# Arylamino-Functionalized Fluorene- and Carbazole-Based Copolymers: Color-Tuning Their CdTe Nanocrystal Composites from Red to White

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ABSTRACT: Four alternating arylamino-functionalized copolymers were synthesized in a Suzuki copolymerization applying 4, 4'-(2,7-dibromo-9*H*-fluorene-9,9-diyl)dianiline, 4,4'-(2,7-dibromo-9*H*-fluorene-9,9-diyl)*bis*(*N*,*N*-diphenylaniline), 4-(3,6-dibromo-9*H*carbazol-9-yl)aniline and 4-(3,6-dibromo-9*H*-carbazol-9-yl)-*N*,*N*diphenylaniline in combination with 2,2'-(9,9-dioctyl-9*H*-fluorene-2,7-diyl)*bis*(1,3,2-dioxaborinane). The resulting novel alternating copolymers were fully characterized. The copolymers revealed blue light emission and wide optical bandgaps of at least 2.93 eV for the fluorene-based and 3.07 eV for the carbazole-based polymers. The amino-functions allow to tie semiconducting CdTe nanocrystals (NCs) and to synthesize a series of composites with CdTe NCs. Moreover, tuning the emission color over a wide range by tying these CdTe NCs results in a facile preparation of organic-inorganic semiconductor composites with emission colors "à la carte." © 2010 Wiley Periodicals, Inc. J Polym Sci Part A: Polym Chem 49: 392–402, 2011

**KEYWORDS**: conjugated polymers; fluorescence; nanocrystals; synthesis

**INTRODUCTION** Semiconducting conjugated copolymers<sup>1</sup> have been often described in a multitude of derivatives.<sup>2-6</sup> Poly(fluorene)s (PFs)<sup>7</sup> are especially of importance as lightemitting materials used in polymer light-emitting diodes<sup>8-10</sup> and are of particular significance due to their high-photoluminescence quantum yields<sup>3,9,10</sup> and rather large bandgaps. However, their major problem is their tendency to structurally decompose due to oxidation over time in the solid-state on heating, leading to color instability and green electroluminescence when incorporated in the light emitting diodes (LEDs).<sup>11-14</sup> Functionalization of the fluorene C-9 position by introducing bulky aryl-groups<sup>7</sup> allows to overcome stability matters<sup>15</sup> and to reduce the interchain interactions, thereby, improving the optoelectronic properties of the resulting polymers.<sup>16-18</sup> The latter may be enhanced when the polymer backbone comprises spirofluorene moieties<sup>19</sup> and is further furnished with electron-withdrawing cyano substituents and carbazole segments to complement the rather inefficient charge transport of PFs.<sup>20</sup>

As mentioned, further promising candidates for technological applications are poly(carbazole)s. Polymers based on carbazole have good electroactive and photoactive properties due to their high hole-transporting mobility, strong absorption in the ultraviolet spectral region, and blue light emission.<sup>21,22</sup> A further benefit is that the carbazole unit can raise the highest occupied molecular orbital (HOMO) energy level of the polymers.<sup>23</sup> These bandgap variations are important to host other semiconductor moieties and to, thus, tune the emission color of the host-guest system.

Triarylamines are widely used as hole-transporting materials in LEDs<sup>24,25</sup> or incorporated in polymer backbones to enhance the performance of LEDs.<sup>26–29</sup> It was shown that covalent attachment of triarylamine substituents in the 9position of carbazole repeating units of carbazole main chain polymers led to polymers with low-ionization potential and high-fluorescence quantum efficiencies.<sup>30,31</sup> Apart from their hole-transporting ability, triarylamines can act as chromophores in an electrochemical system and be, furthermore, used as linkers to be attached to nanocrystalline surfaces, i.e.,  $TiO_2$ .<sup>32,33</sup>

To design and synthesize alternating PFs and poly(carbazole)s, palladium-interceded cross-coupling reactions such as the Suzuki polycondensation<sup>34</sup> are useful.<sup>35,36</sup> Copolymer-

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SCHEME 1 The synthetic routes of monomers 2-8 as well as of alternating copolymers 9-12.

ization of functional monomers, that keep the wide bandgap can be connected to other functional or light-emitting species such as nanoparticles or semiconductor nanocrystals (NCs)<sup>37</sup> and are, therefore, of increasing impact in modern light-emitting technology involving simple and efficient color-tuning on demand mechanisms.

In this work, we introduce the synthesis and characterization of four alternating copolymers that were designed with 4,4'-(2,7-dibromo-9H-fluorene-9,9-diyl)dianiline and 4,4'-(2,7dibromo-9*H*-fluorene-9,9-diyl)*bis*(*N*,*N*-diphenylaniline) as monomers for the fluorene-based copolymers and with 4-(3,6-dibromo-9H-carbazol-9-yl)aniline or 4-(3,6-dibromo-9Hcarbazol-9-yl)-N,N-diphenylaniline as monomers for the poly (carbazole)s. The comonomers were copolymerized with 2,2'-(9,9-dioctyl-9*H*-fluorene-2,7-diyl)*bis*(1,3,2-dioxaborinane) following a classical Suzuki protocol. The resulting alternating copolymers revealed blue-light emission with an emission maximum at 418 nm. Because of their nitrogencontaining side chains, they may function to attach to a variety of nanoparticles. Here, we show the interconnection of the functional copolymers to CdTe semiconductor NCs indicated by tuning the emission color of the host-guest system. The composites possess a color change from blue (copolymers) and green to orange-red (CdTe NCs) to a red, reddishwhite, or white (composites) emission color.

