INDUCING CHIRALITY IN CONJUGATED POLYMERS

by

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ABSTRACT

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This study demonstrates the successful induction and tuning of chirality in achiral conjugated polymers—poly(9,9-dioctylfluorene-alt-benzothiadiazole) (F8BT) and poly(9,9-dioctylfluorene) (PFO) via molecular doping with enantiomeric dopants (R/S)-1,1-Bi-2-naphthol (BINOL) and (R/S)-1,1-Binaphthyl-2,2-diamine (BN). Polymer–dopant blends were prepared in chlorobenzene, spin-coated onto ITO substrates, and characterized using circular dichroism (CD) spectroscopy, with thermal annealing (180 °C, 10 min) applied to enhance molecular ordering. Results reveal dopant-specific efficacy: BINOL optimally induces chirality in F8BT (post-annealing CD peaks 200 mdeg), while BN excels with PFO (peaks up to –550 mdeg for S-BN). In PFO:F8BT blends, chirality is composition-tunable, with the 50:50 ratio yielding the strongest CD signals (±60 mdeg with BINOL), reflecting cooperative intermolecular interactions.

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Chapter 1

Introduction to Conjugated Polymers and Chirality

1.1 Background on Conjugated Polymers

Conjugated polymers are a class of organic materials that are characterized by alternating single and double bonds along their backbone. This repeating π-conjugated structure enables delocalization of π-electrons over multiple adjacent atoms, producing a quasi-one-dimensional electronic system. This delocalization lowers the bandgap and allows charge carriers to move through the polymer chain more freely than in conventional organic materials. The extent of this delocalization and its disruption by structural disorder, defects, or side-chain engineering are central factors that determine the electrical and optical properties of conjugated polymers.

Although the terms conjugated polymer and conducting polymer are often used interchangeably, they are not strictly synonymous. As noted by (Rasmussen, 2023) [2], neutral conjugated polymers are typically semiconducting, exhibiting moderate conductivities in the range of 10^{-9} to 10^{-4} S cm^{-1}, and in some cases behaving as insulators. Their conductivity can be dramatically enhanced through oxidation or reduction processes that introduce mobile charge carriers along the π-conjugated backbone. This process, often termed redox doping, includes oxidative (p-type) and reductive (n-type) doping, which add holes or electrons, respectively.

Over the past decade, the scope of conjugated-polymer-based charge transport has broadened with the rise of organic mixed ionic-electronic conductors (OMIECs). [3] Unlike conventional conducting polymers that primarily transport electrons or holes along the π-conjugated backbone, OMIECs are designed to conduct both electronic charges and ions simultaneously. This dual transport is made possible by hydrophilic side chains that allow electrolyte ions to penetrate the film, swell the polymer matrix, and modulate the electronic conductivity through reversible electrochemical doping/dedoping.

The most successful device platform exploiting this mixed conduction is the organic electrochemical transistor (OECT), in which an OMIEC serves as the channel material. By applying a small gate voltage through an aqueous electrolyte, ions enter or leave the OMIEC film, dramatically changing its conductivity and thereby amplifying tiny biological signals into measurable electrical currents. [3] This unique transduction mechanism has enabled OECTs to function as highly sensitive biosensors (e.g., for glucose, lactate, or neurotransmitters), neural recording/stimulation interfaces, and even neuromorphic circuits that mimic synaptic behavior.

A typical polythiophene, poly(3-[2-(2-methoxyethoxy)ethoxy]-ethoxymethylthiophene-2,5-diyl) (P3MEEMT), remains benchmark p-type OMIECs because of their high capacitance, excellent stability in water, and biocompatibility [3]. The ability to tune both electronic mobility and ionic uptake through side-chain chemistry and backbone design is currently driving the development of next-generation OMIECs for wearable and implantable bioelectronics. [3]

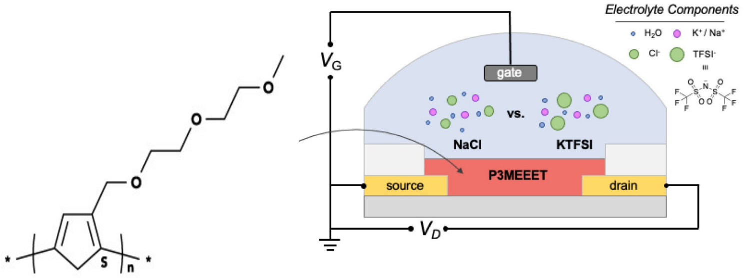

Figure 1.1 Polymer structure of P3MEET and usage in transitor.

Introducing molecular chirality into OMIECs either via chiral side chains or chiral dopants represents an underexplored opportunity to add spin or polarization selective transport on top of the existing mixed-conduction properties. The work presented in this thesis investigates whether the co-crystallization-mediated chirality-transfer strategies recently demonstrated in polyfluorene systems can be extended to create the first examples of chiral OMIECs, potentially opening new avenues in enantioselective biosensing and spin-polarized bioelectronic interfaces.

