

Synthesis and Characterization of 8-hydroxyquinoline Complexes of Tin(IV) and Their Application in Organic Light Emitting Diode

Yousef Fazaeli · Mostafa M. Amini · Ezzatollah Najafi ·
Ezeddin Mohajerani · Mohammad Janghouri ·
Amirreza Jalilian · Seik Weng Ng

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Abstract A series of 8-hydroxyquinoline complexes of tin, Q_2SnCl_2 (Q=2-methyl-8-hydroxyquinoline, 8-hydroxyquinoline, 5,7-dibromo-8-hydroxyquinoline, 5-chloro-8-hydroxyquinoline, 5,7-dichloro-8-hydroxyquinoline and 5-nitro-8-hydroxyquinoline) were prepared by reacting stannous dichloride with 8-hydroxyquinoline and its derivatives. All complexes were characterized by elemental analysis, mass spectrometry and infrared, UV–vis and 1H NMR spectroscopes. Furthermore, the molecular structure of a representative complex, dichlorido-bis(5-nitro-quinolin-8-olato-2N,O)tin(IV), was determined by single-crystal X-ray diffraction. The photoluminescence (PL) properties of all prepared compounds and electroluminescence (EL) property of a selected complex (Q=5-chloro-8-hydroxyquinoline) were investigated. The results showed that the emission

wavelength can be tuned by electron donating or withdrawing group substituent on 8-hydroxyquinoline. Application of prepared complexes in fabrication of an OLED has been demonstrated.

Keywords Tin · 8-Hydroxyquinoline · Photoluminescence · Electroluminescence · OLED

Introduction

Organic light-emitting diodes (OLEDs) continues to thrive since the first presentation of thin film devices based on small molecule organic materials by Tang and Van Slyke in 1987 [1]. Now design and synthesis of small molecules for use in organic electronics materials have become an active area of research [2–6]. Among organic light emitting materials, aluminum tris(8-hydroxyquinoline) (AlQ_3) and its derivatives are unique electron transport and emitting materials and have widely been used in the commercial fabrication of OLEDs [7–9]. It is well known that by substitution of a π -donor group such as chlorine atom on the phenolate ring and an electron-withdrawing one on the pyridine ring results in red and blue shifted emissions, respectively [10–13]. For instance, by introduction of a methyl substituent on the 2-, 3-, 4- and 5-position of the Q ligand, the emission shifts to 495 [14], 520 [15], 505 [16] and 545 nm [15], respectively, in comparison to 525 nm for the parent Q_3Al [17]. In spite of the many advantages of aluminum quinolinolate complexes as OLEDs, there are some drawbacks, including low light emission,

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Y. Fazaeli · M. M. Amini (✉) · E. Najafi
Department of Chemistry, Shahid Beheshti University G.C.,
Tehran 1983963113, Iran
e-mail: m-pouramini@sbu.ac.ir

E. Mohajerani · M. Janghouri
Laser Research Institute, Shahid Beheshti University G.C.,
Tehran 1983963113, Iran

A. Jalilian
Radiopharmaceutical Research and Development Lab, NSTRI,
P.O. Box 14395-836 Tehran, Iran

S. W. Ng
Department of Chemistry, University of Malaya,
50603 Kuala Lumpur, Malaysia

poor high-voltage stability in general, and low internal quantum efficiency of blue phosphorescence in particular [18]. In this regards, several efforts have been devoted to improving the electricity to light conversion efficiency of OLED devices, such as modifying the indium tin oxide electrode and replacing fluorescence-emitting materials with phosphorescence-emitting materials [19, 20]. Furthermore, for tuning of emission wavelength and improving and understanding correlation between the electronic structure and photonic properties other metal 8-hydroxyquinoline derivatives of main and transition metal ions have been synthesized, including, beryllium [21] and magnesium [22] from the group IIA, boron [23], gallium [24, 25] and indium [26] from the group IIIA, zinc [27] from the group IIB, platinum from group VIII B [28] and gold from group IB [29]. In spite of well known photoluminescence of aforementioned main group metal complexes very little known about the luminescence of group IVA metal complexes and known ones are limited to SnCl_3^- , GeCl_3^- and PbCl_3^- [30]. To the best of knowledge photoluminescence behaviour of 8-hydroxyquinoline derivatives of tin is not known. In continuation of our interest in photoluminescence studies of the main group elements we report here synthesis, characterization and photoluminescence studies of several 8-hydroxyquinoline complexes of SnCl_2 and demonstrate utilization of them in fabrication of an electro luminescence device.

