Supporting Information for

High electroluminescence of the ZnS:Mn nanoparticle/cyanoethyl-resin polymer/single-walled carbon nanotube composite using the tandem structure

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Contents

Characteristics of the high-field EL device

In general, alternating current driven inorganic electroluminescence (EL) can be defined as luminescence under the high electric field without a thermal generation, and thus this type of EL is called as high-field EL.[1] In the case of high-field EL types, a high electric field, i.e., 10^6 (powder) or 10^8 (thin-film) V/m, is necessary to obtain EL emission, which leads to the fact that a high voltage is applied to the device, and thus an insulation layer should be used in this EL device to avoid a catastrophic breakdown. In contrast with the injection type, the luminescence of the high-field type is generally derived from non-mobile charges.[1,2] High-field EL devices have a relatively high driving voltage with a low current (e.g., in the case of a powder EL device, which has low power consumption, the current density of the device is around 0.07 ~ 0.3 mA/cm^2 at the driving voltage of 100 ~ 200 V, the frequency of 400 Hz, and the luminance of 70 ~ 220 cd/m^2.[3-6] The most important factor is an electric field applied to the phosphor in the inorganic powder EL, because the brightness and efficiency depend strongly on an electric field. The efficiency of the powder EL device generally does not show a high efficiency at high injection level. Although the brightness rapidly increases with the frequency, the efficiency does not. It is due to the limitation of light emission mechanism at luminescent centers.

1 Y. A. Ono, in *Electroluminescent Displays*, ed. H. L. Ong, World Scientific, Singapore, 1995, pp. 7.

2 S. Shinoya and W. M. Yen, in *Phosphor Handbook*, ed. R. Stem, CRC Press, Boca Raton, 1999, pp. 581.

3 W. Wang, F. Huang, Y. Xia and A. Wang, *J. Lumin.*, 2008, **128**, 199.

4 M. J. Kim, D. W. Shin, J.-Y. Kim, S. H. Park, I. T. Han and J. B. Yoo, *Carbon*, 2009, **47**, 3462.

5 J.-Y. Kim, S. H. Park, T. Jeong, M. J. Bae, S. Song, J. Lee, I. T. Han, D. Jung and S. Yu, *IEEE Trans. Electron Dev.*, 2010, **57**, 1470.