1.2 Importance of Inducing Chirality

Chirality refers to the property of a molecule that makes it non-superimposable on its mirror image, much like a left hand cannot perfectly overlap a right hand. Inducing chirality in conjugated polymers introduces a form of control over their optical, electronic, and structural properties. While conventional conjugated polymers are typically achiral, introducing helical or chiral order enables these materials to interact selectively with circularly polarized light. This selective interaction underlies phenomena such as circular dichroism and circularly polarized luminescence (CPL), allowing the emission or detection of light with a specific handedness. Such a control over optical activity is important for the development of next-generation photonic and display technologies, as well as miniaturized circularly polarized light detectors that eliminate the need for complex optical components.

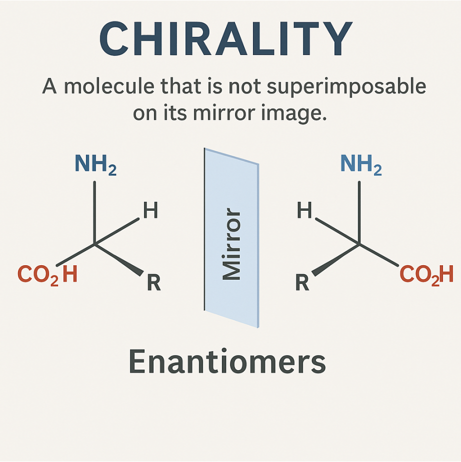

Figure 1.2 Simplified visualization of chirality generated using ChatGPT (OpenAI GPT-5).

Beyond optics, chirality in conjugated polymers has profound implications for charge and spin transport. The helical arrangement of π-conjugated backbones can give rise to the chirality-induced spin selectivity (CISS) effect, where electrons of one spin orientation are preferentially transmitted through the chiral medium. This spin filtering capability enables the manipulation of spin-polarized currents without the use of magnetic materials, offering a new route toward spintronic and quantum devices. The enhanced molecular order often associated with chiral packing can improve doping efficiency and charge mobility, leading to materials that exhibit better conductivity and stability compared to their achiral counterparts.

Chirality also plays a central role in controlling self-assembly and interactions with biological systems. By tuning the handedness and helical pitch of conjugated polymers, researchers can guide nanoscale organization and design materials with tailored functions. This structural control opens opportunities for chiral catalysis, enantioselective sensing, and bioelectronic interfaces capable of distinguishing between enantiomers of biomolecules. Since most biological systems are inherently chiral, the ability to engineer chiral conjugated polymers enables selective communication with living tissue, making them highly promising for biosensing and therapeutic applications.

1.3 Prior Studies in Chirality Transfer

Recent work has demonstrated a method for inducing chiroptical properties in achiral π-conjugated polymers through simple solution blending with a chiral small-molecule inducer, namely (R/S)-1,1′-binaphthyl-2,2′-diamine (BN). Lee and co-workers showed that when poly(3-hexylthiophene) (P3HT) or a range of other π-conjugated polymers are processed from aromatic solvents in the presence of BN, the small molecule co-crystallizes within the polymer, giving rise to intense circular dichroism and circularly polarized photoluminescence signals at the main π-π^* absorption band of the polymer. [1] The chirality transfer was attributed to asymmetrically misaligned transition dipoles along the polymer backbone induced by the incorporated chiral BN units.

Given that poly(9,9-dioctylfluorene) (PFO) and poly(9,9-dioctylfluorene-alt-benzothiadiazole) (F8BT) are also π-conjugated polymers that readily form semi-crystalline or liquid-crystalline thin films, much like P3HT, and exhibit extended π-conjugation with strong absorption and emission in the visible region, we hypothesized that the same co-crystallization-mediated chirality-transfer method could be applied to these materials.

The work presented in this thesis therefore investigates whether blending PFO and F8BT with chiral small-molecule additives (in particular, derivatives of (R/S)-1,1′-bi-2-naphthol and (R/S)-1,1′-binaphthyl-2,2′-diamine) can induce comparable chiroptical responses.

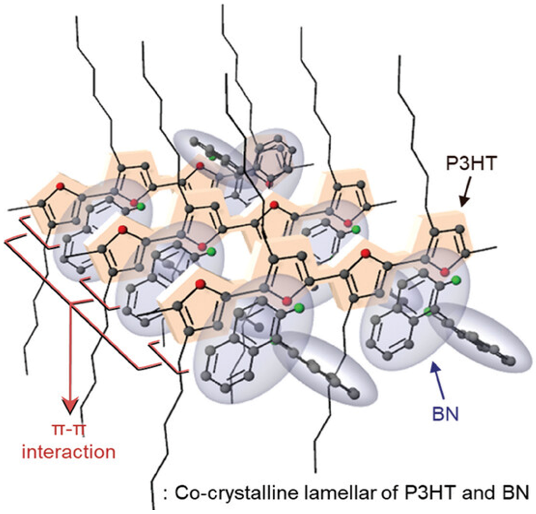

Figure 1.3 Representation of the co-crystallization chirality transfer mechanism in P3HT/BN hybrid films. Reproduced from Lee et al., [1]

Beyond polythiophene-based systems, chirality induction has also been explored in polyfluorene derivatives, most notably in poly(9,9-dioctylfluorene-*alt*-benzothiadiazole) (F8BT). Zhang and co-workers demonstrated that blending achiral F8BT with low loadings (∼10 %) of blue-emitting chiral binaphthyl-pyrene derivatives (R/S-3) yields solution-processed circularly polarized organic light-emitting diodes (CP-OLEDs) with exceptionally high brightness (>20,000 $\mathrm{cd\,m^{-2}}$), low turn-on voltages (∼4 V), and respectable dissymmetry factors in electroluminescence. [4] These results established F8BT as one of the most promising host polymers for dopant-induced circularly polarized emission owing to its excellent film-forming properties and high photoluminescence quantum yield.