Experimental

Materials

Tin dichloride hydrate ($\text{SnCl}_2 \cdot \text{H}_2\text{O}$) was purchased from Merck, and 5,7-dichloro-8-hydroxyquinoline, 5-dichloro-8-hydroxyquinoline, 5,7-dibromo-8-hydroxyquinoline, 8-hydroxy-2-methyl-quinoline and 8-hydroxy-5-nitro-quinoline 8-hydroxy quinoline were obtained from Aldrich and used without further purification. All solvents were dried and distilled under a nitrogen atmosphere prior to use, according to a standard procedure.

Physical Measurements

Melting points were obtained with an Electrothermal 9200 melting point apparatus and are not corrected. Infrared spectra from $4,000\text{--}400\text{ cm}^{-1}$ were recorded on a Shimadzu 470 FT-IR instrument, using KBr pellets. ^1H and ^{119}Sn NMR spectra were recorded at room temperature in CDCl_3 on a Bruker AVANCE 300-MHz operating at 300.3 and 111.9 MHz, respectively. The NMR spectra are referenced to Me_4Si (^1H) or Me_4Sn (^{119}Sn) as external standards. Mass spectrometric measurements were performed on a Varian Matt 44 instrument (electron impact, 20 eV). Elemental

analyses were performed with a Thermo Finnigan Flash-1112EA microanalyzer. The electroluminescence and photoluminescence spectra of fabricated OLED was obtained on a HR4000 Oceanoptic and USB2000 spectrometers, respectively. A Keithley 2400 instrument was used for the electrical characterization. The thickness of the samples was measured using a DekTak 8000 profilometer.

X-ray Crystallography

Single crystal X-ray diffraction data were collected on a Bruker SMART APEX at 100K with graphite monochromated Mo-K_α radiation at room temperature using APEX2 software [31]. Data were collected to a maximum 2θ value of 25.0° . Cell constants and an orientation matrix for the data collection were obtained by least-squares refinement of diffraction data from 28867 unique reflections [32]. A numerical absorption correction was applied using SADABS [33] software. The structure was solved by direct methods, and refined on F^2 using a full-matrix least-squares procedure with anisotropic displacement parameters [34]. Refinement was performed using the SAINT (Bruker, 2009) crystallographic software package [31]. Crystal data and refinement details are listed in Table 1.

Table 1 Crystal data and refinement details for complex 6

Molecular Formula	$\text{C}_{18}\text{H}_{10}\text{N}_4\text{Cl}_2\text{O}_6\text{ Sn}$
Formula weight	567.89
Crystal size (mm)	$0.3 \times 0.03 \times 0.06$
Crystal color	yellow
Wavelength (Å°)	0.71073
Crystal system	orthorhombic
Space group	(<i>Pbca</i>)
<i>a</i> (Å)	16.3675(15)
<i>b</i> (Å)	13.7121(1)
<i>c</i> (Å)	17.4519(15)
$\alpha = \beta = \gamma$ ($^\circ$)	90.00
<i>V</i> (Å^3)	3916.8(6)
<i>Z</i>	8
<i>F</i> (000)	2224
Limiting indices	$-19 \leq h \leq 19$ $-16 \leq k \leq 15$ $-20 \leq l \leq 20$
Maximum and minimum transmission	0.9525 and 0.6415
Calculated density (mg/m^3)	1.926
Absorption coefficient (mm^{-1})	1.624
θ range ($^\circ$)	2.26 to 25.00
Goodness of fit on <i>F</i> ²	0.991
Data/restraints/parameters	3457/0/280
Final <i>R</i> indices [$I > 2\sigma(I)$]	$R1 = 0.0345$, $wR2 = 0.0747$

Synthesis of Complexes

Dichlorido bis(2-methylquinolin-8-olato-2N,O)tin(IV) (1)

2-Methyl-8-hydroxyquinoline (1 mmol, 0.16 g) was added to a solution of stannous chloride (1 mmol, 0.23 g) in DMSO (10 ml). The mixture was stirred at room temperature for two hours and then the clear solution was set aside in which yellow crystals formed after several days (m.p. > 300 °C). Anal. Calc. for $C_{20}H_{16}Cl_2N_2O_2Sn$: C, 47.48; H 3.19; N, 5.54 %. Found; C, 47.62; H, 3.25; N, 5.22 %. UV-vis: $\lambda(\log \epsilon)$ (CH_2Cl_2): 351 nm (3.18). IR (KBr, cm^{-1}): 3049(w), 2925(w), 1792(m), 1673(m), 1509(w), 1470(w), 1428(m), 1379(m), 1321(m), 1263(m), 1029(s), 870(s), 825(m), 793(m), 574(m). 1H NMR ($CDCl_3$, ppm): 2.35, 7.10, 7.28, 7.30, 8.02 and 8.80. Mass spectrum data: m/e 506 $[M]^+$. Mass number is based on 1H , ^{12}C , ^{14}N , ^{16}O , ^{35}Cl and ^{120}Sn .