# **RESULTS AND DISCUSSION**

To obtain alternating copolymers based on 2,2'-(9,9-dioctyl-9*H*-fluorene-2,7-diyl)*bis*(1,3,2-dioxaborinane) (**1**) and arylamino-functionalized fluorenes (Scheme 1, left side), 4,4'-(2,7dibromo-9*H*-fluorene-9,9-diyl)dianiline (**3**)<sup>38</sup> was synthesized by introducing two phenylamine groups in the 9-position of 2,7-dibromo-9*H*-fluoren-9-one (2) using an excess of aniline for this condensation reaction. 4,4'-(2,7-Dibromo-9H-fluorene-9,9-diyl)bis(N,N-diphenylaniline) (4)<sup>39</sup> was synthesized following a similar route, however, by applying an excess of triphenvlamine in the presence of methane sulfonic acid (Scheme 1). To generate alternating carbazole-based copolymers (Scheme 1, right side), 3,6-dibromo-9-(4-nitrophenyl)-9H-carbazole (5) was synthesized from 3,6-dibromo-9Hcarbazole with addition of 1-fluoro-4-nitrobenzene in the presence of potassium carbonate via a nucleophilic substitution.<sup>40,41</sup> Through reduction via tin(II) chloride of monomer 5, 4-(3,6-dibromo-9*H*-carbazol-9-yl)aniline (6) was obtained as a yellow crystalline solid.<sup>40,41</sup> 4-Iodo-*N*,*N*-diphenylaniline (7) was synthesized by application of an Ullmann coupling reaction of diphenylamine and 1,4-diiodobenzene under the presence of copper(II) sulfate and potassium carbonate at a reaction temperature of 220 °C. Precursor 7 was obtained as a white solid and further used in an Ullmann coupling with 3,6-dibromo-9Hcarbazole by the aid of copper(I) iodide and [18]-crown-6 to end up with 4-(3,6-dibromo-9H-carbazol-9-yl)-N,N-diphenyl aniline (8) (Scheme 1). Subsequently, the copolymerizations were performed according to a Pd(0)-mediated Suzuki C-Ccoupling protocol.<sup>42</sup> Using 4,4'-(2,7-dibromo-9H-fluorene-9,9divl)dianiline (3) or 4,4'-(2,7-dibromo-9H-fluorene-9,9-divl)bis(N,N-diphenylaniline) (4) in combination with 2,2'-(9,9dioctyl-9*H*-fluorene-2,7-diyl)*bis*(1,3,2-dioxaborinane) (1) the fluorene-based alternating polymers 9 and 10 were obtained (Scheme 1, left side). 4-(3,6-Dibromo-9H-carbazol-9-yl)aniline (6) or 4-(3,6-dibromo-9H-carbazol-9-yl)-N,N-diphenylaniline (8) in combination with comonomer 1 yielded the carbazole-based alternating copolymers 11 and 12 (Scheme 1,

 TABLE 1
 Monomer Ratio of 3,4,6, and 8 to 1, GPC Characterizaton and Thermal Properties of

 9–12

Polymer (Monomer Ratio)	Monom ( <b>3, 4</b> , (mol	ner Ratio <b>6, 8/1</b> ) ar %)	<i>M</i> n (g mol <sup>-1</sup> )	<i>M</i> <sub>w</sub> (g mol <sup>−1</sup> )	PDI Units	7 <sub>d</sub> ° (°C)	<i>T</i> g (°C)
<b>9</b> (M3/M1)	46/54 <sup>a</sup>	46/54 <sup>b</sup>	5,700	17,300	3.0	420	-
10 (M4/M1)	48/52 <sup>a</sup>	47/53 <sup>b</sup>	5,500	12,900	2.4	440	150
<b>11</b> (M6/M1)	46/54 <sup>a</sup>	45/55 <sup>b</sup>	2,900	5,300	1.8	420	-
<b>12</b> (M8/M1)	46/54 <sup>a</sup>	46/54 <sup>b</sup>	2,900	5,300	1.8	420	128

<sup>a</sup> Calculated from <sup>1</sup>H NMR.

<sup>b</sup> Calculated from elemental analysis.

<sup>c</sup> At 5% weight loss.

right side). The palladium(0)-catalyzed polycondensations were conducted with *tetrakis*(triphenylphosphine)palladium(0) as catalyst,  $K_2CO_3$  of 2 M concentration as base and refluxing toluene as the reaction medium. The crude yields obtained for **9–12** are in the range of 60–92%.

However, to remove impurities and low-molecular-weight species and to, thus, obtain unimodal molecular-weight distributions, the crude copolymers 9-12 were exhaustively purified by continuous extractions with chloroform–*iso*propanol mixture over 3 days by means of a Soxhlet-apparatus, whereby the chloroform fraction was isolated and reprecipitated from methanol/ethyl acetate mixtures, methanol/tetrahydrofuran ones, or acetone. After these extensive purification procedures, the copolymers were obtained as yellowish solids still in yields of 30–36%, well soluble in solvents of medium polarity like toluene, chloroform, or dichloromethane. Moderate yields are not an uncommon occasion in fluorene-based backbones<sup>43</sup> and fluorene-carbazole systems furnished with bulky side chains have led to middle-rate yields as well.<sup>44,45</sup>

The <sup>1</sup>H NMR spectrum of polymer **9** is confirming the presence of the amine-group in the polymer backbone from the resonance at 3.62 ppm. For copolymer **10**, the nitrogen content is evidenced by elemental analysis (N 2.55%). The <sup>1</sup>H NMR spectrum of copolymer **11** indicates the presence of the amino-functionalized carbazole derivative **6** in the backbone of the polymer by a resonance at 3.94 ppm. For copolymer **12**, elemental analysis (N 3.09%) elucidated the successful copolymerization of the two comonomers **1** and **8**. Combination of <sup>1</sup>H-NMR spectroscopy and elemental analysis allowed the determination of the actual comonomer percentages in each of the copolymers backbone.

The calculations by the two different methodologies revealed the comonomers' ratio in the backbone of the copolymers **9– 12**, approximately determining a 50% ratio (Table 1) as typically expected for alternating copolymers. Both methodologies revealed almost similar results for **9–12** with an excess of comonomer **1** (about one to two repeating units more) compared to the values obtained for monomers **3**, **4**, **6**, and **8** in the respective copolymers backbone **9–12**. Likewise, the copolymers were characterized by means of gel permeation chromatography (GPC) (Table 1). In Figure 1, the molecular weight distributions of the copolymers are illustrated.

The approximately by half-reduced molecular weights (Table 1) for polymers **11** and **12** are typical for Suzuki-mediated polycondensation reactions<sup>10,44</sup> and not unusual for carbazoles participating in such kind of polymerizations<sup>44,46</sup> even in the case of homopolymers.<sup>47</sup> The nature of the *N*-substituents in the palladium-catalyzed coupling polycondensation influences the solubility of the polymers and can lead to modest molecular weights of  $M_{\rm w} \leq 10^{4.48}$  Despite the fact that the copolymers reveal modest molecular weights, the low-polydispersity indices evidence the homogeneity of the synthesized materials. As known from literature, the



**FIGURE 1** Molecular weight distribution of polymers **9–12** determined by GPC. Concentration of 0.5 mg mL<sup>-1</sup> was applied for all polymers and the analysis was performed on MZSD columns of particle size 5  $\mu$ m, using chloroform as eluent for polymers **9**, **10** (calibration based on polystyrene standards) and on GRAM columns, using dimethyl formamide (DMF) as eluent with ammonium hexafluorophosphate 5 mM as salt at a temperature of 40 °C for polymers **11** and **12** (calibration based on poly (methyl methacrylate) standards).