However, the physical origin of large chiroptical signals in thin films of achiral π-conjugated polymers has been debated. Early reports frequently attributed intense circular dichroism (CD) and circularly polarized luminescence (CPL) to supramolecular helical arrangements of the polymer chains. In a 2020 study, Wade, Fuchter, and co-workers conclusively showed, using a combination of magneto-optical measurements, Mueller matrix polarimetry, and structural probes,that the dominant contribution in many annealed polymer/chiral-additive films arise instead from "natural optical activity" or magneto-electric coupling rather than true structural chirality of the π-conjugated backbone. [5] This paradigm-shifting conclusion, later reinforced by reviews of thin-film chiroptical spectroscopies, [6] highlighted the critical importance of distinguishing intrinsic molecular chirality from apparent chiroptical artifacts caused by long-range orientational order in solid-state films.

1.4 Objectives

The primary objective of this project was to explore the induction of chirality in conjugated polymers using molecular dopants of defined handedness. While conjugated polymers such as poly(9,9-dioctylfluorene-alt-benzothiadiazole) (F8BT) [7] and poly(9,9-dioctylfluorene) (PFO) are intrinsically achiral, previous studies have shown that chiral dopants can influence their supramolecular organization and electronic structure [8]. By introducing dopants, it is possible to transfer chirality from small molecules to the polymer matrix, potentially leading to materials that exhibit circular dichroism peaks, circularly polarized luminescence, or spin-selective charge transport. Investigating this process provides insight into how chiral information can be communicated at the molecular and electronic levels in π-conjugated systems.

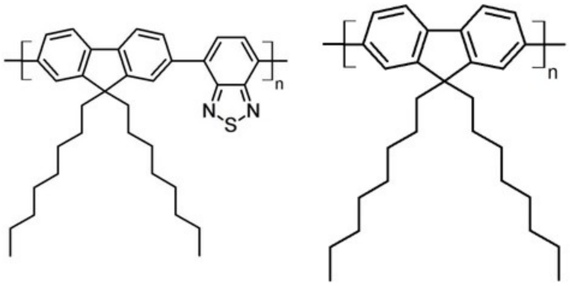

Figure 1.4 Polymer structures of F8BT (left) and PFO (right).

In this work, the approach centered on doping F8BT and PFO with two sets of right and left, (R/S), chiral dopants: 1,1′-bi-2-naphthol (BINOL), and 1,1′-binaphthyl-2,2′-diamine (BN). Each dopant represents a distinct molecular architecture and electronic character, allowing a comparative study of how molecular structure affects chirality induction in polymer films. The experimental methods included preparing polymer-dopant blends, forming thin films, and analyzing their optical and electronic responses by using circular dichroism spectroscopy. Through systematic variation of the dopant type, the goal was to determine the extent to which each chiral molecule could impose optical activity on the host polymer.

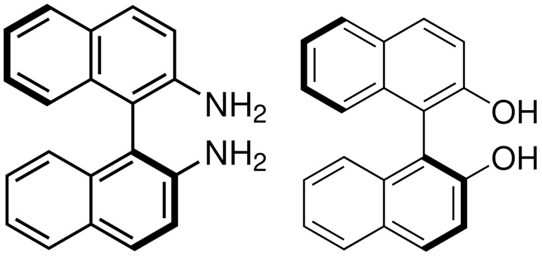

Figure 1.5 Dopant structures of BN (left) and BINOL (right).

Ultimately, this study aimed to assess whether chirality could be induced and tuned in these model conjugated polymers, and to identify the structural factors that promote efficient chiral transfer. Demonstrating such control would contribute to a deeper understanding of the relationship between molecular chirality, electronic delocalization, and macroscopic optical activity. In the broader context, the findings could help inform the design of next-generation organic mixed ionic electronic conductors (OMIECs) and optoelectronic devices that use chiral functionality for improved performance in sensing, display, and spintronic applications.

Chapter 2

Experimental Methods for Preparation and Doping of Conjugated Polymer Films

This chapter will detail the experimental procedures developed to prepare thin films of the achiral π-conjugated polymers poly(9,9-dioctylfluorene) (PFO) and poly(9,9-dioctylfluorene-*alt*-benzothiadiazole) (F8BT), both in their undoped state and when blended with the chiral small-molecule dopants (R/S)-1,1′-bi-2-naphthol (BINOL) and (R/S)-1,1′-binaphthyl-2,2′-diamine (BN). The primary goal was to induce and detect chiroptical responses in these polymers, following strategies recently established for other conjugated systems. [1, 4] All films were prepared by spin-coating from chlorobenzene solutions onto rigorously cleaned indium tin oxide (ITO)-coated glass substrates under controlled conditions.

