Hong Kong Student Science Project Competition 2021

Team Number: SAPE19
Project Title: A Better Lighting for Hong Kong
Project Type: Invention Design Proposal

Background

The vibrant and never-ending nightlife in Hong Kong has gained itself the nickname "Pearl of the Orient." However, it is the same vibrant and never-ending nightlife that creates nuisance in some daily lives, in the form of light pollution. Light pollution is defined as any "adverse effects" caused by “excessive, misdirected or obtrusive artificial light,” including "glare, light trespass and skyglow" (Globe at night, 2020). According to Karol *et al*. (2010), neon signs from buildings in Causeway Bay and Mong Kok were about 150 to 500 lux, which is far higher than British agencies recommend.

Objective

The aim of this project is to investigate the light pollution reduction effectiveness of replacing street lights and neon flashing signs with strontium aluminate glowstone in severe light-polluted locations, such as the MX building in Causeway Bay, Hong Kong as an example (Figure 1). Brightness levels, durabilities and costing will be the three main perspectives of this project.

Methodology

The design of the alternative lighting system is based on the use of euphorium-dysprosium doped strontium aluminate (Eu^{2+},Dy^{3+}:$SrAl_2O_4$, Figure 2), a kind of ceramic photoluminescent phosphors, coated on light-contacting surface. These phosphors, when exposed under UV light, “traps” radiant energy, in the form of photons, inside the defects, or “holes”, inside their lattice structure (Figure 3), and releases such wave energy at a longer wavelength (λ) (Illuminating Engineering, 1954; Hong *et al*, 2015). From the equation of the propagation velocity of wave, v,

$$v = f\lambda$$

where f is the frequency of the wave, it can be deduced that the frequency, hence the brightness, of the light emitted by phosphors will be lower than that of the absorbed light. According to Bite *et al*. (2018), euphorium-dysprosium doped strontium aluminate shows a greenish emission spectrum ranging from 400 to 700nm, and peaked at a greenish emission of 520 nm (Figure 4). At room temperature, strontium aluminate glowstone can glow for up to 12 hours, at only 6 candelas during its soft “ambient glow” phase after fully charged for 1 hour, as compared to LED electric street lights which emit hundreds.

According to Ptáček (2014), there are multiple synthetic routes for strontium aluminates, with the thermally-driven solid state reaction of aluminium oxide (Al_2O_3)

and strontium carbonate ($SrCO_3$) being the most traditional and commonly used. At a temperature of 1250 centigrade, with an addition of a flux such as boron trioxide (B_2O_3) or boric acid (H_3BO_3), the strontium aluminate phosphor powder can be synthesized by suspension and drying.

To assess the brightness level of our invention design, a photometer is used to measure and compare the brightness.

__Design of proposal__

According to the survey by Karol *et al*. (2010), as a part of their study of Hong Kong's light pollution (Figure 7), flashing signs are the second most severe perceived sources of light pollution, indicating a high risk of adverse effects. In general, neon advertising flashing signs in Hong Kong can emit upto 500 lux, as seen from the raw observation data from the same report.

In terms of durability, strontium aluminate gemstone has an expected lifetime of more than 20 years, which is much higher than that of neon light flashing signs, lasting for only upto 15 years (CORE Landscape Products, 2020; NeonPlus, 2021).

The costing of the lighting system can be roughly approximated with two parts: the purchasing cost and the utility cost. The cost of a pound of Strontium aluminate glowstone, which can cover an area of 16 m^2, starts from 20 USD, equivalent to 150 HKD (Glowstones USA, 2020). Using solar energy as its power source, there is no utility cost associated with strontium aluminate gemstones. However, the minimum cost of running a neon flashing sign, according to ACG SIGNS (2019), is 270 CAD, equivalent to 1700 HKD.

One disadvantage of strontium aluminate gemstone over conventional neon lights, is that the immediate effectiveness of advertisements will decrease, lowering the motivation of merchants to replace their flashing signs with gemstone. Campaigns of green advertising on social media platforms are recommended, appreciating merchandises who switch their flashing sign to strontium aluminate. Through these campaigns, merchants will understand their switch to strontium aluminate gemstone is a good demonstration of corporate social responsibility to the public's increasing awareness of eco footprint.

__Application__

According to Karol *et al*. (2010), the brightness of the MX building in Causeway Bay is 176 lux. By replacing the conventional lighting to strontium aluminate, the brightness of the MX building is theoretically 101 lux, which is 45% less than that using conventional lighting. Similar comparison can be made using the Lukfook Jewelry on Nathan Road, which has a brightness level of 500 lux. By replacing the lighting with luminous gemstones, a decrease in lighting intensity of about 399 lux can be measured.

Conclusion

To summarise, strontium aluminate gemstone provides merchants a cheaper, more durable and environmentally friendly option to advertising their merchandise, and by universally implementing such technology, our “Pearl of Orient” may be less light polluted.