TABLE 2	Optical	Properties of	of Copolymers	9-12
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	Abs <sub>sol</sub> <sup>a</sup> (nm) (Lg ε [L mol <sup>-1</sup> cm <sup>-1</sup> ])	Abs <sub>film</sub> (nm)	Em <sub>sol</sub> <sup>a,b</sup> (nm)	Em <sub>film</sub> b (nm)	Eg <sub>sol</sub> <sup>a,c</sup> (eV)	Eg <sub>film</sub> c (eV)	$\Phi_{\rm sol}{}^{\rm a,d}$
P9	385 (6.28)	387	418/442	424/448	2.93	2.84	0.32
P10	381 (6.34)	395	416/441	428/447	2.94	2.71	0.66
P11	343 (6.68)	350	401/420	411/425	3.10	2.76	0.84
P12	341 (6.10)	358	404/420	409/426	3.07	2.72	0.51

<sup>a</sup> In chloroform solution ( $10^{-6}$  mol L<sup>-1</sup>).

 $^{\rm b}$   $\lambda_{\rm exc}$  380 nm for **9/10,** 360 nm for **11/12**.

<sup>c</sup> Calculated from the absorption band edge.

 $^{\rm d}$  Determined according to Demas and Crosby by using PF (  $\Phi_{\rm sol}$  0.71) as a reference.  $^{52,53}$ 

presence of oligomers can degrade the quality of the final product, a phenomenon which can come up in polymerizations based on fluorene comonomers.<sup>49</sup> Moreover, precipitation into acetone is known to induce an increased solubility of the higher molecular weight fractions.<sup>50</sup> Acetone seems to be the optimal medium for amino-functionalized copolymers. A previous study in our laboratories showed that more polar solvents such as methanol reduce the yields of the aminofunctional copolymers drastically, even below 10%, due to the alcohol solubility of the amino-functional side chain.<sup>51</sup> This effect is certainly to a large extent undesired in terms of yield optimization, however, highly desired when focusing on multilayer thin-film processing using orthogonal solvents. All copolymers 9-12 possessed favorable thermal stabilities indicated by  $T_d$  values at 5% weight-loss of 420 °C or even higher (Table 1). Thus, copolymers 9-12 feature thin-film processing from high-boiling point solvents. While for copolymers 9 and 11, no glass transitions could be obtained, copolymers 10 and 12 revealed  $T_{\rm g}$  values in the expected range of 128-150 °C (Table 1). The optical properties of the copolymers were additionally determined and represented in Figure 2(a) and Table 2. In solution and film, all of them exhibit blue-light emission with a red shift of  $\sim$ 5–12 nm for the solid-state experiments. In Figure 2(b), the optical properties of the NCs are represented as well in combination to an exemplary transmission electron microscopy (TEM) image for the orange-emitting CdTe NCs E [Fig. 2(c)].

The spectral overlap between the blue emission of the copolymers **9–12** and the absorption of the CdTe NCs [Fig. 2(a,b)] fulfills basically the prerequisites for energy transfer (ET) from the polymer backbones to the NCs. Moreover, **9–12** revealed wide bandgaps of 2.93–3.10 eV in solution, whereas, in the films, the optical bandgaps were slightly reduced to 2.71–2.84 eV (Table 2). Therefore, solid-state measurements of the optical properties of bare NCs, polymers, and NC-polymer systems were conducted.

In Figure 3(a), the fluorescence spectra ( $\lambda_{exc}$ : 380 nm) of films of the composites of CdTe NCs E (orange-red emission) with polymers **9** and **10** are shown. The photographs (**9**, **9** + CdTe, CdTe, **10**, **10** + CdTe, in that order left to right) of the composites under UV illumination illustrate the color change from blue to red in the case of **9** and to reddishwhite in the case of **10** [Fig. 3(a)]. In Figure 3(b), the fluo-

rescence excitation experiments ( $\lambda_{exc}$ : 370 nm) of films of the composites of CdTe NCs E with the carbazole-based arylamino-functionalized copolymers 11 and 12 are depicted. The pictures in Figure 3(b) (11, 11 + CdTe, CdTe,**12**, **12** + CdTe, in that order left to right) visualize a color change from blue or red in the bare polymer or NC solutions compared with a reddish-white emission of the composites. The morphology of the achieved composites, drop casted from the polymer-CdTe mixtures onto glass substrates, was investigated using atomic force microscopy (AFM) in the tapping mode. In Figure 4(a), the topography of the respective composite films, prepared by mixing DMF solutions of the CdTe E NCs (8 mg mL $^{-1}$ ) with THF solutions of the polymers  $(1 \text{ mg mL}^{-1})$  in a 1:1 (v/v) ratio is illustrated, indicating the formation of CdTe nanoparticle clusters with a domain size of  $\sim$ 200 nm. CdTe NCs seem to form aggregates while being overcoated with a layer of the individual polymer. The roughness of the film surfaces is extreme and traversing from CdTe composites built with polymer 9-12, following the recorded values: 146.6, 322.8, 254.5, and 165.7 nm. In Figure 4(b), the AFM images of the bare polymers 9-12 are depicted. The big spots, most likely due to dewetting, vary regarding their size from 5 to 16  $\mu$ m, while the smaller spots are polymer as well with a size in the scale of 0.8–2  $\mu$ m. The tailing of the latter and the repeating pattern is assigned to artifacts arising due to material dragged from the cantilever over the scanned surface. Finally, the AFM image [Fig. 4(c)] of CdTe E NCs reveals an even larger aggregation tendency, most likely due to large packed regions (10-21  $\mu$ m) with a roughness of 319.9 nm. The film of bare NCs is more uniform compared with those of composites and bare polymers but cracked due to shrinkage by solvent evaporation.

