A Mono-Chelated Boron Complex as a New Blue Emission Layer in Organic Light Emitting Diodes

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Abstract

In this study, a mono-chelated compound as novel blue light emitting material, BPh_2(pbi) (pbi = 2-(2-Pyridyl)benzimidazole) was synthesized Organic light emitting Diodes (OLEDs), which has a ITO/NPB(40 nm)/Boron(30 nm)/Alq_3(1 nm)/Liq(3 nm)/Al(150 nm) structure, has been fabricated. The maximum brightness of the device is up to about 900 cd/m^2 and 0.54 cd/A at 11.5 V. The EL peaks and CIE coordinates of our OLEDs is 457 nm and (0.26, 0.29), respectively.

1. Introduction

After Tang's report on the multilayered organic light emitting diodes (OLEDs), the development of OLEDs devices focused on the optimization of cell structures for obtaining high luminance and development of organic materials for obtaining a wide variety of emission colors.[1,2]

Recently, various boron compounds have been utilized as blue emitting materials in OLEDs.[3-8] Boron is strongly electrophilic by virtue of its tendency to fill the vacant orbital to complete the octet. Consequently, the properties of many boron compounds have been explained by postulating electron-donating atom coordination to boron. Thus, boron compounds can provide extra stability as emitting materials. Herein, we report the optical and electroluminescent propertiese of new boron compound BPh_2(pbi). We synthesized boron chelated compound from the reaction of 2-(2-Pyridyl)benzimidazole(pbi) with $B(Ph)_3$. 2-(2-Pyridyl)benzimidazole ligand was employed because it possesses two nitrogens and thus would provide stable chelation to the boron center. These two nitrogens were coordinated with boron center, completing boron's octet. The blue shift in emission energy displayed by BPh_2(pbi), in comparison to that of BPh_2(2-py-in)((2-py-in)=2-(2-pyridyl)indole, synthesized by Wang's group[8]), can be attributed to the presence of an extra nitrogen atom in 2-(2-Pyridyl)benzimidazole. Since the role of the nitrogen is an electron withdrawer, the replacement of the carbon to the nitrogen decreased the HOMO level. The boron compound exhibits blue emission at 457 nm in solid state.

2. Experimental

Reagents and were purchased from Aldrich Co. and used without further purification. The solvents for the synthesis of the boron compounds were the reagent grades and pre-dried according to the purification methods freshly when needed. Anhydrous solvents packed under nitrogen were purchased if necessary and used with standard Schlenk techniques. ^{1}H NMR spectra were obtained on Bruker 200MHz spectrometer. Mass spectra were determined on JEOL, JMS-AX505WA, HP 5890 Series II Hewlett-Packard 5890A (capillary column) at Seoul National University, Korea. UV-Vis absorption spectra were measured on Hewlett Packard 8425A spectrometer. The PL spectra were measured on Perkin Elmer LS 50B spectrometer. And the electrical and the optical properties of devices were measured under ambient conditions in air without any encapsulation against degradation. Current-Voltage characteristics of the OLEDs were measured with source measure unit (keithly 236), and the CIE coordinates of devices was obtained by Minolta CS-100.

2.1. Synthesis of BPh_2(pbi)

2-(2-Pyridyl)benzimidazole (0.292g, 1.5mmol) was placed in 15ml toluene in 2-neck rbf. Triphenylborane (0.363, 1.5mmol) was added in the mixture. The mixture was refluxed for 5hr in nitrogen atmosphere. It cooled at room temperature and evaporated under vacuum. The precipitate was recrystallized in toluene/THF solution.

mp. 290℃ MS calcd for $C_{24}H_{18}BN_3$ m/e 359.16, found m/e 359. Anal. calced for : $C_{24}H_{18}BN_3$: C 80.24, H

5.05, N 11.7 found C 80.03, H 5.12, N 11.37

2.2. Fabrication of the device

OLEDs were fabricated by high vacuum (5×10^{-6} torr) thermal deposition of organic materials onto the surface of an indium tin oxide (ITO, 30Ω/□, 80nm) coated glass substrate chemically cleaned using acetone, methanol, distillated water and isopropyl alcohol.