Dichlorido-bis(quinolin-8-olato-2N,O)tin(IV) (2)

8-Hydroxyquinoline (1 mmol, 0.15 g) was added to a solution of stannous chloride (1 mmol, 0.23) in DMSO (10 ml). The mixture was stirred at room temperature for two hours and then the clear solution was set aside in which yellow crystals formed after several days (m.p. > 300 °C). Anal. Calc. for $C_{18}H_{12}Cl_2N_2O_2Sn$: C, 45.24; H 2.53; N, 5.86 %. Found; C, 45.29; H, 2.73 N, 5.35 %. UV-vis: $\lambda(\log \epsilon)$ (CH_2Cl_2): 386 nm (3.16). IR (KBr, cm^{-1}): 3050(w), 1900(s), 1880(s), 1680(s), 1474(m), 1281(m), 1117(m), 1060(m), 976(s), 898(s), 743(s), 576(m). 1H NMR ($CDCl_3$, ppm): 7.43, 7.61, 7.68, 8.00 and 8.81. Mass spectrum: m/e 478 $[M]^+$. Mass numbers are based on 1H , ^{12}C , ^{14}N , ^{16}O , ^{35}Cl and ^{120}Sn .

Dichlorido-bis(5-chloroquinolin-8-olato-2N,O)tin(IV) (3)

5-Chloro-8-hydroxyquinoline (1 mmol, 0.18 g) was added to a solution of stannous chloride (1 mmol, 0.23) in DMSO (20 ml). The mixture was stirred at room temperature for two hours and then the clear solution was set aside in which yellow crystals formed after several days (m.p. > 300 °C). Anal. Calc. for $C_{18}H_{10}Cl_4N_2O_2Sn$: C, 39.51; H 1.81; N, 5.12 %. Found; C, 39.82; H, 1.94; N, 5.44 %. UV-vis: $\lambda(\log \epsilon)$ (CH_2Cl_2): 386 nm (3.19). IR (KBr, cm^{-1}): 3070(w), 1982(w), 1623(s), 1616(s), 1580(s), 1574(s), 1498(w), 1279(m), 1238(s), 1197(s), 1142(s), 1035(s), 1014(s), 942(m), 820(s), 721(m), 529(m). 1H NMR ($CDCl_3$, ppm): 7.02, 7.33, 8.52 and 8.92. Mass spectrum: m/e 546 $[M]^+$. Mass numbers are based on 1H , ^{12}C , ^{14}N , ^{16}O , ^{35}Cl and ^{120}Sn .

Dichlorido-bis(5,7-dibromoquinolin-8-olato-2N,O)tin(IV) (4)

5,7-Dibromo-8-hydroxyquinoline (1 mmol, 0.30 g) was added to a solution of stannous chloride (1 mmol, 0.23 g) in DMSO (30 ml). The mixture was stirred at room temperature for two hours and then the clear solution was set aside in which yellow crystals formed after several days (m.p. > 300 °C). Anal. Calc. for $C_{18}H_8Cl_2Br_4N_2O_2Sn$: C, 27.25; H 1.02; N, 3.53 %. Found; C, 27.29; H, 1.08; N, 3.85 %. UV-vis: $\lambda(\log \epsilon)$ (CH_2Cl_2): 388 nm (2.88). IR (KBr, cm^{-1}): 3071(s), 1973(w), 1961(s), 1720(s), 1602(s), 1578(m), 1490(m), 1218(s), 850(m), 680(m), 607(s), 501(m). 1H NMR ($CDCl_3$, ppm): 7.41, 7.71, 8.30 and 9.01. Mass spectrum data: m/e 790 $[M]^+$. Mass numbers are based on 1H , ^{12}C , ^{14}N , ^{16}O , ^{35}Cl , ^{79}Br and ^{120}Sn .

Dichlorido-bis(5,7-dichloroquinolin-8-olato-2N,O)tin(IV) (5)

5,7-Dichloro-8-hydroxyquinoline (1 mmol, 0.25 g) was added to a solution of stannous chloride (1 mmol, 0.23 g) in DMSO (20 ml). The mixture was stirred at room temperature for two hours and then the clear solution was set aside in which yellow crystals formed after several days (m.p. > 300 °C). Anal. Calc. $C_{18}H_8Cl_6N_2O_2Sn$: C, 35.12; H 1.31; N, 4.55 %. Found; C, 34.88; H, 1.35; N, 4.84 %. UV-vis: $\lambda(\log \epsilon)$ (CH_2Cl_2): 391 nm (3.18). IR (KBr, cm^{-1}): 3067(w), 2927(m), 2910(m), 1808(m), 1602(m), 1462(m), 1440(s), 1401(w), 1393(m), 1260(m), 1050(m), 807(w), 800(s), 620(m), 587(m). 1H NMR ($CDCl_3$, ppm): 7.51, 7.58, 8.72, and 9.11. Mass spectrum data, tin-bearing fragment: m/e 614 $[M]^+$. Mass numbers are based on 1H , ^{12}C , ^{14}N , ^{16}O , ^{35}Cl and ^{120}Sn .