Combining now the blue-emitting polymers **9–12** and a yellow-emitting species prepared from the orange-red emitting CdTe NCs E with the green-emitting CdTe NCs B, a white-light emission in solution was approached, revealed by the emission bands at ~425 nm and ~545 nm [Fig. 5(a)]. Thin-film experiments are illustrated in Figure 5(b). In these solid-state measurements, the band of blue emission is shifted to ~420 nm while its complementary yellow band needed for the achievement of white light is found at ~510 nm [Fig. 5(b)]. Figure 5(c) illustrates exemplarily the achieved favorable white-light emission (**10** + CdTe NCs B



**FIGURE 3** Normalized emission spectra (a) ( $\lambda_{exc}$ : 380 nm) of copolymers **9** + CdTe E and **10** + CdTe E and (b) ( $\lambda_{exc}$ : 370 nm) of copolymers **11** + CdTe E and **12** + CdTe E drop casted from THF (spectra of films) and a DMF/THF (1/3) mixture (photographs: daylight and under illumination of UV light ( $\lambda_{exc}$ : 366 nm), respectively.

a)



**FIGURE 4** AFM images (tapping mode) of films of composites prepared by mixing DMF solutions of the CdTe E NCs (8 mg mL<sup>-1</sup>) with THF solutions of the polymers (1 mg mL<sup>-1</sup>) in a 1:1 (v/v) ratio (a), of films of the polymers (concentrations of 0.5 mg mL<sup>-1</sup> in THF) (b) and film of the CdTe E NCs (4 mg mL<sup>-1</sup> concentration in DMF) (c) on glass substrates obtained by drop casting the respective solutions. The AFM images have a scale of 30  $\times$  30  $\mu$ m<sup>2</sup>. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]



FIGURE 5 (a) Emission spectra of copolymers 9, 10 + CdTe ( $\lambda_{exc}$ : 380 nm) and copolymers 11, 12 + CdTe ( $\lambda_{exc}$ : 370 nm) in DMF solutions showing white-light emission. (b) Normalized emission spectra of copolymers 9, 10 + CdTe ( $\lambda_{exc}$ : 380 nm) and copolymers 11, 12 + CdTe ( $\lambda_{exc}$ : 370 nm) in films drop casted from DMF. (c) Exemplary photograph of white-light emission under illumination of UV light ( $\lambda_{exc}$ : 366 nm). [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

and E) in DMF solution. More detailed measurements involving photo-physical and electro-optical investigations will be carried out in our laboratories taking the possible fine colortuning process of differently labeled and colored NCs into consideration. A potential target for the future will be pure white-light emission from composite materials.

#### **EXPERIMENTAL**

#### Instrumentation

<sup>1</sup>H NMR and <sup>13</sup>C NMR spectra were recorded in deuterated chloroform (CDCl<sub>3</sub>) with TMS as internal standard on a Bruker ARX 400 and 600 Fourier Transform nuclear resonance spectrometer. The chemical shift  $\delta$  is given in ppm. Infrared studies were conducted on a JASCO FT/IR-4200 Fourier-transform-spectrometer. Mass spectra were obtained using a Bruker micrOTOF instrument equipped with an electrospray ionization source (ESI-MS). For the electron impact ionization (EI) mass spectra, the device MAT 311A from Varian was utilized. GPC analysis of polymers 9 and 10 was carried out on a Jasco AS950 apparatus using Jasco UV-2070, Jasco RI-930, and Viscotek T60 as detectors (column MZSD of particle size 5  $\mu$ m, eluent chloroform). For the determination of the molecular weights, a calibration based on polystyrene standards was applied. For polymers 11 and 12, GPC analysis was performed by means of a Jasco AS2055 Plus apparatus using Jasco UV/VIS-2070/75 and Jasco RI-2031 as detectors (GRAM columns, DMF as eluent with ammonium hexafluorophosphate 5 mM as salt). For the determination of the molecular weights, a calibration based on poly (methyl methacrylate) standards was applied. The elemental analyses were performed by means of the Vario Elemental EL analyzer. Ultraviolet-visible measurements (UV-vis) were performed on a Jasco V-550 spectrophotometer (1-cm cuvettes, chloroform), while fluorescence spectroscopic measurements were done on a Cary Eclipse fluorescence spectrophotometer (1-cm cuvettes, chloroform). For the measurements in solution, concentrations of  $10^{-4}$  mol  $L^{-1}$  were utilized for compounds 2, 4-8, whereas monomer 3 and all polymers were measured in concentrations of  $10^{-6}$  mol L<sup>-1</sup>. The film measurements were performed with concentrations of 1 mg  $mL^{-1}$ for the polymers while the ET experiments by drop casting 1 mg mL $^{-1}$  polymer solutions mixed in a 1:1 ratio with THFdiluted CdTe NCs. Thermal gravimetric analysis (TGA) was performed under argon with a Mettler Toledo TGA/DSC 1 with a heating correspondingly cooling rate of 10 K min<sup>-1</sup>. TEM was performed on a Tecnai T20 microscope operating at 200 kV (FEI). The TEM specimens were prepared by dropping diluted NC solutions onto copper grids coated with a thin Formvar-carbon film with subsequent evaporation of the solvent. AFM was performed on a Q-Scope<sup>TM</sup> 250 (Quesant Instrument Corporation). A scan head was utilized of 1nm lateral resolution, 9-µm maximal vertical range, 0.1-nm vertical resolution, and a four-quadrant photodiode. In the case of composites, samples were prepared by mixing DMF solutions of the CdTe NCs (8 mg  $mL^{-1}$ ) with THF solutions of the polymers (1 mg mL<sup>-1</sup>) in a 1:1 (v/v) ratio and subsequently drop casted on glass substrates. Polymer solutions

of 0.5 mg mL<sup>-1</sup> concentration in THF and a CdTe DMF solution of 4 mg mL<sup>-1</sup> concentration were prepared and drop casted on glass as well. For the purification of the monomers by means of column chromatography, silica gel of particle size 50–200 mesh was used as the stationary phase.