The constituent organic layers of the OLEDs were deposited by a thermal vacuum evaporation. The structure of multi-layer OLEDs were shown as follow: NPB (α-napthylphenylbiphenyl, hole transport layer), boron compound (BPh_2(Pbi), emitting layer), Alq_3 (tris-(8-hydroxyquinoline) aluminum , electron transport layer), Liq (Lithium quinolate, electron injection layer). Finally the 150 nm of Al was deposited as a cathode. The deposition rate of the organic thin film was 1~ 2 Å at the base press of 5×10^{-6} torr. A four-layer organic staked structure consisting of NPB(40 nm)/Boron compound(30 nm)/Alq_3(1 nm)/Liq(3 nm)/Al (150 nm) was formed, as shown in Figure 1. The chemical structures of these materials are shown in Figure 2. An emitting area of the OLEDs was 0.03×0.03 cm^2.

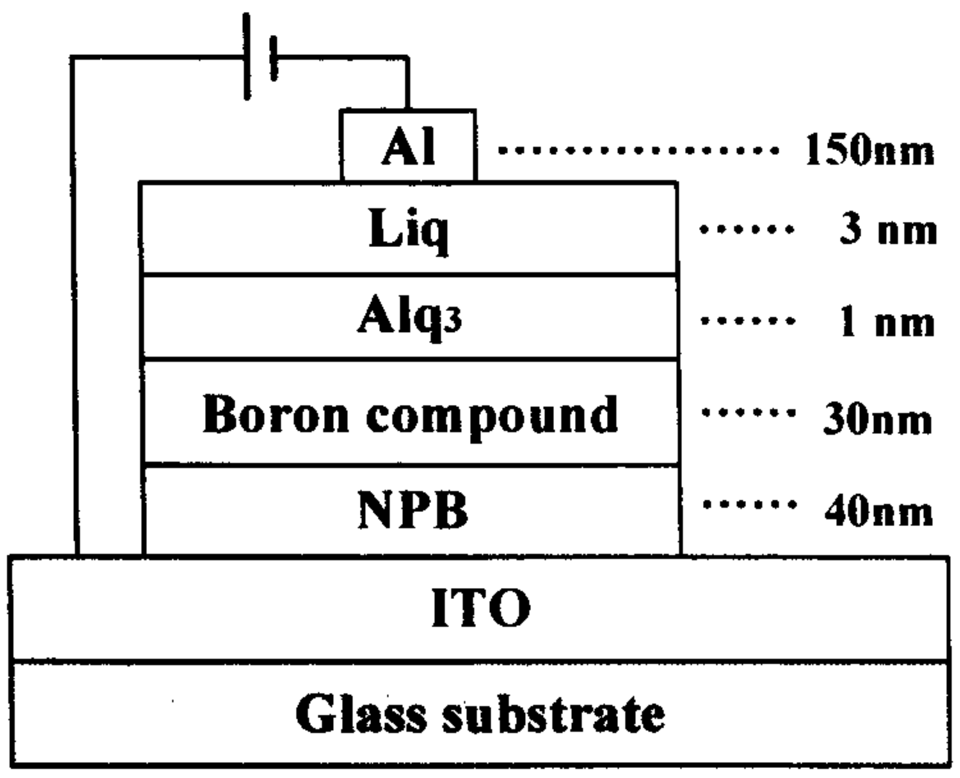

Figure 1. The device structure of OLEDs; ITO/NPB(40 nm)/BPh_2(pbi)(30 nm)/Alq_3(1 nm)/Liq(3 nm)/Al(150 nm)