Dichlorido-bis(5-nitro-quinolin-8-olato-2N,O)tin(IV) (6)

5-Nitro-8-hydroxyquinoline (1 mmol, 0.19 g) was added to a solution of stannous chloride (1 mmol, 0.23) in DMSO (10 ml). The mixture was stirred at room temperature for two hours and then the clear solution was set aside in which brown crystals formed after several days (m.p. > 300 °C). Anal. Calc. for $C_{18}H_{10}Cl_2N_4O_6Sn$: C, 38.07; H 1.77; N, 9.87 %. Found; C, 38.00; H, 1.95; N, 10.02 %. UV-vis: $\lambda(\log \epsilon)$ (CH_2Cl_2): 392 nm (3.39). IR (KBr, cm^{-1}): 3049(w), 2092(w), 1925(w), 1622(m), 1502(m), 1570(m), 1281(w), 1001(s), 802(m), 790(m), 421(m), 722(m), 643(m), 600(m), 491(m). 1H NMR ($CDCl_3$, ppm): 7.12, 7.65, 8.13, 8.74 and 9.13. Mass spectrum data: m/e 568 $[M]^+$. Mass numbers are based on 1H , ^{12}C , ^{14}N , ^{16}O , ^{35}Cl and ^{120}Sn . Suitable crystals of **6** for crystal structure determination were obtained by slow evaporation of the DMSO at room temperature.

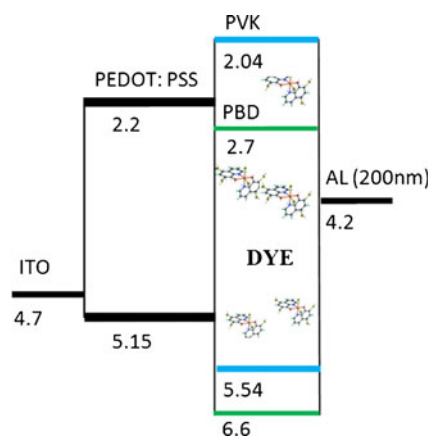


Fig. 1 Schematic drawing of the OLED. ITO (indium tin oxide), PVK (polyvinyl carbazole), PEDOT:PSS [poly(3,4-ethylenedioxythiophene):poly(styrene-sulfonate)], and PBD (2-(4-biphenyl)-5-(4-t-butyl-phenyl)-1,3,4-oxadiazole). Electrons from Al and holes from ITO injects into PBD as electron transport layer and PEDOT:PSS as the hole transport layer

Fabrication of OLED by Utilization of dichlorido-bis(5-chloroquinolin-8-olato-2N,O)-tin(IV)

For fabricating OLED from prepared complexes, initially the ITO coated glass substrate was washed thoroughly in ultrasonic bath by mild soap, distilled water, acetone, dichloromethane, dichloroethane and methanol. PEDOT:PSS (poly(3,4-ethylenedioxythiophene):poly(styrenesulfonate)) as hole injecting layer was then spin coated on a clean substrate. The required thickness of the layer was 90 nm. The coated layer was then cured at 120 °C to reduce the surface roughness. The emitting layer was spin coated from a solution of PVK (polyvinyl carbazole):PBD(2-(4-biphenyl)-5-(4-t-butyl-phenyl)-1,3,4-oxadiazole):Dichlorido-bis(5-chloroquinolin-8-olato-2N,O)tin(IV) (**3**) at 100:40:6 weight percent in dichloromethane to make a sample with the following structure: ITO/PEDOT:PSS(90 nm)/PVK:PBD:Sn/HQ-Cl (70 nm)/Al(200 nm). PVK as hole-transporting materials and PBD as an electron-transporting material were doped with tin compound all as an emissive layer. Before thermal vacuum

