promoted the International Year of Light, with the participation of numerous scientific and educational organizations from around the world. The principal aim of this celebration was to highlight the importance of light and lighting technologies in people's lives and in the development of society [4]. From torches to the widespread use of LEDs today, a lighting system may be defined as a set of components designed to provide artificial light within a given space. Such systems can vary greatly in complexity and technology [5]. Consequently, a lighting system is not merely about switching on a bulb; it involves optimizing light distribution, improving energy efficiency, and creating safe and comfortable environments [4,5].

Before delving further into lighting systems, it is useful to take a panoramic view of the history of illumination. The earliest civilizations, such as those of Mesopotamia and Egypt, relied on torches and oil lamps. In Greece and Rome, oil lamps were refined using improved wicks and more efficient containers. During the Middle Ages, the use of oil lamps and candles continued across Europe, while in China oil lamps evolved with increasingly sophisticated designs. In the Renaissance, chandeliers became popular in Europe, significantly enhancing indoor lighting. In the 18$^{th}$ century, Aimé Argand invented the Argand lamp, which employed a tubular wick and a glass chimney to improve the efficiency of oil lamps. Shortly thereafter, William Murdoch used gas to illuminate his house in Redruth, Cornwall, marking the beginning of gas lighting. By the 19$^{th}$ century, the first public gas lighting systems were installed in London. In 1879, Thomas Alva Edison and Joseph Swan independently developed practical, commercially viable incandescent light bulbs, and in 1881 Edison established the first commercial power station in Pearl Street, New York, supplying electricity for incandescent lighting.

In the twentieth century, Henry Joseph Round observed electroluminescence in 1907, laying the foundations for the development of LEDs. By the 1930s, fluorescent lamps were introduced, offering a more efficient alternative to incandescent lamps. In 1962, Nick Holonyak Jr developed the first visible red light-emitting diode. During the 1990s, LEDs began to be used for general illumination following significant improvements in efficiency and the production of white light. More recently, at the beginning of the twenty-first century, LEDs became the dominant lighting technology due to their energy efficiency, durability, and reduced costs. In 2010, the European Union and other countries began to phase out incandescent bulbs because of their poor energy efficiency. This timeline highlights the major milestones in the history of artificial lighting (Figure 2), from the earliest uses of fire to modern LED technology [5].

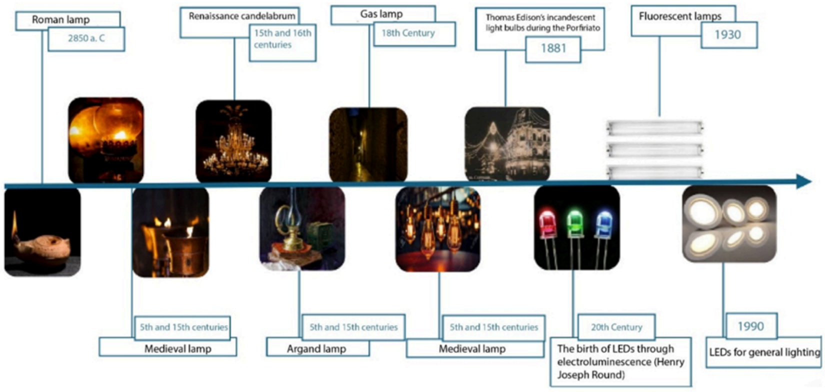


**Figure 2:** Timeline for the evolution of lighting systems.
Source: Courtesy of photographs https://stocksnap.io/search/Candles+and+torches

At present, solid-state lighting (SSL) has revolutionised the way we illuminate our surroundings. Light-emitting diodes (LEDs) have been at the forefront of this transformation, offering lighting solutions that are both highly efficient and long-lasting [6]. Research into new materials that make the application of LEDs promising in lighting systems for homes, industry, and public illumination has been driven by the emergence of blue-, green-, and red-emitting LEDs. The simultaneous combination of emissions from these three colours makes it possible to obtain white light (Figure 3). This capacity for combining the three primary emissions underpins LED-based technology for the generation of white light sources [7].

**Figure 3:** LED lamps; internal details for solid-state lighting systems (SSL).
Source: Courtesy of photograph https://stocksnap.io/search/lampara+LED+parte+interna

The active component responsible for light emission in an LED is commonly referred to as the phosphor, luminophore, or luminescent matrix. At present, research efforts are focused on replacing the use of three separate phosphors for white-light emission traditionally achieved by combining three colours: blue, green, and red with a single luminescent matrix capable of producing the same effect [7]. Human beings have evolved to carry out their activities under natural light; consequently, solid-state lighting (SSL) technologies seek to provide light sources that span the entire electromagnetic spectrum (Figure 4), echoing, in an engineered form, the richness and continuity of daylight itself.