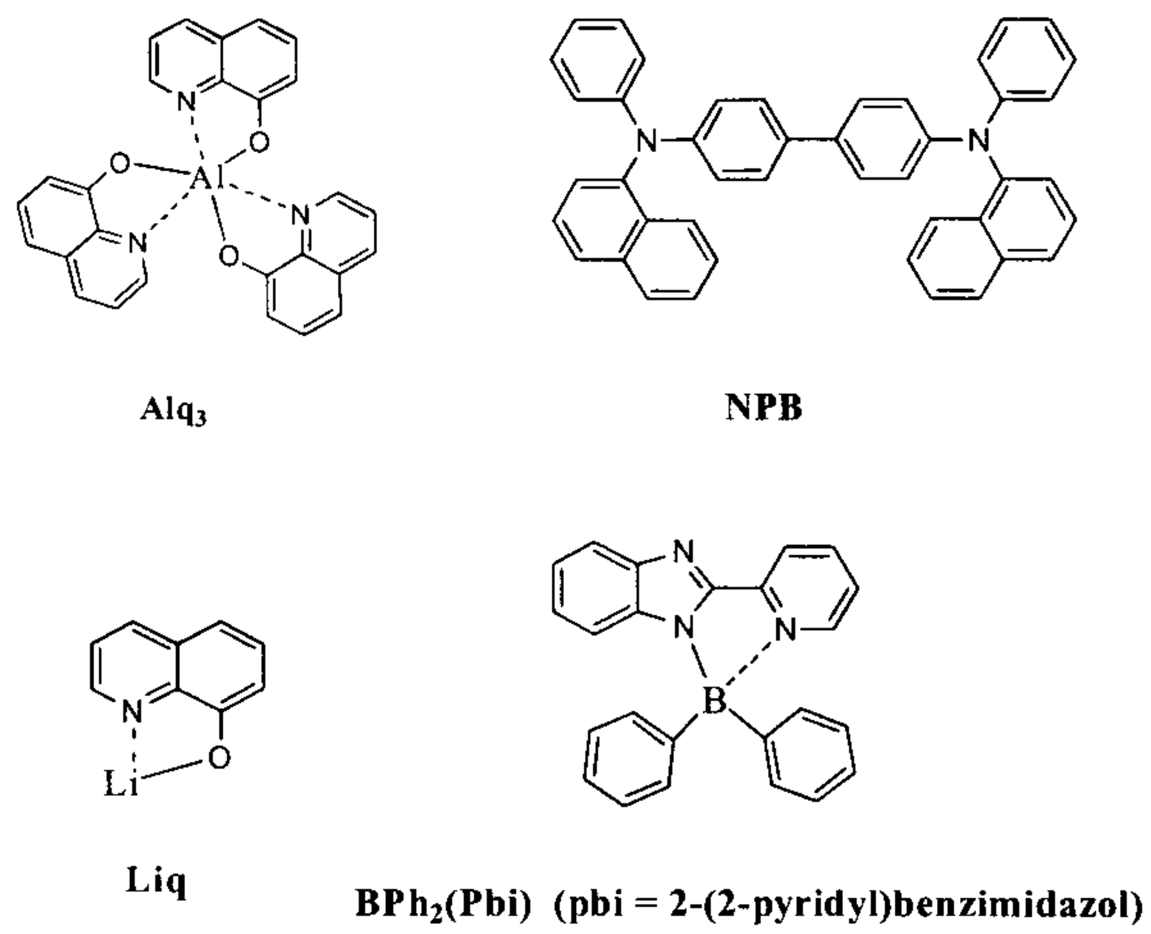

Figure 2. The molecular structure of organic materials used.

3. Results and discussion

Figure 3 and Figure 4 show the injected current density-biased voltage and luminance-biasied voltage characteristics for the EL devices. The emission started at a driving voltage of 3 V. This multilayer EL device exhibited relatively performances with a maximum luminance and Luminous efficiency can reach about 900 cd/m^2 at driving voltage of 11.5 V and Luminous efficiency of 0.54 cd/A.