#### Materials

All reactions were carried out under inert conditions (argon). 9-*H*-Fluorenone, methanesulfonic acid, 1-fluoro-4-nitrobenzene, tin(II) chloride, 2,2'-(9,9-dioctyl-9*H*-fluorene-2,7diyl)*bis*(1,3,2-dioxaborinane) were purchased from Aldrich, triphenylamine, 1,4-diiodobenzene, diphenylamine, copper(II) sulfate, and aniline hydrochloride from Acros, 3,6-dibromo-9*H*-carbazole, *tetrakis*(triphenylphosphine)palladium(0) from ABCR, [18]-crown-6 and copper(I) iodide from Alfa Aesar and aniline from Merck. All polymerizations were performed in extra dry toluene and freeze-pumped 2-M potassium carbonate solution according to literature known procedures.<sup>39</sup>

# Monomer Synthesis

### 2,7-Dibromo-9H-fluoren-9-one (2)

Compound **2** was obtained as a yellow solid (24.77 g, 76%) from 9*H*-fluoren-9-one (38.99 g, 17.40 mmol) by addition of bromine (2 mL, 38.99 mmol) in water using a literature precedure.<sup>54</sup> <sup>1</sup>H NMR (CDCl<sub>3</sub>):  $\delta$  = 7.40 (d, *J* = 7.9 Hz, 2H), 7.65 (dd, *J* = 7.9/1.8, 2H), 7.79 (d, *J* = 1.8, 2H). <sup>13</sup>C NMR (CDCl<sub>3</sub>):  $\delta$  = 190.8, 142.2, 137.4, 135.3, 127.8, 123.3, 121.8. IR (cm<sup>-1</sup>): 3407 (w, C=0, stretching), 3080 (w, C–H, stretching), 3055 (w, C–H, stretching), 1720 (s, C=0, stretching), 1051 (m, C–Br, stretching). GC-MS *m/z* Calcd. for C<sub>13</sub>H<sub>6</sub>Br<sub>2</sub>O 337.9; found 338. Anal. Calcd. for C<sub>13</sub>H<sub>6</sub>Br<sub>2</sub>O: C, 46.20; H, 1.79. Found: C, 46.42; H, 2.79. UV-vis:  $\lambda_{max}$  (lg  $\varepsilon$  [L mol<sup>-1</sup> cm<sup>-1</sup>]) 299 nm (2.59), 311 nm (2.50). Emission:  $\lambda_{max}$  387 and 399 nm.

# 4,4'-(2,7-Dibromo-9H-fluorene-9,9-diyl)dianiline (3)

Compound 3 (4.30 g, 70%) was prepared from 2,7-dibromo-9H-fluoren-9-one (4.2 g, 12.4 mmol), aniline hydrochloride (2 g, 15.3 mmol), and aniline (10 ml, 109 mmol) using a literature procedure.<sup>38</sup> The product was isolated after column chromatography (*n*-hexane/ethyl acetate 4:1) as a grey solid). <sup>1</sup>H NMR (CDCl<sub>3</sub>):  $\delta$  = 3.64 (s, 4H), 6.58 (d, J = 8.6 Hz, 4H), 6.96 (d, I = 8.6 Hz, 4H), 7.47 (dd, I = 8.1/1.8 Hz, 2H), 7.49 (d, I = 1.6 Hz, 2H), 7.57 (d, I = 8.1 Hz, 2H). <sup>13</sup>C NMR  $(CDCl_3): \delta = 154.1, 145.3, 137.8, 134.4, 130.5, 129.2, 128.9,$ 121.7, 121.4, 115.0, 64.4. IR (cm<sup>-1</sup>): 3457-3339 (w, N-H, stretching), 3030 (w, C-H, stretching), 1616 (s, N-C, deformation), 1049 (s, C-Br, skeleton). ESI-MS m/z Calcd for C<sub>25</sub>H<sub>18</sub>Br<sub>2</sub>N<sub>2</sub> 506.2; found 507. Anal. Calcd for C<sub>25</sub>H<sub>18</sub>Br<sub>2</sub>N<sub>2</sub>: C, 59.31; H, 3.58; N, 5.53. Found: C, 59.32; H, 3.53; N, 5.52. UV-vis:  $\lambda_{max}$  (lg  $\varepsilon$  [L mol<sup>-1</sup> cm<sup>-1</sup>]) 293 nm (6.20), 319 nm (6.18). Emission:  $\lambda_{\text{max}}$  335 nm.

# 4,4'-(2,7-Dibromo-9H-fluorene-9,9-diyl)bis(N,Ndiphenylaniline) (4)

Compound **4** (white solid, 4.8 g, 81%) was prepared from 2,7-dibromo-9*H*-fluoren-9-one (2.46 g, 7.28 mmol), triphenylamine (25 g, 102 mmol) and methane sulfonic acid (1.4 g, 14.56 mmol) following a literature procedure.<sup>39</sup> <sup>1</sup>H NMR (CDCl<sub>3</sub>):  $\delta$  = 6.95 (d, *J* = 8.8 Hz, 4H), 7.01–7.06 (m, 4H), 7.11 (dd, J = 8.4/0.8 Hz, 8H), 7.24–7.30 (m, 12H), 7.51 (dd, J = 8.1/1.7 Hz, 2H), 7.56 (d, J = 1.7 Hz, 2H), 7.60 (d, J = 8.1 Hz, 2H). <sup>13</sup>C NMR (CDCl<sub>3</sub>):  $\delta = 153.4$ , 147.5, 146.7, 137.9, 137.6, 130.8, 129.3, 129.2, 129.1, 128.6, 124.6, 124.4, 123.0, 122.9, 122.8, 122.7, 121.7, 121.5, 64.6. IR (cm<sup>-1</sup>): 3030 (w, C–H, stretching), 1270 (s, C–N, stretching). ESI-MS m/z Calcd. for C<sub>49</sub>H<sub>34</sub>Br<sub>2</sub>N<sub>2</sub> 810.1; found 810.6. Anal. Calcd. for C<sub>49</sub>H<sub>34</sub>Br<sub>2</sub>N<sub>2</sub>: C, 72.60; H, 4.23; N, 3.46. Found: C, 72.28; H, 3.95; N, 3.23. UV-vis:  $\lambda_{max}$  (lg  $\varepsilon$  [L mol<sup>-1</sup> cm<sup>-1</sup>]) 295 nm (3.19), 308 nm (3.23). Emission:  $\lambda_{max}$  388 nm, 399 nm.