2.1 Substrate Preparation and Cleaning

The polymer films were deposited onto indium tin oxide (ITO)-coated glass substrates. The ITO glass was first cut into slides approximately 5 mm × .7 mm in size. The slides were placed in a custom 3D-printed sample holder to ensure consistent handling during cleaning. The cleaning process ensures the removal of organic and particulate contaminants that may interfere with film uniformity or adhesion.

The cleaning procedure began with sonication of the substrates in a 1% Alconox detergent solution for 10 minutes. The holder containing the slides was then sequentially sonicated in beakers of distilled water, isopropyl alcohol (IPA), and acetone, each for 10 minutes. After each step, the cleaning solution was replaced to minimize cross-contamination. This sequence effectively removes residues from both the glass surface and the conductive ITO layer, producing a smooth surface suitable for polymer film deposition.

After the final rinse, the slides were dried under a stream of nitrogen gas and stored in a clean container prior to use. Proper substrate cleaning is important to ensure reproducible film quality and to prevent unwanted effects during spin coating or electrical characterization (which in this case will be Circular Dichroism Spectroscopy). All cleaning steps were performed using nitrile gloves and clean tools to maintain surface integrity.

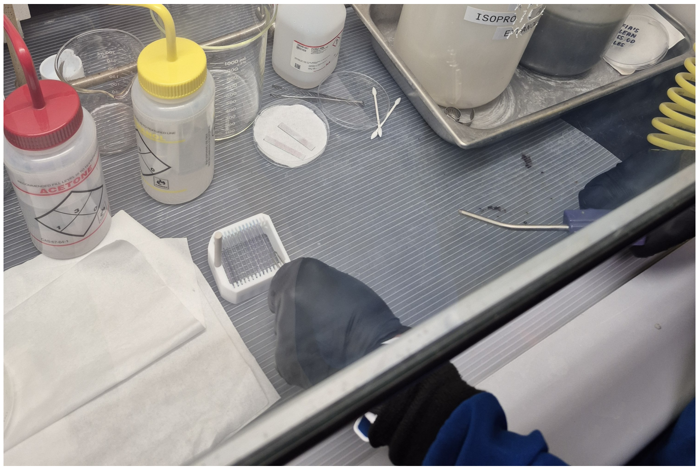

Figure 2.1 Drying the cleaned glass slides with the Nitrogen hose.

2.2 Polymer Solution Preparation

All polymer solution preparations were conducted inside a nitrogen-filled glovebox to avoid oxygen and moisture contamination. The polymers used in this study were poly(9,9-dioctylfluorene-alt-benzothiadiazole) (F8BT) and poly(9,9-dioctylfluorene) (PFO). Prior to handling solvents, the glovebox circulation was turned off to prevent solvent vapor from spreading. Approximately 3.6 mg of polymer was weighed using a microbalance and transferred into a clean amber vial.

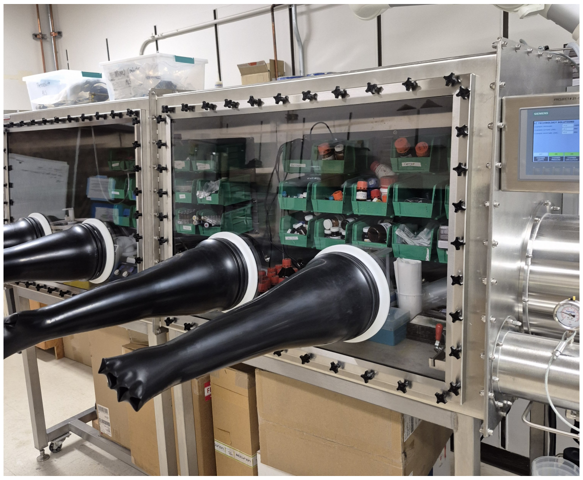

Figure 2.2 Nitrogen filled Glovebox environment

Chlorobenzene was used as the solvent to prepare polymer solutions with a concentration of 20 mg/mL. Since the amber vials could hold a maximum of 4 mL, the chosen polymer mass ensured that the total volume did not exceed the vial capacity. Once the solvent was added, the vials were sealed and placed on a magnetic hot plate within the glovebox overnight to ensure complete dissolution of the polymer. The resulting homogeneous solutions were used as the undoped stock for subsequent doping experiments.

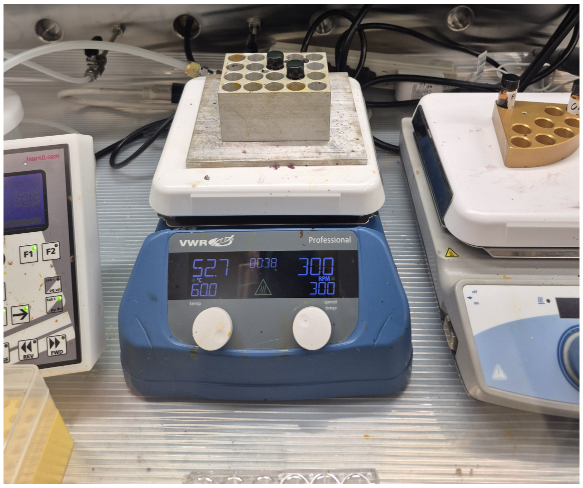

Figure 2.3 Polymers left on hot plate for overnight stirring

Throughout the process, care was taken to prevent exposure of the polymer solutions to air or light, as both can induce degradation or affect the optical properties of the conjugated backbones. The solutions were stored in sealed amber vials until ready for use in the doping and film deposition steps.