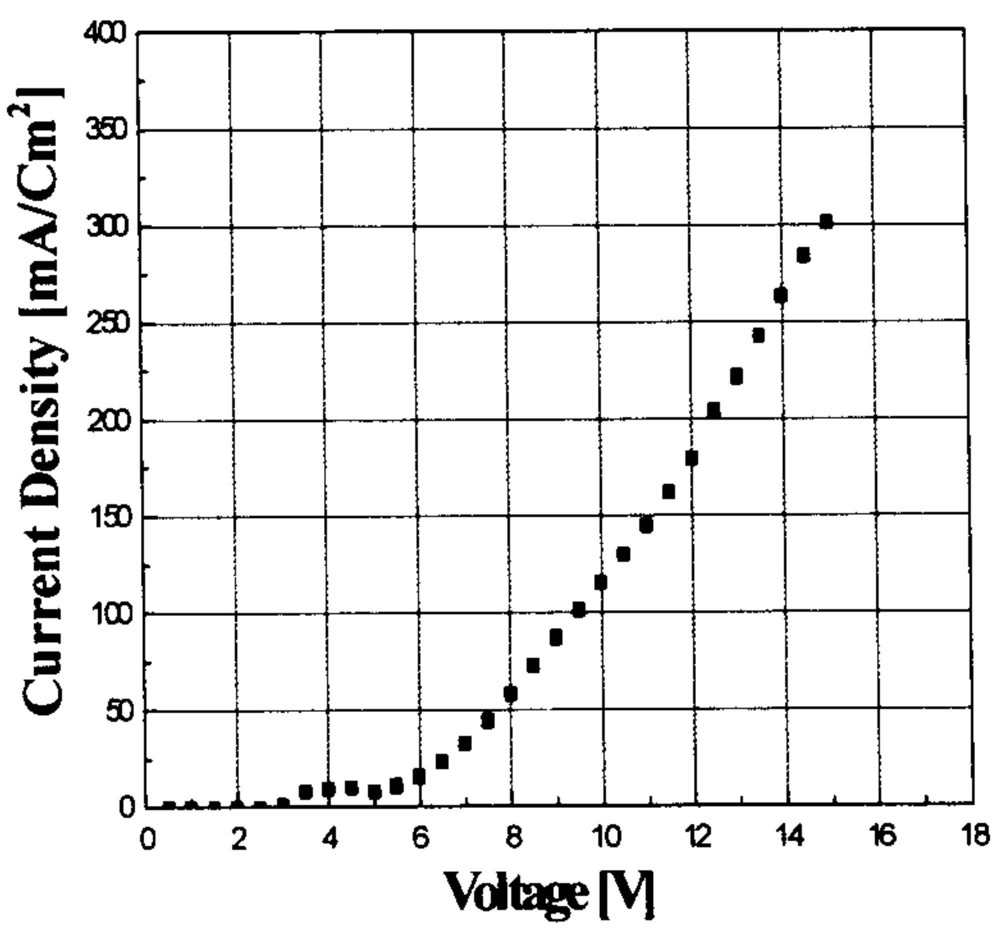

Figure 3. Current density vs voltage characteristics of OLEDs.