# 3,6-Dibromo-9-(4-nitrophenyl)-9H-carbazole (5)

Compound **5** (yellow crystals, 4.3 g, 76%) was prepared from 3,6-dibromo-9*H*-carbazole (4.09 g, 12.6 mmol), potassium carbonate (8.71 g, 62.02 mmol) and 1-fluoro-4-nitrobenzene (7.11 g, 50.42 mmol) in DMF using literature procedures.<sup>40,41</sup> <sup>1</sup>H NMR (CDCl<sub>3</sub>):  $\delta$  = 7.33 (d, *J* = 8.7 Hz, 2H), 7.56 (d, *J* = 8.7 Hz, 2H), 7.74 (d, *J* = 8.6 Hz, 2H), 8.21 (s, 2H), 8.50 (d, *J* = 8.5 Hz, 2H). <sup>13</sup>C NMR (CDCl<sub>3</sub>):  $\delta$  = 146.4, 142.8, 138.9, 129.9, 126.8, 125.7, 124.7, 123.6, 114.3, 111.2. IR (cm<sup>-1</sup>): 1498 (s, N=O, asymmetric stretching), 1325 (s, N=O, symmetric stretching), 1054 (m, C—Br, skeleton). ESI-MS *m*/*z* Calcd for C<sub>18</sub>H<sub>10</sub>Br<sub>2</sub>N<sub>2</sub>O<sub>2</sub> 446.1; found 446. Anal. Calcd for C<sub>18</sub>H<sub>10</sub>Br<sub>2</sub>N<sub>2</sub>O<sub>2</sub>: C, 48.46; H, 2.26; N, 6.28. Found: C, 48.41; H, 1.46; N, 6.29. UV-vis:  $\lambda_{max}$  (Ig  $\varepsilon$  [L mol<sup>-1</sup> cm<sup>-1</sup>]) 374 nm (2.44). Emission:  $\lambda_{max}$  388 and 398 nm.

# 4-(3,6-Dibromo-9H-carbazol-9-yl)aniline (6)

Compound **6** (1.02 g, 87%) was prepared from 3,6-dibromo-9-(4-nitrophenyl)-9*H*-carbazole (1.25 g, 2.80 mmol) by addition of tin(II) chloride (3.16 g, 14.01 mmol) in ethanol according to literature procedures.<sup>40,41</sup> After recrystallization from toluene, white crystals were obtained. <sup>1</sup>H NMR (CDCl<sub>3</sub>):  $\delta = 6.88$  (d, J = 1.6 Hz, 2H), 7.17–7.29 (m, 4H), 7.50 (dd, J = 8.7/1.7 Hz, 2H), 8.20 (d, J = 1.6 Hz, 2H). <sup>13</sup>C NMR (CDCl<sub>3</sub>):  $\delta = 146.4$ , 140.4, 129.1, 128.3, 127.0, 123.5, 123.0, 115.9, 112.5, 111.5. IR (cm<sup>-1</sup>): 3443–3357 (m, N—H, stretching), 3048 (m, C—H, stretching), 1619 (s, C—N, deformation), 1271 (s, C—N, stretching), 1051 (m, C—Br, skeleton). ESI-MS m/z Calcd for C<sub>18</sub>H<sub>12</sub>Br<sub>2</sub>N<sub>2</sub> 416.1; found 416. Anal. Calcd. for C<sub>18</sub>H<sub>10</sub>Br<sub>2</sub>N<sub>2</sub>: C, 51.96; H, 2.91; N, 6.73. Found: C, 52; H, 2.55; N, 6.73. UV-vis:  $\lambda_{max}$  (Ig  $\varepsilon$  [L mol<sup>-1</sup> cm<sup>-1</sup>]) 346 nm (2.04), 358 nm (2.05). Emission:  $\lambda_{max}$  387 and 398 nm.

#### 4-Iodo-N,N-diphenylaniline (7)

Compound **7** was obtained as a white solid (2.2 g, 42%) from 1,4-diiodobenzene (8.8 g, 26 mmol), diphenylamine (2.4 g, 14.10 mmol), copper(II) sulfate (0.176 g, 0.705 mmol), and potassium carbonate (1.95 g, 14.1 mmol) using a literature-known procedure.<sup>55 1</sup>H NMR (CDCl<sub>3</sub>):  $\delta$  = 6.86 (d, *J* = 8.9 Hz, 2H), 7.07 (dd, *J* = 7.8/6.9, 2H), 7.11 (dd, *J* = 8.5/ 1.0 Hz, 4H), 7.29 (dd, *J* = 8.5/7.5 Hz, 4H), 7.53 (d, *J* = 8.9, 2H). <sup>13</sup>C NMR (CDCl<sub>3</sub>):  $\delta$  = 147.7, 147.2, 138.0, 129.3, 125.2, 124.5, 123.3, 84.7. IR (cm<sup>-1</sup>): 3059 (w, C—H, stretching), 3030 (w, C—H, stretching), 1583 (s, C=C, stretching), 1060 (s, C—I, skeleton). GC-MS *m*/*z* Calcd. for C<sub>18</sub>H<sub>14</sub>NI 371.21; found 371. Anal. Calcd. for C<sub>18</sub>H<sub>14</sub>NI: C, 58.24; H, 3.80; N, 3.77. Found: C, 58.67; H, 3.13; N, 3.81. UV-vis:  $\lambda_{max}$  (Ig  $\varepsilon$  [L mol<sup>-1</sup> cm<sup>-1</sup>]) 307 nm (2.72). Emission:  $\lambda_{max}$  387 and 398 nm.

4-(3,6-Dibromo-9H-carbazol-9-yl)-N,N-diphenylaniline (8) Compound 8 (0.402 g, 57%) was obtained from 4-iodo-N,Ndiphenylaniline (0.557 g, 1.50 mmol), 3,6-dibromo-9H-carbazole (0.4 g, 1.23 mmol), copper(I) iodide (0.05 g, 0.263 mmol), [18]-crown-6 (0.03 g, 0.114 mmol), and potassium carbonate (0.8 g, 5.80 mmol) in DMSO following a literature procedure.<sup>56</sup> Purification by column chromatography (petrol ether/ethyl acetate 15:1) gave a white solid as isolated product. <sup>1</sup>H NMR (CDCl<sub>3</sub>):  $\delta = 7.13$  (t, I = 7.4 Hz, 2H), 7.23–7.27 (m, 14H), 7.53 (dd, J = 6.7/2.0 Hz, 2H), 8.21 (d, J = 1.8 Hz, 2H).  $^{13}\mathrm{C}$  NMR (CDCl\_3):  $\delta =$  147.7, 147.3, 140.1, 130.0, 129.5, 127.6, 125.0, 123.8, 123.7, 123.5, 123.1, 112.8, 111.6. IR (cm<sup>-1</sup>): 3055 (w, C–H, stretching), 3038 (w, C–H, stretching), 1585 (s, C=C, stretching), 1054 (s, C-Br, skeleton). ESI-MS *m/z* Calcd. for C<sub>30</sub>H<sub>20</sub>Br<sub>2</sub>N<sub>2</sub> 568.3; found 568. Anal. Calcd. for C<sub>30</sub>H<sub>20</sub>Br<sub>2</sub>N<sub>2</sub>: C, 63.40; H, 3.55; N, 4.93. Found: C, 63.21; H, 3.38; N, 4.87. UV-vis:  $\lambda_{max}$  (lg  $\varepsilon$  [L mol<sup>-1</sup> cm<sup>-1</sup>]) 305nm (3.00). Emission:  $\lambda_{max}$  387 and 399 nm.

