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Article / Book Information

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（博士課程）
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論 文 要 旨

THESIS SUMMARY

専攻： Department of	材料物理科学　専攻	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of　（　工学　）
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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

OLED lighting is expected to be a next generation light source. However there still remain critical issues, such as short circuits and lower power efficiency in the technical viewpoint. In the present study, the OLED with a zinc silicate film as an electron injection and transport layer (EIL/ETL) fabricating on the scattering layer with high-*n*-glass matrix was invented to solve these issues. Here the zinc silicate film and the scattering layer with high-*n*-glass matrix were developed by prof. Hosono and the author of the present study, respectively.

First, we have investigated the mechanism underlying the exceptional properties of zinc silicate thin films developed for organic electronics: low work function, high mobility, ohmic contact to an electrode, and high visible transparency. It is found that sinc silicate films [$(Zn_{(1-x)}Si_x)O_y$, for x = 0.14 ~ 0.19] consist of aggregates of nanoscale ZnO crystals and areas of a-ZnO-SiO_2. Our experimental measurements indicate that a thin a-ZnO-SiO_2 layer exists at the interfaces between the ZnO nanocrystals. We found that this thin a-ZnO-SiO_2 layer makes it possible for each nanocrystal of ZnO to be optically isolated, exhibiting the quantum size effect that leads to an enlarged optical bandgap, but is electronically connected by hopping conduction. Although the presence of a-ZnO-SiO_2 at the interfaces between the ZnO nanocrystals degrades the mobility, the value remains at ~1cm^2/(Vs), which is larger by several orders of magnitude than that of organic electron-transport materials. The origin of the ohmic contact originates from the high carrier concentrations in the ZnO nanocrystals generated by oxygen vacancy. Furthermore, this carrier doping can push the Fermi level close to the energy level of the CBM, which is upshifted by the quantum size effect. As a result, a low work function is obtained. In addition, the deposition and structuring processes for the zinc silicate/ a-C12A7:e^- were developed. Zinc silicate thin films can be deposited radio-frequency sputtering, and the film can be structured by the conventional photolithography and wet etching. Ethylene diamine tetra acetic acid disodium salt,2-hydrate (EDTA) is the most suitable because of the preferable etching rate, and the pattern edge of the film can be well tapered. In addition the sputtered zinc silicate films have the excellent step coverage of the electrode pattern, which indicates that conventional resin banks to cover the electrode edges can be omitted

Secondly, The scattering layer with high-*n*-glass matrix for OLED light extraction was developed. Mie scattering: strong forward scattering by large size of scattering center (order of 1 μm) with the concentration of more than 10 percent is desired for higher light extraction. To accommodate these scattering centers, high-*n*-matrix must be thick enough (an order of 10 μm), and its surface must be smooth. It is revealed that the fired high-*n*-glass-frit paste with inorganic scattering centers or pores

satisfies these requirements which seem like a contradiction. The out-coupling efficiency of OLEDs on the scattering layer with high-*n*-glass matrix are 1.7 ~ 1.8 times higher than that of the OLED without the scattering layer, which is confirmed by the optical simulation. In addition, the OLEDs on the scattering layers have additional advantages: less angular dependence of the color and less color variation between OLED panels due to the variation of the interference conditions.

The author combined these two technologies: very thick zinc silicate films for EIL/ETL and the high-*n*-index scattering layer to realize inverted OLEDs with high out-coupling efficiency and reliability. The results of the optical simulation indicate that the prominent feature of the zinc silicate film: extremely high visible-transparency is quite important to keep high out-coupling efficiency. To suppress the color variation due to the thickness variation of zinc silicate thick films, the compositions of the zinc silicate and the matrix of the scattering layer were determined, so that the refractive indices of the zinc silicate, ITO and the matrix of the scattering layer are the close values. The OLEDs with very thick zinc silicate film (245 nm) and the scattering layer keeps the higher out-coupling efficiency (~1.7 times compared to the reference), and the leak current can be suppressed. From these results, it is concluded that the high out-coupling efficiency was confirmed, and the short circuit will be expected to be suppressed by the OLEDs with very thick zinc silicate and the scattering layer. For further light extraction, the surface plasmin polariton (SPP) must be decoupling. It would be possible that the thick zinc silicate between the emitting layer and a metal cathode decouples the SPP. The results of the optical simulation indicate that ~ 60 percent of emitting light including the SPP can be out-coupled by the normal OLED with the thick zinc silicate ETL/EIL fabricated on the scattering layer, which corresponds to a white OLED with the power efficiency of ~100 lm/W.

It is concluded that OLEDs with very thick zinc silicate and the scattering layer with high refractive index are promising and also practical to realize high efficient and reliable OLED lighting devices.