2.3 Doping and Film Deposition

The doping of the conjugated polymers was carried out using the chiral dopants 1,1′-Bi-2-naphthol (R/S-BINOL) and 1,1′-Binaphthyl-2,2′-diamine (R/S-BN). Inside a ventilated fume hood, 0.5 mL of the prepared polymer solution was transferred into a new amber vial using a micropipette. The appropriate chiral dopant (R or S form) was weighed to achieve a concentration of 10 mg/mL in the final mixture. Approximately 5 mg of dopant was measured using a microbalance and added to the vial containing the polymer solution. The mixtures were then placed on a hot plate to promote full incorporation of the dopant molecules into the polymer sample.

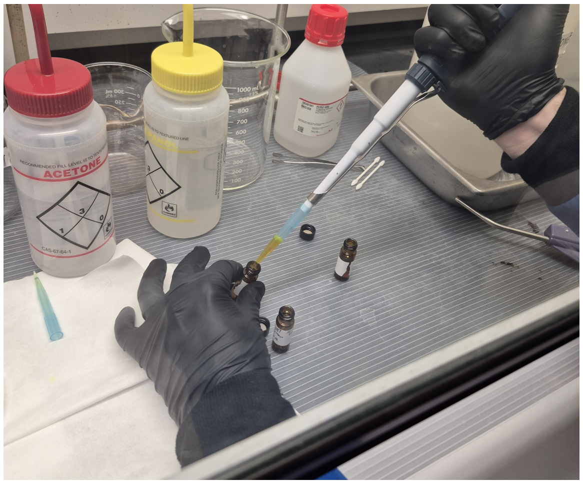

Figure 2.4 Polymers deposited into separate amber vials for chiral doping

Film deposition was performed using an automated spin-coating robot (SCAR). Prior to deposition, the cleaned ITO substrates were positioned on the designated "No Lead" sample holders to prevent cross-contamination from perovskite materials. The robot's control software was configured using an Excel-based interface to specify parameters such as spin speed (1000 rpm) and time. The annealing step was disabled in the program since the polymers required a higher temperature than the SCAR could safely reach. After verifying that the spin-coater brakes were operating correctly, the lid was closed and the automated spin-coating process was initiated to ensure uniform film thickness and reproducibility.

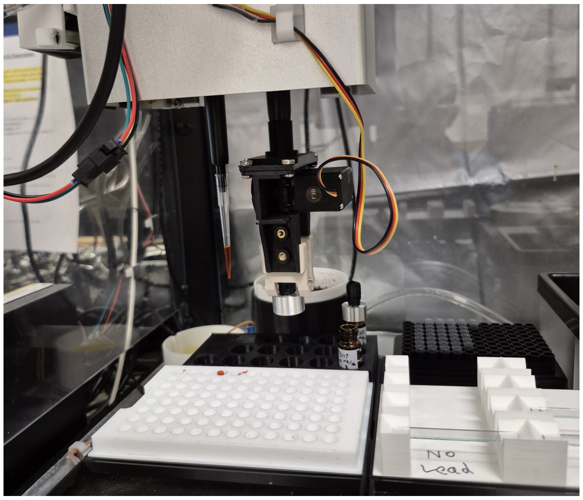

Figure 2.5 Spin Coating Automation Robot (SCAR), depositing and spin coating the polymers onto glass substrates

Following deposition, each sample was divided into two sets: one non-annealed and one annealed. Thermal annealing was carried out on a hot plate at 180°C for 10 minutes with the film side facing up. This step promotes improved molecular ordering and solvent removal. After annealing, the samples were cooled to room temperature and stored in a dark, dry environment prior to optical and electronic characterization.

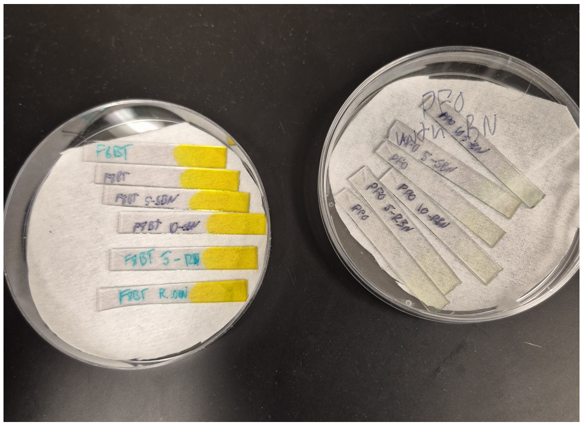

Figure 2.6 Finished Spin-coated Polymer samples

2.4 Characterization Techniques

The primary characterization technique used was Circular Dichroism (CD) spectroscopy [9]. CD spectroscopy utilizes circularly polarized light to probe the chiral properties of materials. By using left and right circularly polarized light through the sample at varying wavelengths, the differential absorption is measured, resulting in a CD spectrum. This spectrum is plotted with wavelength on the x-axis and the CD signal in millidegrees on the y-axis. A significant enhancement in the CD signal, typically exceeding 20-35 millidegrees compared to non-annealed samples, indicates the successful induction of chirality in the polymer. This method is particularly sensitive to the structural asymmetries introduced by chiral dopants, allowing for the classification of induced chirality in conjugated polymers.