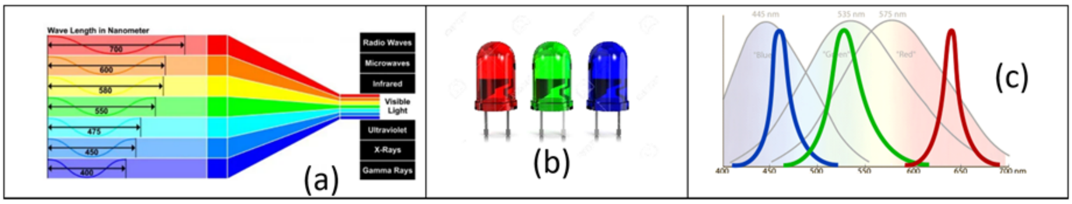


**Figure 4:** Electromagnetic spectrum of the visible portion for the human eye (a), basic commercial colours for LED light sources (b), and luminescent spectrum with the basic LED colours.
Source: Courtesy of photograph of https://www.cientec.or.cr/articulos/radiaciones-electromagneticas

On the other hand, it is well known that of the total global generation of electrical energy, approximately 15-20 % is consumed by lighting. This has clear environmental consequences, particularly in relation to global warming. It is therefore essential to underscore the importance of energy efficiency and the adoption of more sustainable lighting technologies, such as LED technology, which can significantly reduce electrical energy consumption.

The authors of this popular science essay have collaborated in the research and development of new materials with luminescent properties. These materials have the potential to be used as active matrices in devices known as LEDs. The principal contribution of this research group lies in the knowledge and characterization of photoluminescent materials that are suitable candidates for use in such devices.

The property of electroluminescence is defined as the emission of light observed when a semiconductor material is subjected to an electric field, as a result of the recombination of electrons and holes. The collaborative research group initially focused on the synthesis of materials with photoluminescent properties. Photoluminescence refers to the emission of visible light as a consequence of exciting a luminophore with ultraviolet radiation. It is important to bear in mind that these photoluminescent materials may also possess the capability to be utilized as electroluminescent materials, enabling their application in LED technologies. The materials referred to above are synthesised using a technique known as Ultrasonic Spray Pyrolysis (USP) technique [8].

Over the past fifteen years, our field of research into photoluminescent materials has experienced remarkable growth, driven by the global demand for more efficient and sustainable lighting solutions. Without losing sight of the central concept of photoluminescence, these materials have captured the attention of researchers worldwide owing to their wide-ranging applications, which extend from illumination technologies to biomedicine [9].

One of the most significant advances in this field is the development of materials that emit white light. Unlike monochromatic sources, white light is a harmonious combination of multiple wavelengths, producing an illumination that appears natural to the human eye. Luminescent materials capable of generating white light hold the potential to transform lighting technology, as they have progressively replaced conventional light bulbs with more durable and energy-efficient alternatives, such as LEDs. This approach is grounded in the ability of luminophores to convert the blue light emitted by an LED into white light through an appropriate mixing of emissions across the visible spectrum [10].

The research carried out by the present collaborative group, which has led to the development of these materials, is focused on the synthesis and characterization of nano-structured films and powders. These materials emit light across different regions of the visible spectrum: blue, green and red. To this end, rare-earth-based phosphors are employed, renowned for their ability to produce high-intensity light emission. By applying the USP technique, the group has published a series of studies [10-22]. These materials have formed the basis of numerous investigations aimed at optimizing white-light emission through the simultaneous spectral combination of red, green and blue emissions to obtain balanced white light (RGB). The acronym RGB stands for Red, Green and Blue, the primary colours of light; when these colours overlap, they give rise to white light. Within the RGB model, a wide range of colours is generated by mixing different intensities of these three fundamental components. This model is widely used in electronic devices such as computer displays, televisions and digital cameras to represent and reproduce colour images. In this sense, the materials prepared by this group of researchers also show clear potential for application in such technologies. What follows is a brief explanation of the key concepts required to become familiar with the characterization of white-light-emitting materials, particularly through chromaticity coordinates and colour temperature.