6 S. Park, H.-S. Kim, J.-Y. Park, J. C. Lee, Y.-J. Chung and J.-H. Lee, *J. Korean Phys. Soc.*, 2009, **54**, 1123.

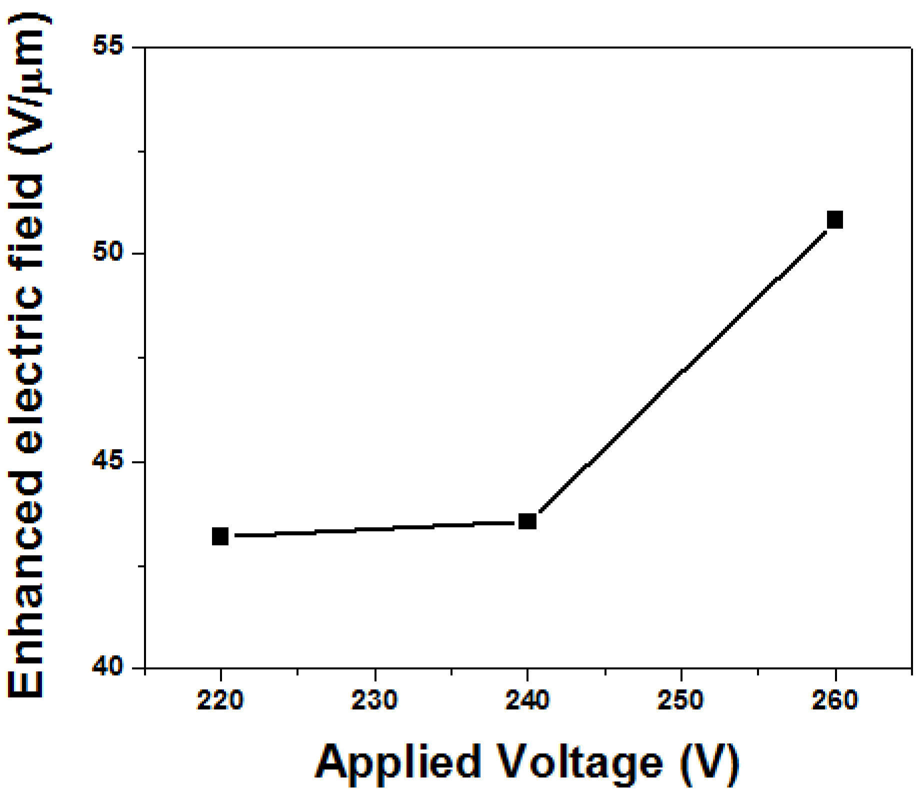

Figure S1. Calculation of the enhanced electric field by SWCNTs as a function of an applied voltage at the frequency of 1 kHz.

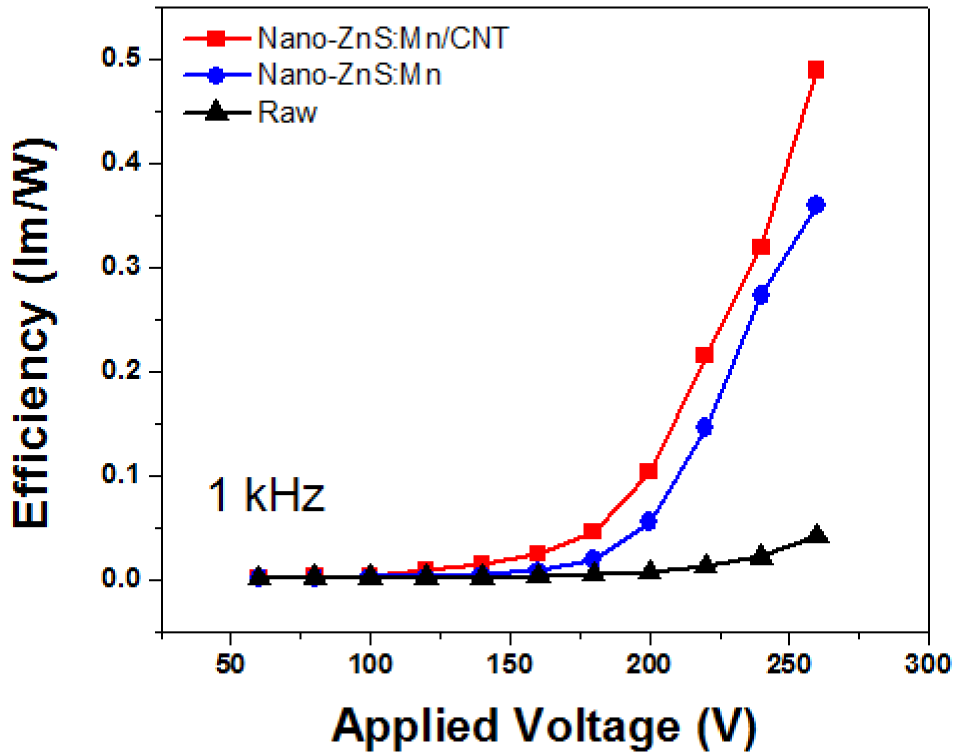

Figure S2. Efficiencies of EL devices for a raw phosphor, nano-sized phosphor, and CNT-phosphor composite as a function of an applied voltage at the frequency of 1 kHz.

