Chapter 7
Future Outlook

Abstract In this final Chapter, we present a future perspective for the light source design. We discuss the existing problems and briefly introduce new material systems and device architectures that can overcome the current issues.

Keywords Narrow-band emitters · Lasers · Cd-free nanocrystals · Nanoplatelets · Perovskites

The performance metrics of high-quality lighting are numerous and their relations with each other are far from trivial. Therefore, defining guidelines for realizing high-quality lighting are challenging; nevertheless, in the literature related problems have been addressed, and important points are identified as also explained in this brief. A similar situation exists for the displays where the main requirement is broadening the color gamut, which was also addressed in the literature and covered in this brief. Clearly, the key point for both applications is the use of narrow-band emitters such as nanocrystal quantum dots. This is because these emitters enable precise control over the photometric characteristics of the light source leading to high-quality and high-efficiency lighting. Although important problems related to their integration into light sources have been resolved, there are still existing issues to address and there is room for further development.

Among those problems, the most well-known issue is the cadmium content of the efficient nanocrystals. To avoid the environmental risks of these issues and compounds, either a proper recycling method has to be developed or proper cadmium-free alternatives have to be synthesized. The existing inorganic cadmium-free nanocrystals possess significantly lower efficiencies compared to their cadmium-containing counterparts. Furthermore, their emission spectra are significantly broader. Therefore, even if we can increase their efficiencies using methods such as incorporation into macrocrystals and near-field interactions, their emission spectra should be definitely narrowed. Otherwise, high-quality lighting cannot be realized using these materials. As an alternative, developing cadmium-free colloidal quantum wells (for example InP) step forward if they are made efficiently emitting. In addition to inorganic nano-emitters, the use of organic nanoparticles may also be utilized for solid-state lighting. However, their emission spectra have to be narrowed before they can be employed ubiquitously in solid-state lighting.

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At this point, it is worth mentioning about a new material system that is very promising for solid-state lighting owing to their very narrow emission bands. These are colloidal nanoplatelets that are essentially very thin atomically flat semiconductors (having a few monolayers of crystal structure) with larger sizes in lateral dimensions [1, 2]. Their super small thickness making these particles colloidal analogs to quantum wells enables very narrow emission linewidths on the order of 7–8 nm at room temperature. Currently, the main difficulty of using these materials is the stability issues in their solid-films. Once these are resolved, these nanoplatelets can help achieving really high-quality indoor and outdoor lighting as well as displays with extremely broad color gamuts.

The main problem of color conversion is the unavoidable energy loss because of the absorption of a high-power photon but the emission of lower energy photons. Even if the quantum efficiency of the color convertors is unity, this energy loss cannot be eliminated. The solution to this issue is developing efficient single-color light sources and using them together to obtain white light. As we have explained in Chap. 5, the reason that currently color conversion based approaches are utilized is the lack of high-efficiency green and yellow LED chips. However, we know that both the industry and academia are putting a lot of effort to solve this problem. Furthermore, nanocrystal quantum dot LEDs that are electrically driven as opposed to color conversion are also very promising. These devices achieved external quantum efficiencies of 20% [3, 4], bringing them closer to be applied in displays and general lighting applications. Once this problem is solved, we believe that using combinations of single-color LED chips will form the essence of solid-state lighting.

When it comes to narrow-band emitters, one should also recall the lasers and discuss their performance for solid-state lighting applications. As these devices have linewidths of ca. 1–2 nm, using them in displays will tremendously improve the color gamut. Although it may seem not suitable, correct combinations of lasers are also shown to be very promising for indoor lighting application [5]. However, the green gap problem still remains as a challenge; but once it is solved, utilizing lasers can provide very high power efficiencies as well as high colorimetric and photometric quality. Therefore, it would not be wrong to express that lasers can be the future for general lighting and display applications.

References

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