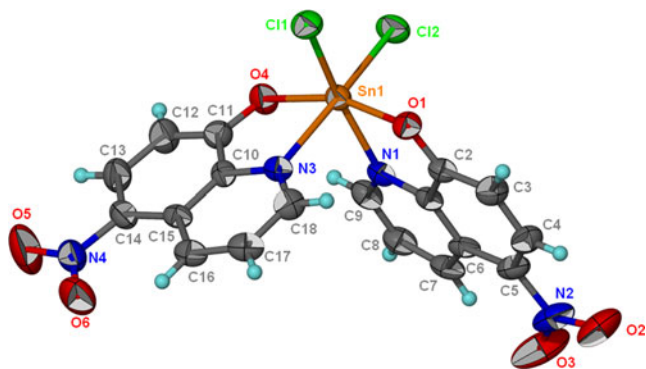


Fig. 2 Molecular structure of a selected complex (**6**). Thermal ellipsoids scaled up to the 30 % probability level

Table 2 Selected bond distances and angles for complex **6**

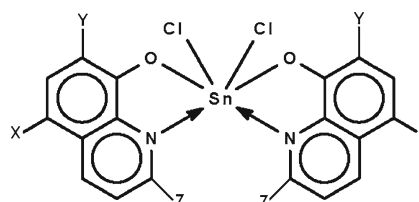
Bond lengths (Å)		Bond angles (°)	
Sn(1)-O(1)	2.044(3)	Cl(1)-Sn(1)-O(1)	90.18(10)
Sn(1)-N(1)	2.218(4)	Cl(1)-Sn(1)-O(4)	100.83(14)
Sn(1)-Cl(1)	2.3560(14)	Cl(1)-Sn(1)-N(1)	166.57(12)
Sn(1)-Cl(2)	2.3582(14)	Cl(2)-Sn(1)-N(3)	168.69(11)
Sn(1)-N(3)	2.236(4)	Cl(1)-Sn(1)-O(1)	90.18(10)
Sn(1)-O(4)	2.050(4)	O(1)-Sn(1)-O(4)	161.59(14)

coating of the Al layer, samples were left in an oven at 120 °C. After coating the Al layer, samples were left in the vacuum chamber in argon atmosphere to reduce the risk of oxidation during cooling down to room temperature. The active area of the prepared samples was 0.25 cm². The final sample structure and the related energy levels are shown in Fig. 1. In fabricated device, electrons from Al and holes from ITO injects into PBD as electron transport layer and PEDOT:PSS as the hole transport layer, respectively. Use of PEDOT:PSS interlayer helps to have a better hole injection layer and this result in an increase of current and transfer of holes to PVK as hole transport. Corollary, holes and electrons are transferred to DYE by PVK and PBD, then electron-hole recombine in DYE and emit light from DYE. HOMO-LUMO energy levels of PEDOT:PSS, PVK and PBD are 5.15–2.2, 5.54–2.04, and 6.6–2.7 eV, respectively.

Results and Discussion

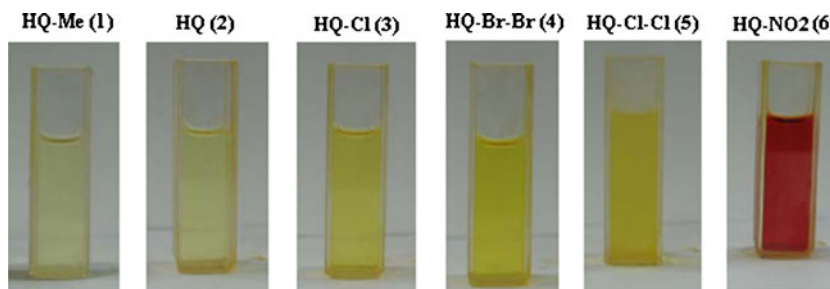
Synthesis

All compounds were obtained by reacting stannous chloride to 8-hydroxyquinoline derivatives in 1:1 mole ratio in DMSO at room temperature. These reactions are fast, facile and their progress was monitored by appearance of fluorescence colours. All prepared compounds are thermally stable and their synthesis was accomplished by IR, ¹HNMR spectroscopies in addition to mass spectrometry and elemental analysis. In the IR spectra of all prepared complexes, the absence of a



Scheme 1 Line drawing structures of the complexes. X=H, Y=H, Z=CH₃ (**1**); X=H, Y=H, Z=H (**2**); X=Br, Y=Br, Z=H (**3**); X=Cl, Y=H, Z=H (**4**); X=Cl, Y=Cl, Z=H (**5**); X=NO₂, Y=H, Z=H (**6**)

Fig. 3 Colorimetric response of prepared complexes with substituent of 8-hydroxyquinoline ligand



broad band in the 2500–3400 cm^{-1} range, and the presence of Sn-O vibration for complexes at about 460 cm^{-1} clearly indicates that deprotonation of the 8-hydroxyquinoline has taken place in the course of coordination to tin.