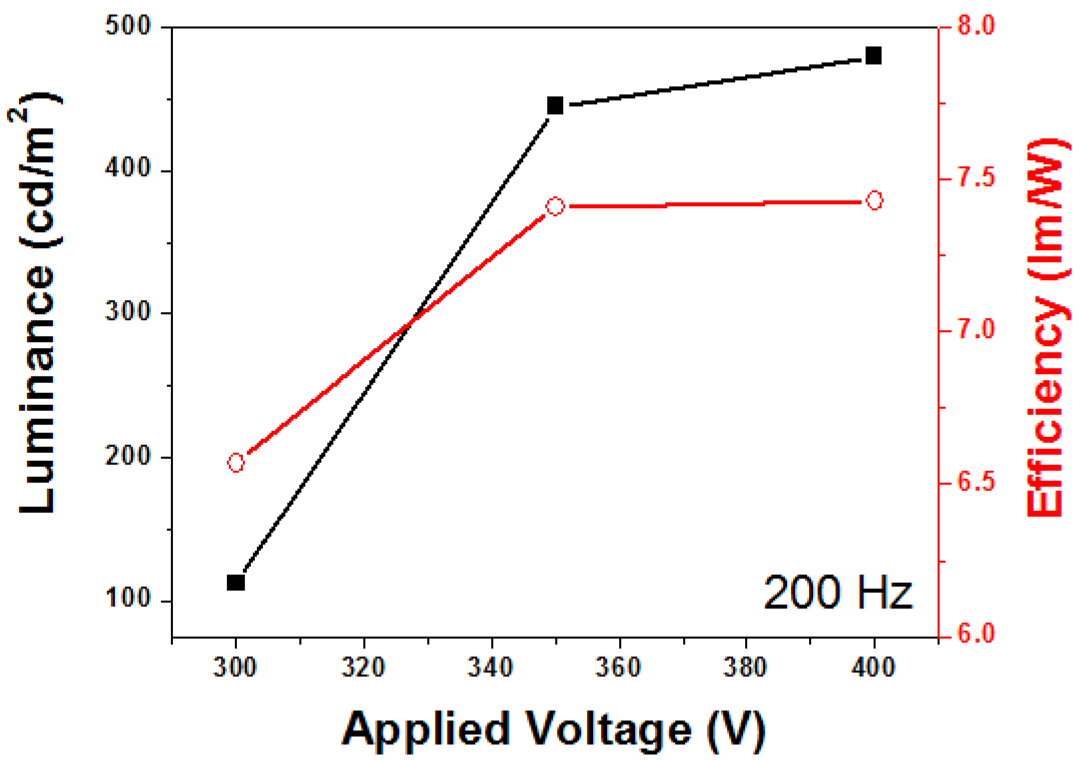

Figure S3. Luminance and efficiency of the EL device for the nano-sized phosphor as a function of an applied voltage at the frequency of 200 Hz.

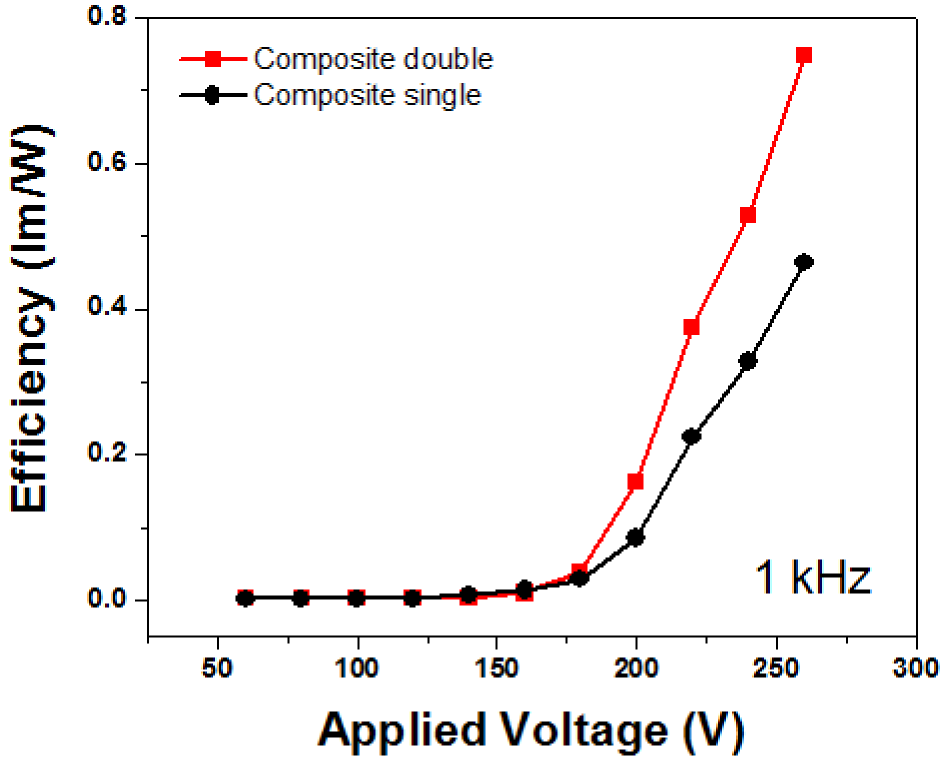

Figure S4. Efficiencies of EL devices for the single- and double-layered composite as a function of an applied voltage at the frequency of 1 kHz.