References

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Appendices

Figure 1: MX building in Causeway Bay

Figure 2: Example of strontium aluminate

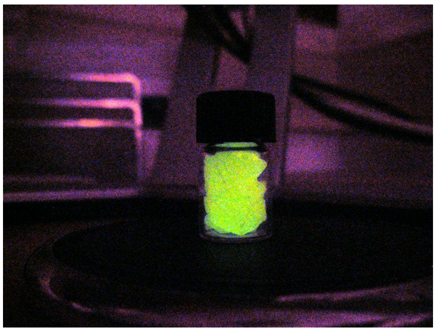

Figure 3: Example of a vacancy defect in $SrAl_2O_4$ (Hong *et al.*, 2015)

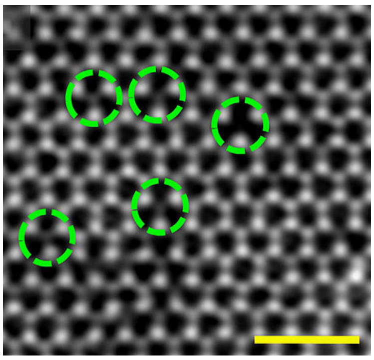

Figure 4: Graphical Illustration of the function of phosphorescent coating (Bite *et al*., 2018)

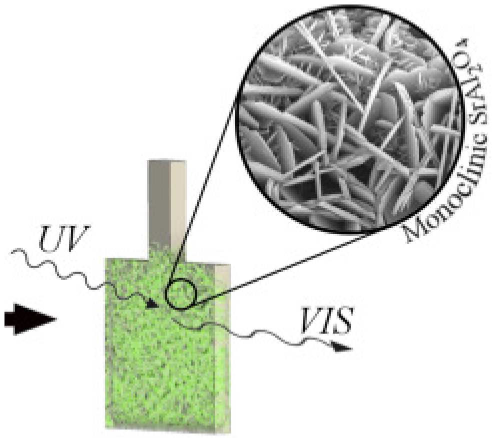

Figure 5: Emission spectrum of Eu (Bite *et al*., 2018)

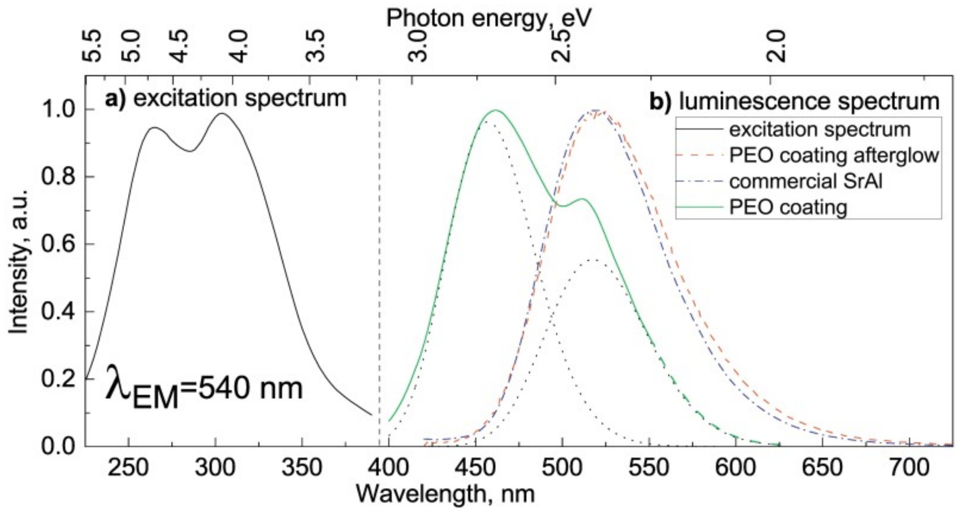

Figure 6: Illustration of solid state synthetic reaction of $SrAl_2O_4$ (Ptáček, 2014)

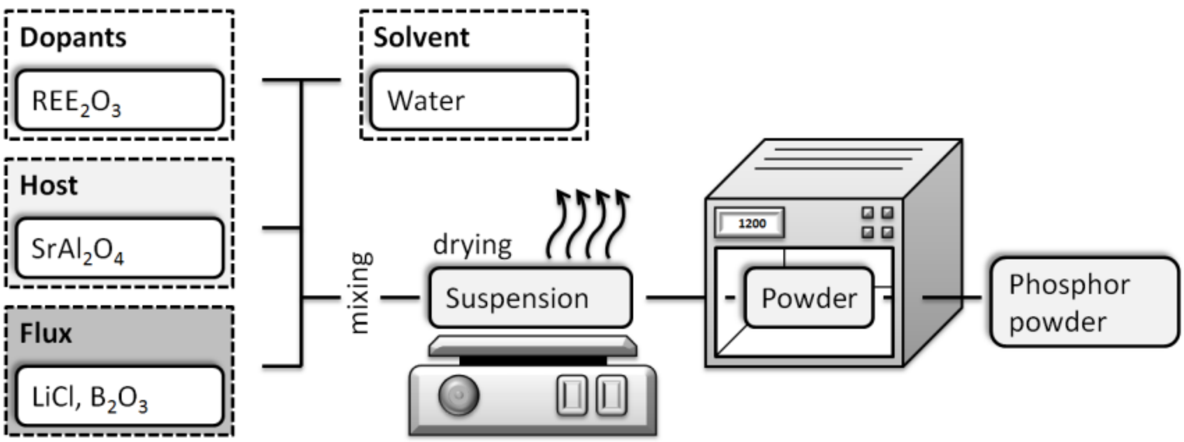

Figure 7: Sources of lighting (Karol *et al*.,2010)