General Characterization

For the determination of structural features of the prepared complexes in solution, we obtained detailed ^1H and ^{119}Sn spectra. The ^1H NMR spectra of complexes showed the expected aliphatic and/or aromatic peaks with the correct integration and multiplicities. The single resonance at -213.2 ppm in the ^{119}Sn NMR spectrum of a selected complex, **2**, suggests that the tin(II) during reaction oxidized to tin(IV) and tin atom in all prepared complexes are six-coordinate [35]. The molecular ions of all six complexes were observed in mass spectra and unambiguously showed molecular formulas and presence two 8-hydroxyquinoline moieties in complexes. Since quality of the dichlorido-bis(5-nitro-quinolin-8-olato-2N,O)tin(IV) (**6**) crystal was suitable than other compounds, it has chosen as a representative sample for further elucidation of molecular structure of complexes by single-crystal structure study.

Furthermore, because compound **3** has the most favorable properties in terms of light emission in comparison to others it was selected for fabrication of OLED.

Description of Crystal Structure

of dichlorido-bis(5-nitro-quinolin-8-olato-2N,O)- tin(IV) (**6**)

The molecular structure of **6** is shown in Fig. 2, selected bond lengths and angles are given in Table 2 and line drawing in Scheme 1 (**6**, X=NO₂, Y=H, Z=H). The geometry around the tin atom is a distorted octahedral and two oxygen atoms of 8-hydroxy-2-methylquinoline ligands that bound to the tin atom with angle of 161.59(14)° are *trans* to each other in contrast to their nitrogen atoms with angle of 85.94(14)°. The bite angles in title complex is also similar to that of found in other tin complexes of 8-hydroxyquinoline, regardless of geometry of the complex [36, 37]. Since other complexes contain other derivatives of 8-hydroxyquinoline, it is reasonable to assume a similar octahedral geometry for them, but it should mention that due to the electron donating or withdrawing character of substituents on ligands, the bond distance and angles in other complexes can differ slightly. Therefore, the variation in

Fig. 4 Photoluminance spectra of complexes 1-6 in 10^{-2}M CH_2Cl_2 solution

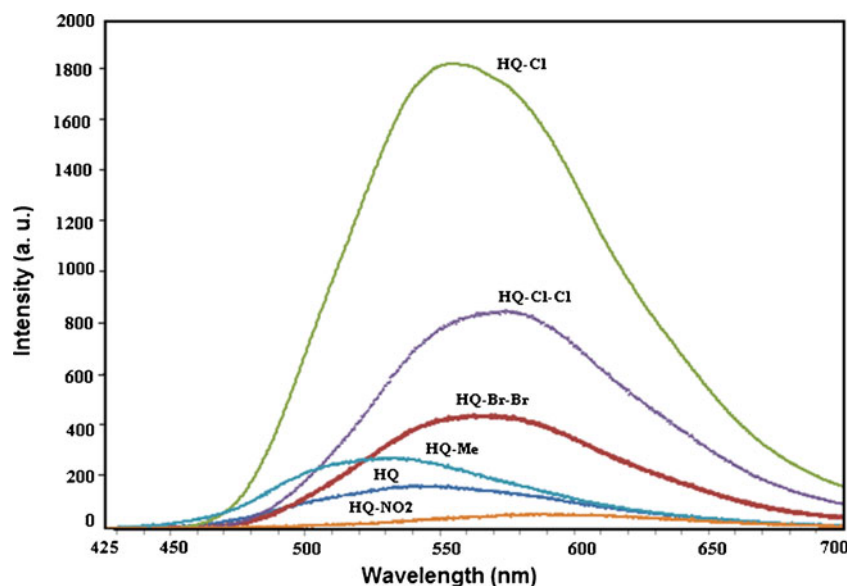
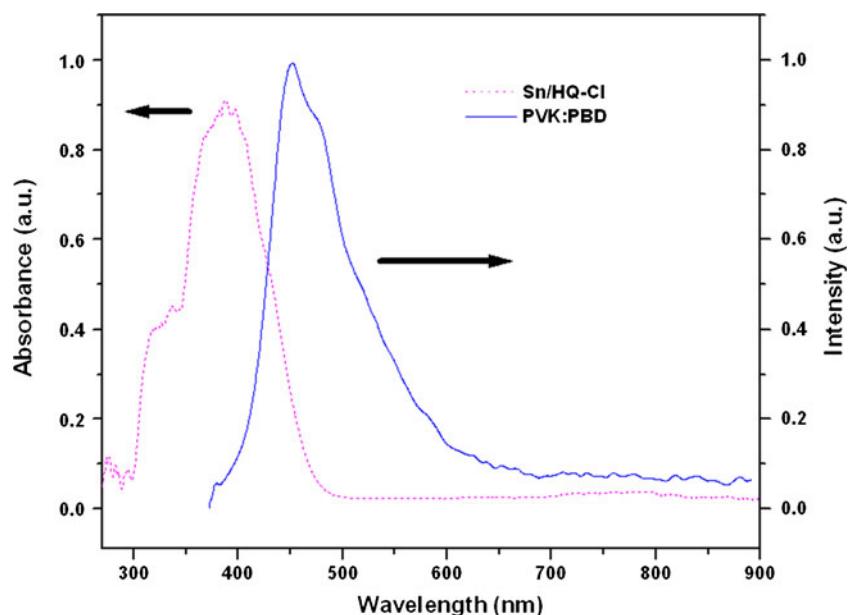