Figure 2.7 Polymer sample in Circular Dichroism spectrometer for CD Spec testing

In addition to CD spectroscopy, Fourier Transform Infrared (FTIR) spectroscopy was used to analyze the molecular composition and interactions within the doped polymers. FTIR measures the absorption of infrared light by the sample, which is related to the vibration's molecular bonds [10]. By comparing the FTIR spectra of pure dopants, undoped polymers, and doped blends, we can identify characteristic peaks that confirm the presence and interaction of the dopant with the polymer matrix. Superimposed spectra that align with expected combinations suggest successful doping without unintended chemical reactions. This technique provides complementary information to CD by verifying the chemical integrity of the samples.

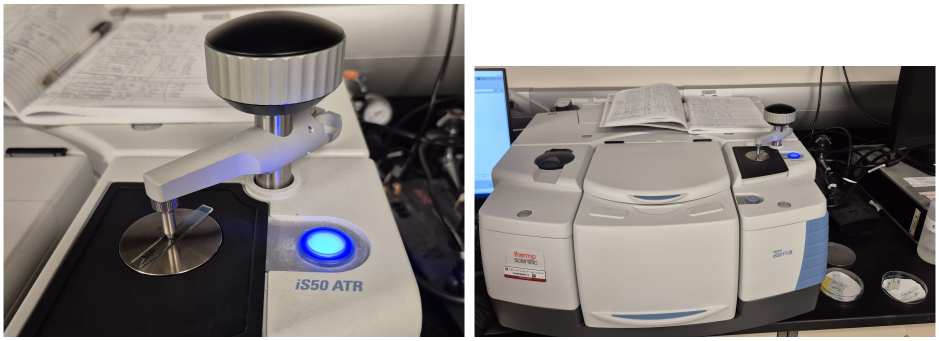

Figure 2.8 Sample on FTIR Spectrometer

Sample preparation played a crucial role in ensuring reliable characterization results. Polymers and dopants were dissolved in appropriate solvents, chlorobenzene, at controlled concentrations before being spin-coated onto Indium Tin Oxide, (ITO), glass substrates for CD measurements and FTIR analysis. Annealing processes were applied to enhance molecular ordering and chirality induction. These steps were used across experiments to minimize variability and ensure comparability of results from different doping conditions and blend ratios.

Chapter 3

Results

3.1 Annealing Effects and Optimal Dopants in Pure Polymers

To establish a baseline for chirality induction prior to blend studies, initial tests were conducted on pure F8BT and PFO polymers doped with either (R)- or (S)-Binol or BN. Samples were measured both before and after thermal annealing, revealing that annealing significantly enhances chiral signatures in most cases, likely by promoting better dopant–polymer interactions and helical ordering.

F8BT with Binol. Non-annealed samples exhibited no detectable CD signal. Upon annealing, strong mirror-image responses emerged, with S-Binol reaching a peak of approximately 200 mdeg and R-Binol approximately -200 mdeg.

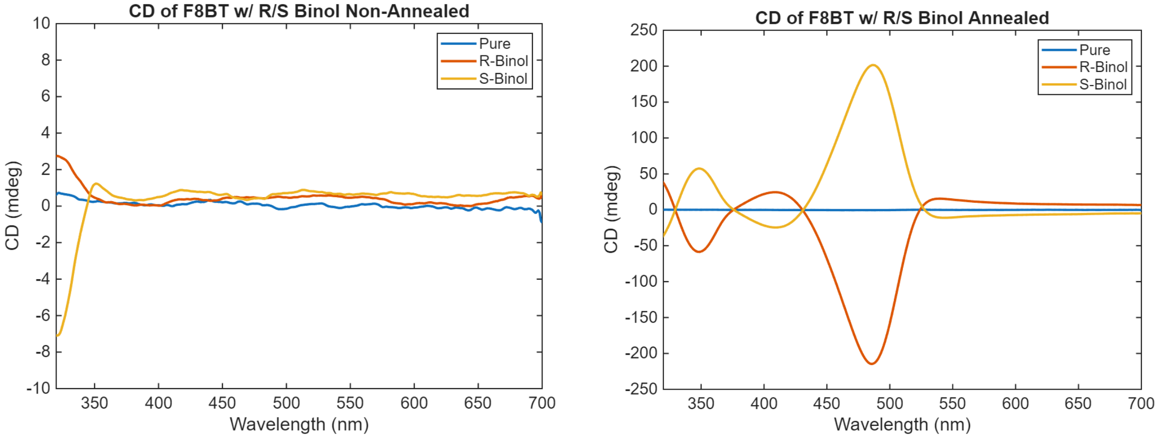

Figure 3.1 CD spectra of F8BT with (R)- and (S)-Binol before (left) and after (right) annealing.