#### Synthesis of the Copolymers—General Procedure

Comonomers **3** or **4** (see Scheme 1), **6** or **8** (see Scheme 1) were added together with 2,2'-(9,9-dioctyl-9*H*-fluorene-2,7-diyl)*bis*(1,3,2-dioxaborinane) (**1**) and Pd(0)(PPh<sub>3</sub>)<sub>4</sub> in a Schlenk tube. Subsequently, freeze-pump degassed toluene (3 mL) and Na<sub>2</sub>CO<sub>3</sub> solution (1 mL) were added, and the reaction system was allowed to stir for 3 days at 120 °C. After cooling down to room temperature, the reaction solution was extracted with chloroform and washed with saturated NaEDTA solution (1  $\times$  50 mL), brine (1  $\times$  100 mL), and water (1  $\times$  50 mL). The organic phase was dried over MgSO<sub>4</sub> and the solvent was removed by reduced pressure. The residue was dissolved in chloroform (1–2 mL), precipitated in methanol-THF-ethyl acetate mixtures, or into acetone (400 mL), and the polymers further purified by Soxhlet extraction using *iso*propanol or chloroform as a solvent.

#### Polymer 9

Compound 3 (0.0254 g, 0.5 mmol), 1 (0.28 g, 0.5 mmol),  $Pd(0)(PPh_3)_4$  (0.05 g, 0.043 mmol). Polymer 9 was precipitated into methanol, Soxhlet extracted with isopropanol and chloroform, while the chloroform fraction was precipitated from a 1:1 (v:v) methanol/ethyl acetate and 3:1 (v:v) methanol/THF mixture yielding a yellow solid (99 mg, 30%). <sup>1</sup>H NMR (CDCl<sub>3</sub>):  $\delta = 0.78$  (b, 6H), 0.9–1.3 (b, 20H.), 1.99 (b, 4H), 3.62 (s, NH<sub>2</sub>, 4H), 6.58 (m, 8H), 7-7.9 (m, 12H). IR  $(cm^{-1})$ : 2919 (s, CH<sub>2</sub>, stretching), 2847 (m, CH<sub>2</sub>, stretching), 1616 (m, C=C, stretching), 1511 (s, =CH, stretching), 1461 (m, C-H, deformation), 1278 (m, C-C, skeletal vibration), 1185 (m, C-N, stretching), 815 (s, =C-H, out-of-plane deformation). GPC (g mol<sup>-1</sup>):  $M_{\rm n} = 5660$ ,  $M_{\rm w} = 17300$ , PDI 3.06. Anal Calcd. for  $(C_{56}H_{64}N_2)_x$ : C, 87.91; H, 8.43; N, 3.66. Found: C, 87.99; H, 8.74; N, 3.35. TGA: T<sub>d5%</sub>: 420 °C. UV-vis:  $\lambda_{\rm max}$  (lg  $\varepsilon$  [L mol<sup>-1</sup> cm<sup>-1</sup>]) 385 nm (6.28). Emission:  $\lambda_{\rm max}$ 418 nm.

#### Polymer 10

Compound **4** (0.406 g, 0.5 mmol), **1** (0.28 g, 0.5 mmol), Pd(0)(PPh<sub>3</sub>)<sub>4</sub> (0.05 g, 0.043 mmol). Polymer **10** was precipitated from methanol, Soxhlet extracted with *iso*propanol-

chloroform mixture, whereas the chloroform fraction was once more precipitated from acetone. A yellow solid was obtained (171 mg, 33%). <sup>1</sup>H NMR (CDCl<sub>3</sub>):  $\delta = 0.9$  (b, 6H), 1.02–1.30 (m, 16H), 1.96 (b, 4H.), 2.06 (b, 4H), 6.93–7.27 (m, 28H), 7.50–7.95 (m, 12H). IR (cm<sup>-1</sup>): 2919 (m, CH<sub>2</sub>, stretching), 2847 (w, CH<sub>2</sub>, stretching), 1587 (m, C=C, stretching), 1490 (s, =CH, stretching), 1447 (m, C—H, deformation), 1271 (s, =CH, in-plane deformation), 1178 (w, C—N, stretching), 1024 (w, =C—H, in-plane deformation), 808 (s, =C—H, out-of-plane deformation), 747 (m, C—C, skeleton). GPC (g mol<sup>-1</sup>):  $M_n = 5520$ ,  $M_w = 12900$ , PDI 2.47. Anal. Calcd. for (C<sub>80</sub>H<sub>80</sub>N<sub>2</sub>)<sub>x</sub>: C, 89.84; H, 7.54; N, 2.62. Found: C, 88.92; H, 6.84; N, 2.55. TGA:  $T_{d5\%}$ : 440 °C. DSC:  $T_{g}$ : 150 °C. UV–vis:  $\lambda_{max}$  (Ig  $\varepsilon$  [L mol<sup>-1</sup> cm<sup>-1</sup>]) 381 nm (6.34). Emission:  $\lambda_{max}$  416 nm.

#### Polymer 11

Compound 6 (0.209 g, 0.5 mmol), 1 (0.28 g, 0.5 mmol), Pd(0)(PPh<sub>3</sub>)<sub>4</sub> (0.05 g, 0.043 mmol). Polymer **11** was precipitated from methanol, Soxhlet extracted with isopropanolchloroform mixture, whereas the chloroform fraction was once more precipitated from a 1:1 (v:v) methanol/ethyl acetate and a 3:1 (v:v) methanol/THF mixture. A yellow solid was obtained (109 mg, 34%). <sup>1</sup>H NMR (CDCl<sub>3</sub>):  $\delta = 0.8$  (b, 6H), 1.0-1.30 (m, 24H), 2.12 (b, 4H), 3.94 (dist. s, 2H), 6.95 (s, 4H), 7.3-7.9 (m, 10H), 8.55 (m, 2H). IR (cm<sup>-1</sup>): 2969 (w, CH<sub>2</sub>, stretching), 2922 (m, CH<sub>2</sub>, stretching), 2855 (w, CH<sub>2</sub>, stretching), 2359 (s, N-H, stretching), 1619 (m, C=C, stretching), 1511 (s, =CH, stretching), 1454 (s, C-H, deformation), 1274 (m, C-C, skeletal), 1174 (m, C-N, stretching), 1131 (w, =CH, in-plane deformation), 955 (w, =C-H, in-plane-deformation), 801 (s, =C-H, out-of-plane deformation). GPC (g mol<sup>-1</sup>):  $M_{\rm n} = 2890$ ,  $M_{\rm w} = 5340$ , PDI 1.85. Anal. Calcd for (C<sub>47</sub>H<sub>52</sub>N<sub>2</sub>)<sub>x</sub>: C, 87.26; H, 8.41; N, 4.33. Found: C, 85.44; H, 6.98; N, 3.87. TGA:  $T_{d5\%}$ : 420 °C. DSC:  $T_{g}$ : 152 °C. UV-vis:  $\lambda_{max}$  (lg  $\varepsilon$  [L mol<sup>-1</sup> cm<sup>-1</sup>]) 343 nm (6.68). Emission:  $\lambda_{max}$  401 nm.