Fig. 5 The overlap between absorption spectrum of Sn/HQ-Cl and electroluminescence of PVK:PBD (polyvinyl carbazole: polybutadiene)



photoluminance properties of complexes only should be affected by substituents rather than slight changes in bond distances or angles. Since spectroscopic data of all prepared compounds are similar, therefore, it is reasonable to extend the molecular structure results of complex **6** to other ones.

Photophysical Properties

The photoluminescence properties of all materials and effect of the substituent of the 8-hydroxyquinoline ligand on their photophysical properties have been investigated. The solid state emission spectra of all materials are collected from 450 to 650 nm with excitation by

100 mW laser at 405 nm. Successful emission color tuning in the complexes can be mediated by the substituent on the complexes. As Fig. 3 shows, replacing electron donating groups with electron withdrawing groups resulted in red-shift in the UV-vis spectra. These shifts increased in order of HQ-Me, HQ, HQ-Cl, HQ-Br-Br, HQ-Cl-Cl and Q-NO₂ with wavelengths of 528.4, 543.3, 556.1, 566.0, 573.3 and 589.4 nm, respectively. The photoluminescence spectra of compounds **1–6** are shown in Fig. 4. The maximum emission peaks shows that a good correlation exists between the electron withdrawing and donating nature of the substituent group on the 8-hydroxyquinoline and emission wavelength. Interestingly, substitution of a methyl