## Chromatic coordinates

Chromatic coordinates and colour temperature are fundamental concepts in colour science and are widely used across a range of technological applications, particularly in lighting. Moreover, these principles are essential to the development of solid-state white-light illumination systems - an emerging technology that has profoundly transformed the lighting industry. Chromatic coordinates provide a mathematical means of representing colour. They are derived from the CIE 1931 colour space, developed by the International Commission on Illumination (CIE). Within this framework, any colour can be described using two chromaticity coordinates, commonly denoted as “x” and “y” (Equations 1 and 2). These coordinates are calculated from the spectral power distribution of light and are normalized according to the following expressions:

$$x = \frac{X}{X + Y + Z} \qquad (1)$$

$$y = \frac{Y}{X + Y + Z} \qquad (2)$$

Here, X, Y and Z are the tristimulus values of the light, obtained by integrating the spectral distribution of the light with the CIE colour-matching functions corresponding to the primary colours. The Y value represents luminance, while “x” and “y” define the chromaticity of the colour that is, its hue and saturation, independent of luminance [23].

In this elegant mathematical description lies a powerful idea; by reducing the complexity of light to a pair of coordinates, we gain the ability to map, compare and ultimately engineer colours with remarkable precision an essential step in shaping the luminous technologies that illuminate our modern world.

## Colour Temperature

Colour temperature is a measure that describes the colour of a light source in terms of the temperature of an ideal radiator known as a black body. It is expressed in degrees Kelvin (K). Light sources with low colour temperatures (approximately 2000 K to 3000 K) emit light that we perceive as warm, characterised by reddish or yellowish hues. By contrast, high colour temperatures (above 5000 K) correspond to cool light, distinguished by bluish tones.

Colour temperature is linked to chromaticity coordinates through the concept of the Planckian locus, a curve on the chromaticity diagram that represents the colour of light emitted by a black body at different temperatures (Figure 5). This locus establishes a meaningful correlation between the perceived colour of light and its temperature, enabling a clear and systematic description and comparison of diverse light sources.

In solid-state lighting systems, chromaticity coordinates and colour temperature are essential parameters for ensuring the quality and consistency of the emitted light. In applications that demand accurate colour rendering, chromaticity coordinates allow engineers to design lighting systems that closely align with the specific requirements of each application, thereby translating physical principles into carefully controlled visual experiences [24].

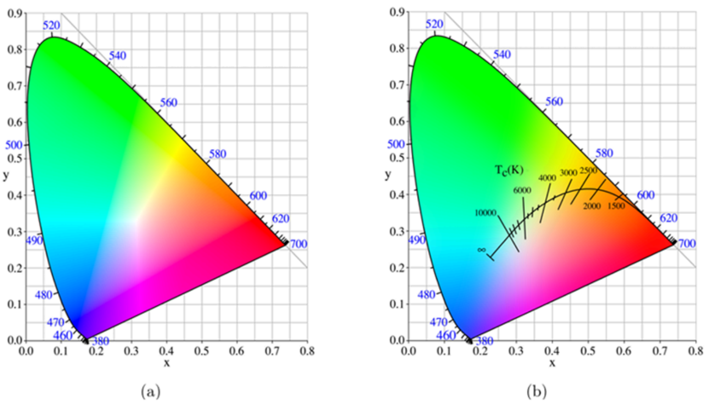


**Figure 5:** a) CIE diagram, b) CIE diagram showing the Planckian locus curve.

These studies address the importance of photoluminescence as a field of research through the analysis of chromaticity coordinates and colour temperature. The authors have reported noteworthy results in internationally circulated scientific journals, suggesting that these investigations are of clear interest to the scientific and technological communities. Three representative examples of this type of analysis are cited below.

In Figure 6(c), this work explores the luminescent properties of HfO2 thin films doped with $Eu^{3+}$, $Tb^{3+}$ ions and co-doped with $Eu^{3+}$ $+Tb^{3+}$ ions excited through both photoluminescence and cathodoluminescence. The $HfO_2$: $Tb^{3+}$ films, when excited at 277 nm, exhibit emission bands centred at 491, 543 (the dominant emission), 551 and 586 nm. In the case of co-doping with $Eu^{3+}$ and $Tb^{3+}$ ions, white-light emission was observed under excitation at 320 nm, as indicated by the CIE chromaticity diagram [19].