# Polymer 12

Compound 8 (0.285 g, 0.5 mmol), 1 (0.28 g, 0.5 mmol), Pd(0)(PPh<sub>3</sub>)<sub>4</sub> (0.05 g, 0.043 mmol). Polymer 12 was precipitated from methanol, Soxhlet extracted with isopropanolchloroform mixture, whereas the chloroform fraction was once more precipitated from acetone. A yellow solid was obtained (143 mg, 36%). <sup>1</sup>H NMR (CDCl<sub>3</sub>):  $\delta = 0.8$  (b, 6H), 1.0-1.50 (m, 24H), 2.16 (b, 4H), 7.31-7.90 (m, 24H), 8.55 (m, 2H). IR (cm<sup>-1</sup>): 2980 (m, CH<sub>2</sub>, stretching), 2915 (m, CH<sub>2</sub>, stretching), 2359 (m, C=NH+, stretching), 1587 (m, C=C, stretching), 1501 (s, =CH, stretching), 1457 (m, C-H, deformation), 1274 (m, C–C, skeletal), 1178 (m, C–N, stretching), 808 (s, =C-H, out-of-plane deformation). GPC (g mol<sup>-1</sup>):  $M_n$ = 2920,  $M_{\rm w}$  = 5290, PDI 1.81. Anal. Calcd for  $(C_{59}H_{60}N_2)_{\rm x}$ : C, 88.67; H, 7.82; N, 3.51. Found: C, 85.60; H, 4.47; N, 3.09. TGA:  $T_{\rm d5\%}$ : 420 °C. DSC:  $T_{\rm g}$ : 128 °C. UV-vis:  $\lambda_{\rm max}$  (lg  $\varepsilon$  [L  $mol^{-1} cm^{-1}$ ]) 341 nm (6.10). Emission:  $\lambda_{max}$  404 nm.

### Synthesis of CdTe/HS-C<sub>6</sub>H<sub>4</sub>-Br NCs

A colloidal solution of 4-bromthiophenol ( $HS-C_6H_4-Br$ )capped CdTe NCs was prepared using the approach reported in ref. 57. Briefly, 0.53 g (2.3 mmol) of Cd(OOCH<sub>3</sub>)<sub>2</sub> and 0.57 g (3 mmol) of 4-bromthiophenol were dissolved in 120 mL of DMF. This solution was deaerated by bubbling with Ar for 30 min. Under stirring, H<sub>2</sub>Te gas, generated by the reaction of 0.67 g (1.5 mmol) of Al<sub>2</sub>Te<sub>3</sub> with an excess of 0.5 M H<sub>2</sub>SO<sub>4</sub> solution, was injected into the reaction mixture with a slow argon flow. The molar ratio of Cd<sup>2+</sup>/Te<sup>2-</sup>/HS-C<sub>6</sub>H<sub>4</sub>-Br was 1/2/1.3. Formation and growth of the NCs proceeded on reflux under open-air conditions. Colloidal fractions A–E containing NCs of different sizes emitting green (2.1 nm) to orange (2.9 nm) were taken during the reaction after 20 min, 1, 2, 4, and 6 h of reflux, respectively.

The colloids obtained were purified by reprecipitation.<sup>58</sup> After removal of ~90% of the solvent with a rotor evaporator, the nanoparticles were precipitated by addition of an excess of methanol. The precipitates were separated by centrifugation and dissolved in DMF, yielding nanocrystal concentrations varying from  $1 \times 10^{-3}$  to  $7.3 \times 10^{-4}$  M. Optical properties of CdTe/HS-C<sub>6</sub>H<sub>4</sub>-Br NCs are shown in Figure 2(b). The UV-vis absorption spectra were recorded using a Cary 50 spectrophotometer (Varian, Palo Alto, CA). Fluorescence spectra were acquired with a FluoroMax-4 spectrofluorometer (HORIBA Jobin Yvon, Edison, NJ).

# Preparation of White-Light-Emitting Composites (Solutions and Films)

The solutions for the achievement of white light were prepared by combining yellow-emitting NCs with blue-emitting polymers and fine tuning the color by addition of orange-emitting NCs and green-yellow ones. In general, a 2.5–2.8 ratio of yellow (CdTe B) to orange (CdTe E) NCs was used. Films were prepared by drop casting the nanocrystal and polymer containing DMF solutions on glass. For this purpose, CdTe B NCs were used in a concentration of  $1.08 \times 10^{-4}$  M, CdTe E in a concentration of  $2.4 \times 10^{-5}$  M and polymers **9**–**12** in a 1 mg mL<sup>-1</sup> concentration.

#### **CONCLUSIONS**

We prepared two fluorene-based and two carbazole-based copolymers using a Suzuki protocol. The copolymers were comprised of 4,4'-(2,7-dibromo-9*H*-fluorene-9,9-diyl)dianiline, 4,4'-(2,7-dibromo-9*H*-fluorene-9,9-diyl)*bis*(*N*,*N*-diphenylaniline), 4-(3,6-dibromo-9*H*-carbazol-9-yl)aniline, and 4-(3,6-dibromo-9*H*-carbazol-9-yl)aniline each copolymerized with 2,2'-(9,9-dioctyl-9*H*-fluorene-2,7-diyl)*bis*(1,3,2-dioxaborinane). The four alternating copolymers revealed wide bandgaps of at least 2.93 eV in chloroform solutions and proved themselves as excellent host materials for CdTe NCs in thin films enabling approving and facile color-tuning over a wide range even to favorable white-light emission within these organic-inorganic composites.

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