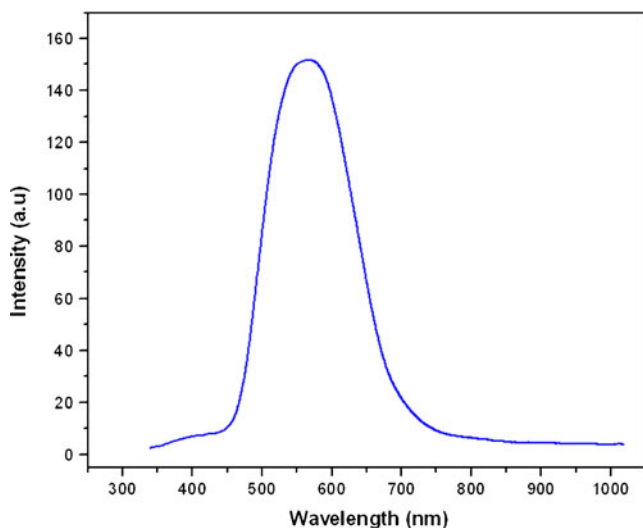


Fig. 6 The EL spectra of tin complex

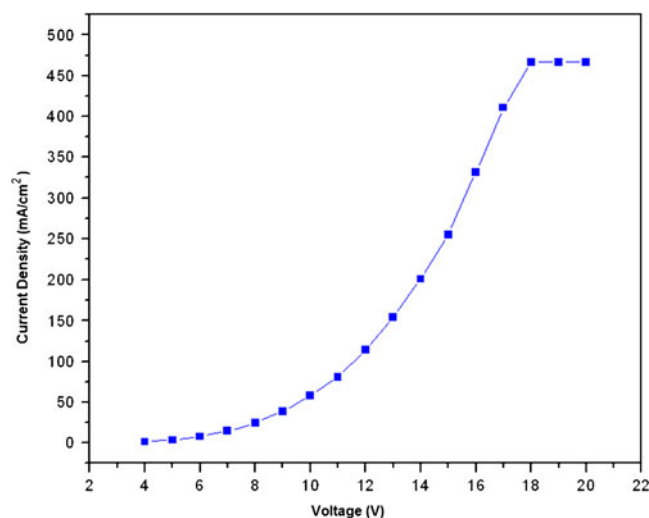


Fig. 7 J-V characteristic of Sn/HQ-Cl

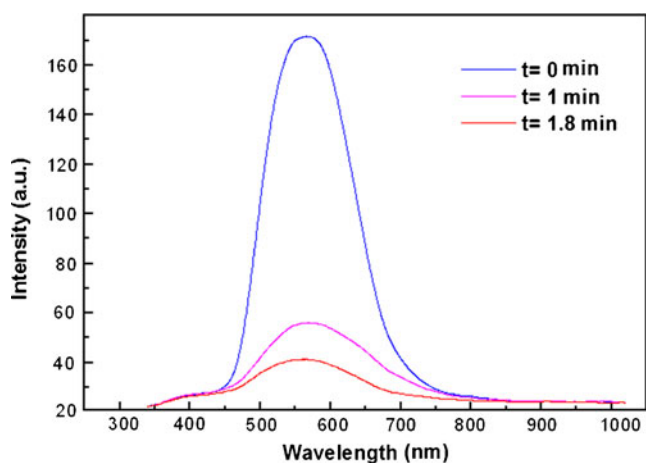


Fig. 8 Changes in the EL spectrum of compound **3** as a function of time

group at the 2-position of the 8-hydroxyquinolate, **1**, shows a blue shift in comparison with unsubstituted one (**2**). It seems emission wavelength of aforementioned complexes can be tuned simply by type of substituted group on 8-hydroxyquinolate. Furthermore, emission spectra in Fig. 4 beyond spectral shifts shows a difference in intensities which is due to the difference in concentration and solubility of complexes. Notably, compound **5** with highest molar absorptivity shows a weak emission and this is consistent with very low solubility and concentration of complex in solution.

OLED

To demonstrate the application of the prepared complexes in OLED, a selected complex, **3**, was used to fabricate an OLED device and its electroluminescence property was investigated. An important condition to have a good energy transfer from a host to guest, the overlap between the absorption spectrum of guest with the EL of the host is required. In this work, as shown in Fig. 5, there is a small ratio of overlap between the absorption spectrum of tin compound as guest with the EL spectrum of PVK:PBD as host. Therefore, we expect the energy transfer from host to guest occurs to some extent. As shown in Fig. 6, the EL of the complex containing one chlorine atom on ligands exhibits a yellow emission around 564 nm with FWHM (full width at half maximum) of 149 nm. This value is close to its PL at 556.1 nm with absorption at 386 nm.

As shown in Fig. 6, the EL of the complex containing one chlorine atom on ligands has exhibited the yellow emission around 564 nm, near to their PL 556.1 nm. There is about 8 nm red shift in EL spectra relative to PL spectra. Similarity of PL and EL supports

that the yellow EL is originated from the tin complex dopant in the emitting layer of the device; as a result this tin compound could be used for fabrication of yellow OLEDs. Figure 7 shows the electrical characteristic of OLEDs at 100:40:6 weight concentration. The probability of exciton formation in the system has direct relation with the numbers of holes and electrons in the bulk. Therefore, with reduction in the current density, the probability of exciton formation during the operation of the device reduces. Since the lifetime is vital to the usefulness of OLEDs, the device lifetime tested for 0, 1 and 1.8 min at 17 V and results are illustrated in Fig. 8. The EL of compound **3** decays to about 23 and 13 % of the original signal after 2 and 3 min, respectively, exposure to atmosphere. Finally, all prepared compounds showed good thermal stability according to their melting point measurements and thermal analysis (TGA-DSC) and they also are stable upon exposure to moisture and air. Therefore, a good level of luminance can be sustained with these complexes. It is also interesting to compare the present OLED with the AlQ₃ a well known OLED. One of the advantages of present OLED is that when the device exposed to ambient environment condition for few days, a decidedly greater shelf life stability as compared with AlQ₃ was observed. Furthermore, the emission of compound **3** is narrow and centered at 560 nm with a relatively longer lifetime in comparison with 526 nm emission and 15 ns lifetime of AlQ₃ [8].

Conclusion

This study shows that the 8-hydroxyquinoline complexes of tin(IV) have a good potential in emission color tuning. Photoluminescence and electroluminescence properties of the tin(IV) complexes correspond to the electron-withdrawing/-donating character of the substituent on 8-hydroxyquinoline. The emission wavelength of the prepared materials can be tuned in the solid-state over a wide range of the wavelength using proper substituent on the 8-hydroxyquinoline ligand. The prepared materials are stable both under air and high temperature which make them suitable for fabrication of OLED.

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Supporting information CCDC 86936 contains the supplementary crystallographic data for **6**. These data can be obtained free of charge via <http://www.ccdc.cam.ac.uk/conts/retrieving.html>, or from the Cambridge

Crystallographic Data Centre, 12 Union Road, Cambridge CB2 1EZ, UK; fax: (+44) 1223-336-033; or e-mail: deposit@ccdc.cam.ac.uk.

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