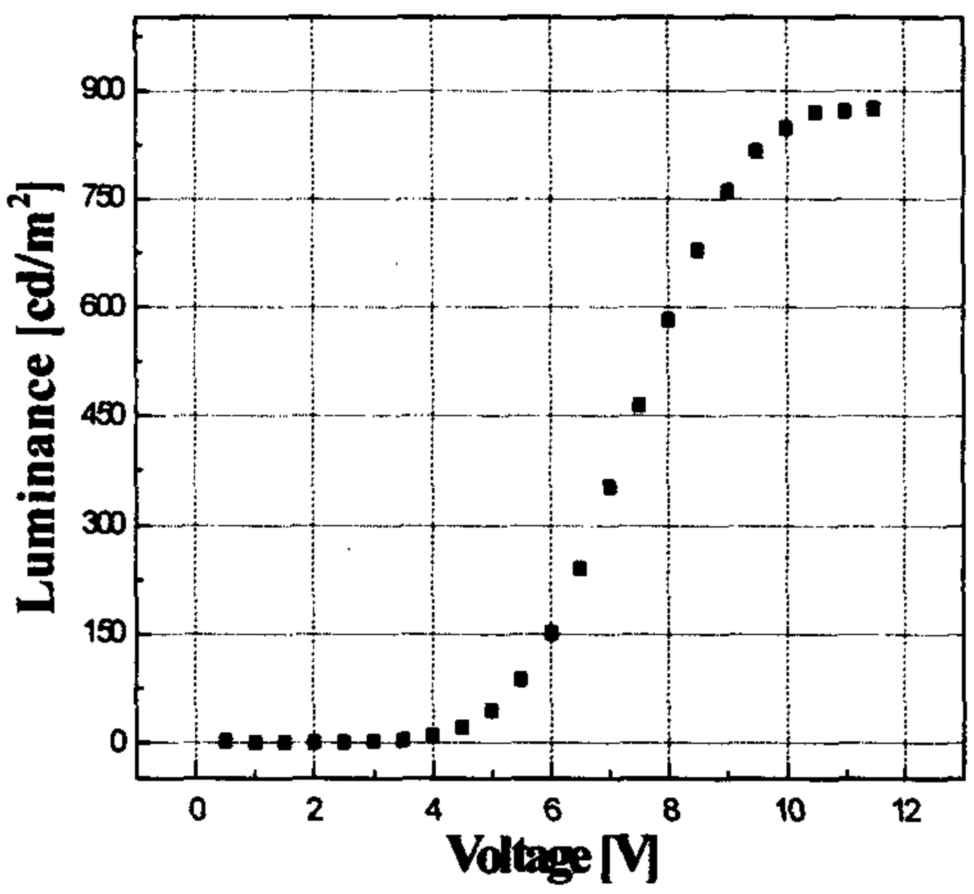

Figure 4. Luminance(L)-voltage(V) characteristics of OLEDs.

The new boron compound, $BPh_2(Pbi)$ was emitted bright blue color in thin film deposited on a quartz substrate upon irradiation by UV light. The UV-vis. absorption and photoluminescencent spectra of $BPh_2(Pbi)$ in solid film are show in figure 5. The absorption maximum peaks at 362 nm and a small shoulder at 242 nm were observed.

The electroluminescence (EL) spectrum was shown in Figure 6. Emission band peaks of OLEDs ranging from 400 to 650 nm were observed interestingly. the blue emission peak of 434 nm in EL spectrum can be attributed to the emission of $BPh_2(Pbi)$, because its emission position is almost identical with PL spectrum of $BPh_2(Pbi)$. The emission band peak about 530 nm is assigned to the characteristics of Alq_3.

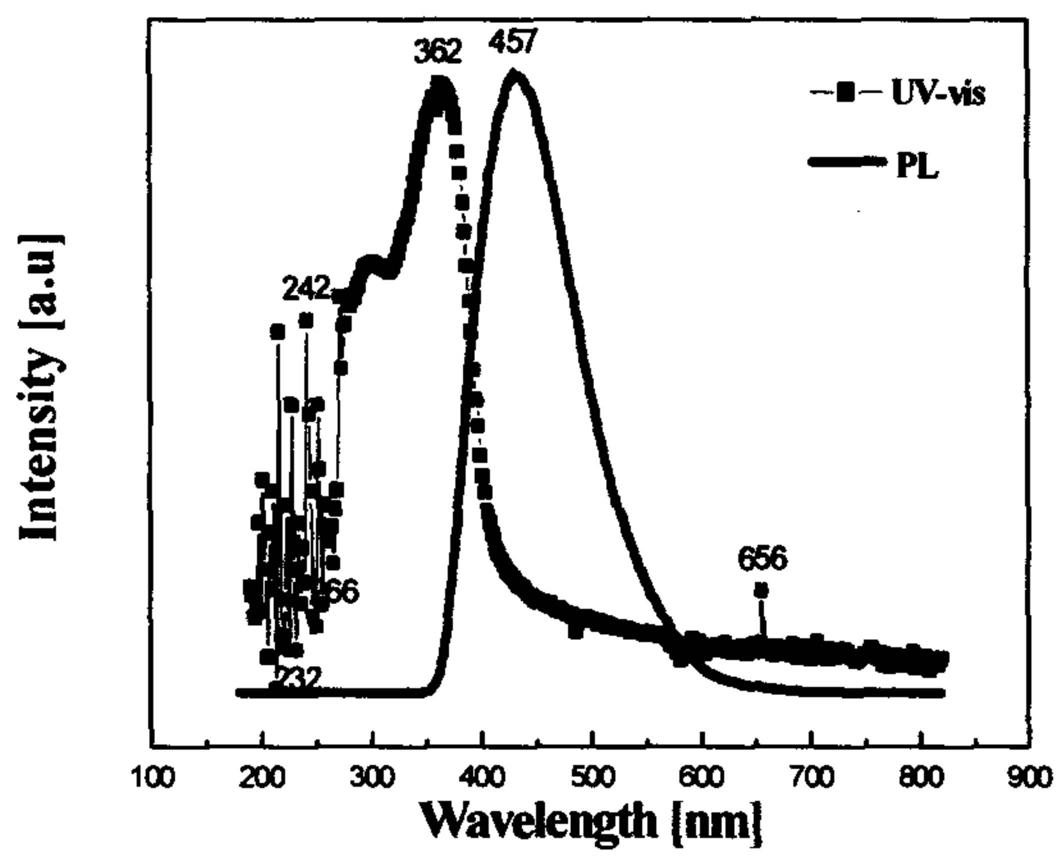

Figure 5. UV/vis. absorption and photoluminescence (PL) spectrum.