F8BT with BN. Non-annealed samples showed no chiral signature. Post-annealing, S-BN induced a peak of about 110 mdeg, but R-BN produced no significant mirror-image response, indicating poor enantiomeric symmetry and limited suitability as a dopant for F8BT.

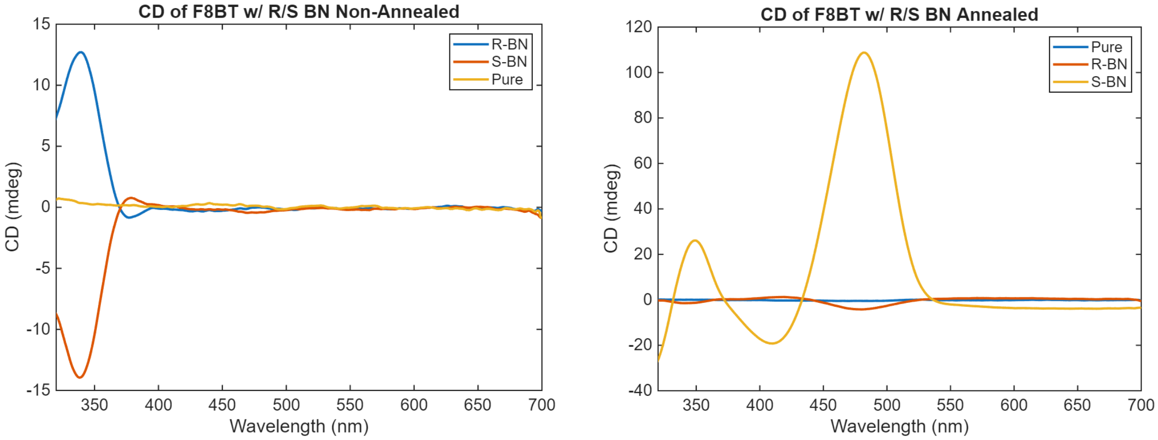

Figure 3.2 CD spectra of F8BT with (R)- and (S)-BN before (left) and after (right) annealing.

PFO with Binol. Annealing had minimal impact; both pre- and post-annealed spectra displayed weak, largely unchanged signals, suggesting Binol interacts poorly with PFO and induces little chirality.

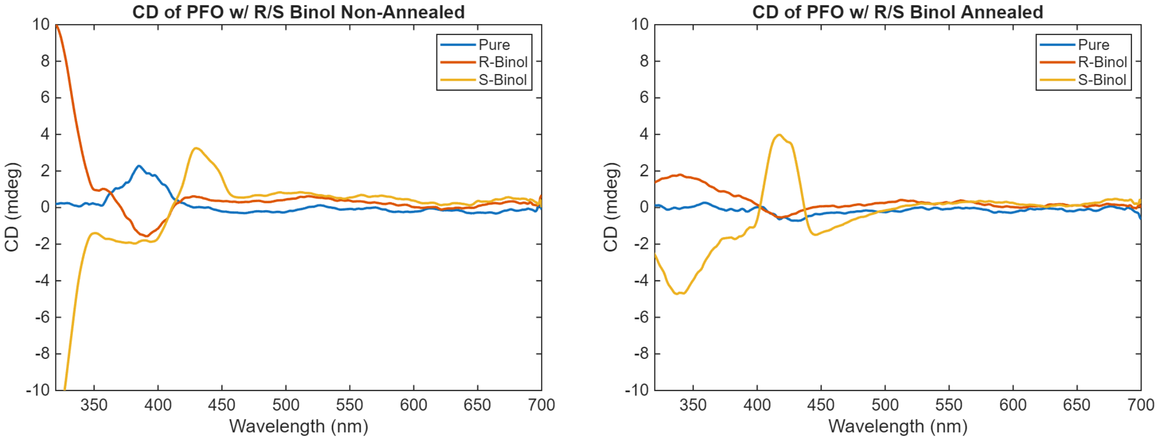

Figure 3.3 CD spectra of PFO with (R)- and (S)-Binol before (left) and after (right) annealing.

PFO with BN. Non-annealed samples showed modest peaks of approximately 20 mdeg and -60 mdeg at 425 nm and 350 nm for R-BN, and -20 mdeg and 40 mdeg at the same wavelengths for S-BN. After annealing, intensities amplified dramatically to 325 mdeg and -125 mdeg for R-BN, and -550 mdeg and 250 mdeg for S-BN, with excellent mirror symmetry.