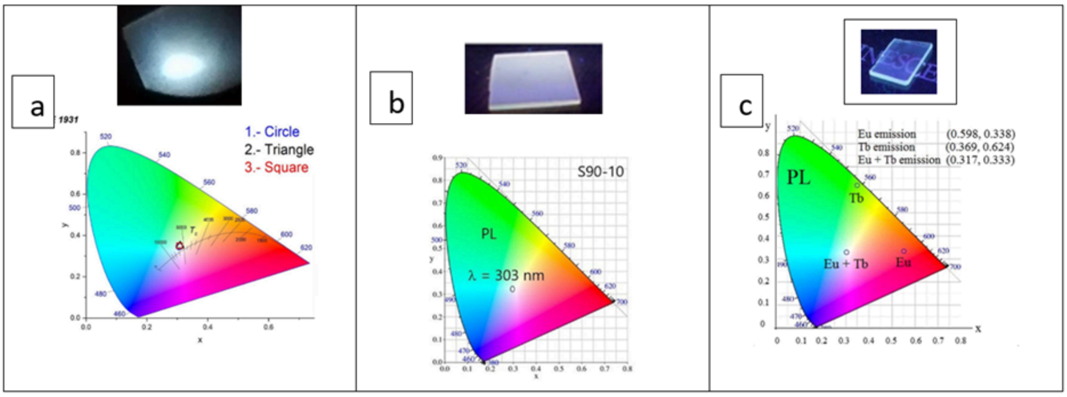


**Figure 6:** (a) CIE chromaticity diagram for polycrystalline $HfO_2$ and $HfO_2$:$Al^{3+}$ coatings [10]; the upper inset shows the observation of white light emission. (b) CIE chromaticity diagram corresponding to zinc aluminate thin films doped with trivalent terbium and europium ions, obtained using the USP technique; the upper inset illustrates the resulting white light emission [14]. (c) Luminescent properties of $HfO_2$ thin films co-doped with $Eu^{3+}$ and $Tb^{3+}$ ions, exhibiting white light emission under excitation at 320 nm; the inset shows a transparent film displaying white light emission [19].

Figure 6(a) presents the results obtained from polycrystalline coatings of $HfO_2$ and $HfO_2$:$Al^{3+}$ synthesised using the USP technique. The photoluminescence and cathodoluminescence characteristics of the coatings were examined as a function of the synthesis parameters, namely the deposition temperature and the impurity content ($Al^{3+}$ ions). From the CIE chromaticity diagram, blue, bluish-white and warm emissions can be observed. White emission was found in the coatings depending on the substrate temperature, the dopant concentration and the excitation wavelength. The corresponding CIE chromaticity coordinates were (0.3067, 0.3462), (0.3091, 0.3502) and (0.3073, 0.3498), all close to the ideal white emission point (0.3333, 0.3333). These values render the materials potentially useful for white-light illumination systems [10].

Figure 6(b) shows zinc aluminate thin films doped with trivalent terbium and europium ions, also obtained by means of the USP technique. In this case, emissions of various colours were achieved, including blue, green, red, yellow, orange and, most notably, white, with CIE coordinates of (0.3364, 0.3305). Such results point towards applications in lighting, photonics, full-colour display devices, flat-panel displays, among others [14].

In these thin films, one may glimpse how subtle changes at the atomic scale can give rise to the rich palette of light that underpins modern illumination and display technologies, an elegant reminder that, in understanding light, we come to a better understanding of both matter and us.

This sequence of diagrams offers a compelling visual narrative of how carefully engineered dopants and excitation conditions can guide materials towards the generation of white light a reminder that, at the intersection of structure and energy, even simple oxides can reveal unexpectedly rich optical behaviour.

## Conclusion

The contribution of this group of collaborators in the field of thin film and powder preparation using the USP technique has led to the development of luminescent materials capable of producing white light. These materials are indispensable in modern life, not only because they extend productive hours beyond sunset, but also because they enhance safety, well-being, and the aesthetic quality of our surroundings.

Moreover, the ability to control both the intensity and the colour of light makes it possible to create personalized environments that can positively influence human mood and health. Nevertheless, it is essential to use artificial lighting responsibly in order to minimise negative impacts, such as light pollution and excessive energy consumption. Artificial lighting should therefore be considered not merely from a functional view, but also through a sustainable and environmentally conscious perspective. With the continued effort and collaboration of this research group, the future of luminescent technology will continue to contribute meaningfully to the generation and understanding of light itself.

## References

1. Weisbuch C (2018) Historical perspective on the physics of artificial lighting. Comptes Rendus Physique 19(3): 89-112.

2. Karlen M, Spangler C, Benya JR (2017) Lighting design basics. In: John Wiley & Sons.

3. Sanderson SW, Simons KL (2014) Light emitting diodes and the lighting revolution: The emergence of a solid-state lighting industry. Research Policy 43(10): 1730-1746.

4. Massimo G (2018) An historical survey on light technologies. IEEE Access 6: 25881-25897.

5. David D (2008) A brief history of lighting. Optics and Photonics News 19(9): 22-28.

6. Kevin BW, Jeffrey TY, Mark HC, Ann ME (2006) International trends in solid state lighting: analyses of the article and patent literature.

7. Branas C, Azcondo FJ, Alonso JM (2013) Solid-state lighting: A system review. IEEE Industrial Electronics Magazine 7(4): 6-14.