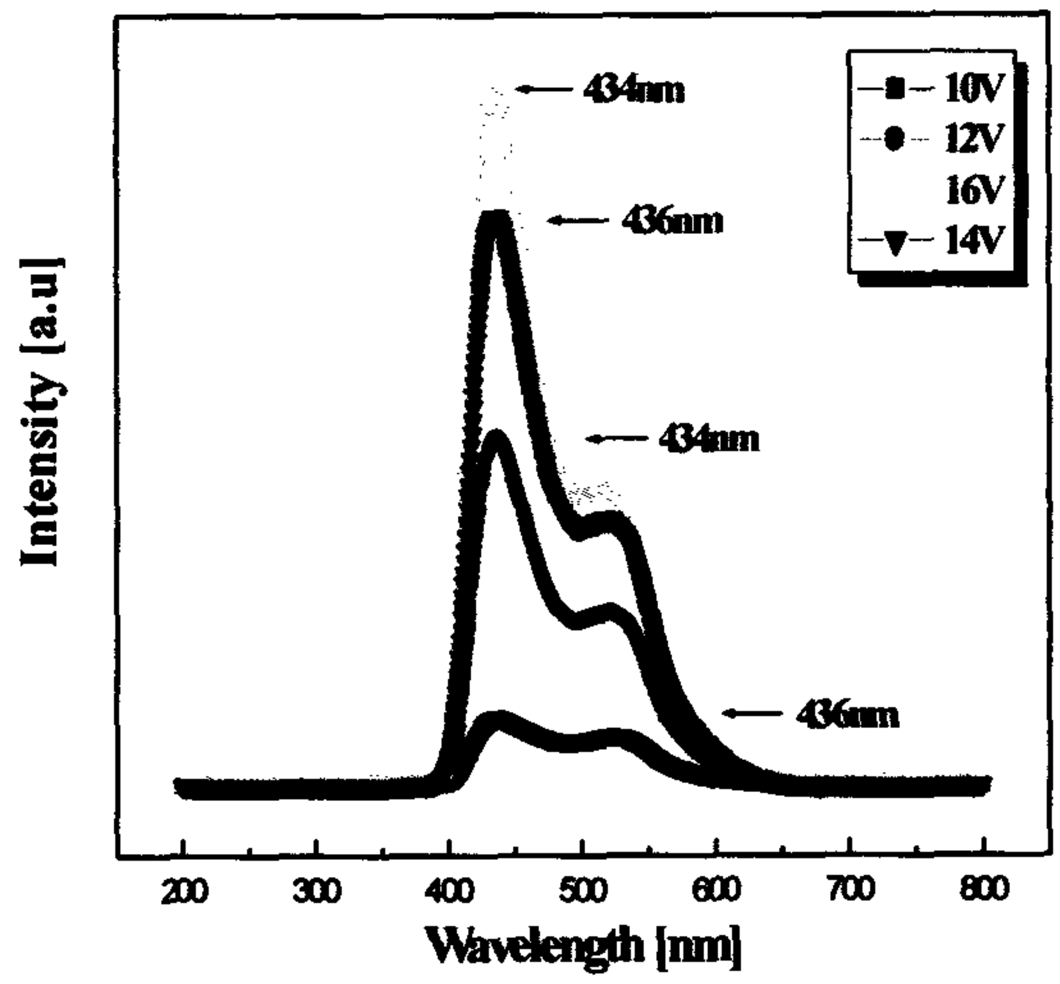

Figure 6. The Electroluminescent (EL) spectra of OLEDs.

4. Conclusion

We fabricated organic light emitting diodes with new boron complex that emits the blue luminescence. The results show the peak emission of electroluminescence (EL) is 434 nm and the CIE chromaticity coordinates are (0.26, 0.29) and the brightness of the device is up to about 900 cd/m^2 at 11.5 V. So far, we have demonstrated the synthesis and the characterization of new blue emitting material. Now, optimization of the devices performance achieve to the high efficiency is now being executed.

5. Acknowledgements

This work was supported by korea Research Foundation Grant

6. References

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