8. Martínez MR, Juárez LG, Olvera RMC, Hipólito MG (2025) Using the USP Technique and White Light Generation. Shrine Journal of Research and Sciences 2(2).

9. Blasse G, Grabmaier BC (1994) Luminescent Materials. In: Springer-Verlag.

10. Cordero MIA, Martínez MR, Juárez LG, Hipólito GM, Frutis AM, et al. (2023) White luminescent emissions from $HfO_2$ and $HfO_2$: $Al^{3+}$ layers deposited by ultrasonic spray pyrolysis technique. Optical Materials 141: 113905.

11. Martínez MR, Speghini A, Bettinelli M, Falcony C, Caldiño U (2009) White light generation through the zinc metaphosphate glass activated by $Ce^{3+}$, $Tb^{3+}$ and $Mn^{2+}$ ions. Journal of luminescence 129(11): 1276-1280.

12. Téllez CS, Falcony C, Aguilar FMA, Flores AG, Hipólito GM, et al. (2013) White light emitting transparent double layer stack of $Al_2O_3$: $Eu^{3+}$, $Tb^{3+}$, and $Ce^{3+}$ films deposited by spray pyrolysis. ECS Journal of Solid State Science and Technology 2(6): R111.

13. Martínez MR, Yescas ME, Álvarez E, Falcony C, Caldiño U (2013) White light generation in rare-earth-doped amorphous films produced by ultrasonic spray pyrolysis. Advances in Science and Technology 82: 19-24.

14. Pérez HCD, Rodríguez BA, Brito RF, Calva BE, González F, et al. (2021) Strategy to achieve the emission of white light and other colors from $ZnAl_2O_4$:($Eu^{3+}$+$Tb^{3+}$) films deposited by the USP technique. Applied Physics A 127: 1-10.

15. González W, Álvarez E, Martínez MR, Yescas ME, Camarillo I, et al. (2012) Cold white light generation through the simultaneous emission from $Ce^{3+}$, $Dy^{3+}$ and $Mn^{2+}$ in $90Al_2O_3{\cdot}2CeCl_3{\cdot}3DyCl_3{\cdot}$ $5MnCl_2$ thin film. Journal of luminescence 132(8): 2130-2134.

16. Martínez MR, Álvarez E, Speghini A, Falcony C, Caldiño U (2010) Cold white light generation from hafnium oxide films activated with $Ce^{3+}$, $Tb^{3+}$, and $Mn^{2+}$ ions. Journal of Materials Research 25: 484-490.

17. Martínez MR, Álvarez E, Speghini A, Falcony C, Caldiño U (2010) White light generation in $Al_2O_3$: $Ce^{3+}$: $Tb^{3+}$: $Mn^{2+}$ films deposited by ultrasonic spray pyrolysis. Thin Solid Films 518(20): 5724-5730.

18. Martínez MR, Speghini A, Bettinelli M, Falcony C, Caldiño U (2009) White light generation through the zinc metaphosphate glass activated by $Ce^{3+}$, $Tb^{3+}$ and $Mn^{2+}$ ions. Journal of luminescence 129(11): 1276-1280.

19. Castillo AA, Hernández AJR, Hipólito GM, Romero LS, Swarnkar RK, et al. (2017) White light generation from $HfO_2$ films co-doped with $Eu^{3+}$+$Tb^{3+}$ ions synthesized by pulsed laser ablation technique. Ceramics International 43(1): 355-362.

20. Guerra RAI, Mendoza GJ, Hipólito GM, Fregoso AO, Falcony C (2015) Multicolored photoluminescence and structural properties of zirconium oxide films co-doped with $Tb^{3+}$ and $Eu^{3+}$ ions. Ceramics International 41(9): 11279-11286.

21. Olguín GJC, Montes E, Mendoza GJ, Rodríguez BA, Peredo ZL, et al. (2017) Tunable white light emission from hafnium oxide films co-doped with trivalent terbium and europium ions deposited by Pyrosol technique. Physica status solidi (a) 214(10): 1700269.

22. Olvera CRM, Ojeda AEA, Hipólito GM, Alcántara HJM, Perez AMA, et al. (2018) Characterization of luminescent $SrAl_2O_4$ films doped with terbium and europium ions deposited by ultrasonic spray pyrolysis technique. Ceramics International 44(7): 7917-7925.

23. Westland S (2003) Review of the CIE system of colorimetry and its use in dentistry. Journal of Esthetic and Restorative Dentistry 15: S5-S12.

24. Schanda J (2007) Colorimetry: understanding the CIE system. In: (Ed.) John Wiley & Sons.