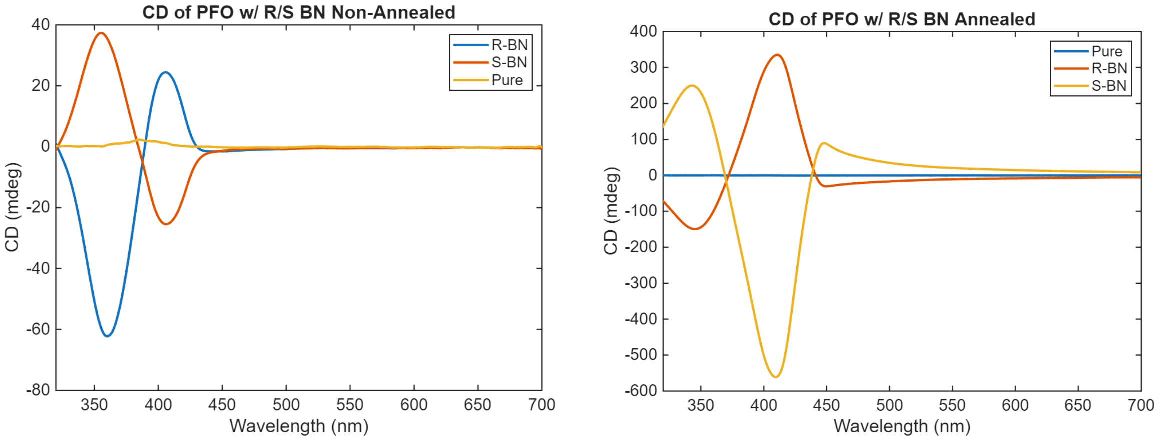

Figure 3.4 CD spectra of PFO with (R)- and (S)-BN before (left) and after (right) annealing.

These results confirm Binol as the optimal dopant for F8BT and BN for PFO, with annealing serving as a critical processing step to maximize chiral induction in compatible systems.

3.2 Tuning Chirality in Polymer Blends

Following the initial experiments of chiral dopants, it was determined that 1,1′-Bi-2-naphthol (Binol) had the strongest CD response when doped into Poly(9,9-dioctylfluorene-alt-benzothiadiazole) (F8BT), while 1,1′-Binaphthyl-2,2′-diamine (BN) was most effective with Poly(9,9-di-n-octylfluorenyl-2,7-diyl) (PFO). These findings prompted further investigation into polymer blends to explore potential effects on chirality induction. Blends of PFO and F8BT were prepared at different volume ratios, maintaining constant overall polymer and dopant concentrations to isolate the impact of blend composition.

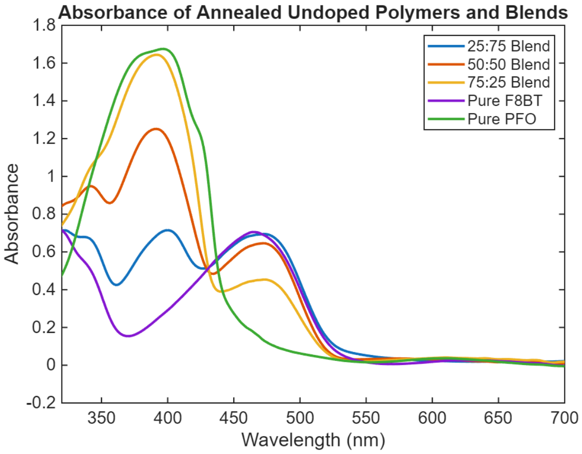

Figure 3.5 Absorbance Spectrum of the blends compared to the pure samples.

The absorption spectra of pure PFO and F8BT provided baseline references, with

PFO showing peaks around 400 nm and F8BT around 500 nm. Three blend ratios were examined: 25:75, 50:50, and 75:25 (PFO:F8BT). Both R- and S-enantiomers of BN and Binol were tested, revealing that Binol consistently outperformed BN in inducing chirality across all blends. This superiority may be attributed to Binol's structural compatibility with the polymer chains, facilitating better intermolecular interactions and helical ordering.

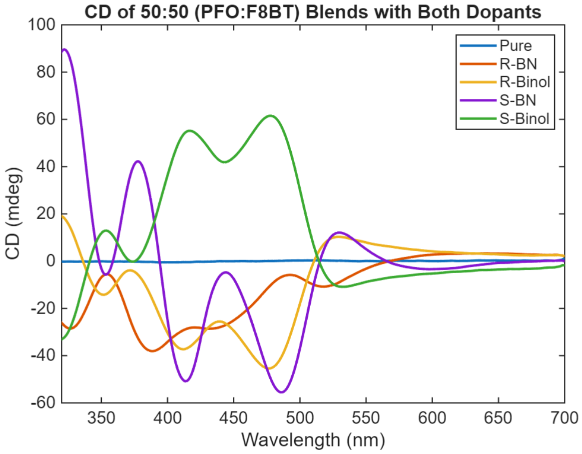

Figure 3.6 CD Spectrum of the blends with both chiral dopants.

Analysis of the CD spectra from these blends demonstrated composition-dependent chiral signatures. In blends with higher F8BT content (e.g., 25:75 PFO:F8BT), CD peaks were prominent around 500 nm, while higher PFO ratios shifted peaks toward 400 nm. Notably, the 50:50 blend yielded the strongest signals, reaching approximately 60 mdeg for S-Binol and -45 mdeg for R-Binol. This enhanced response in the blend suggests intermolecular packing that amplifies chirality transfer from the dopant to the polymer matrix.

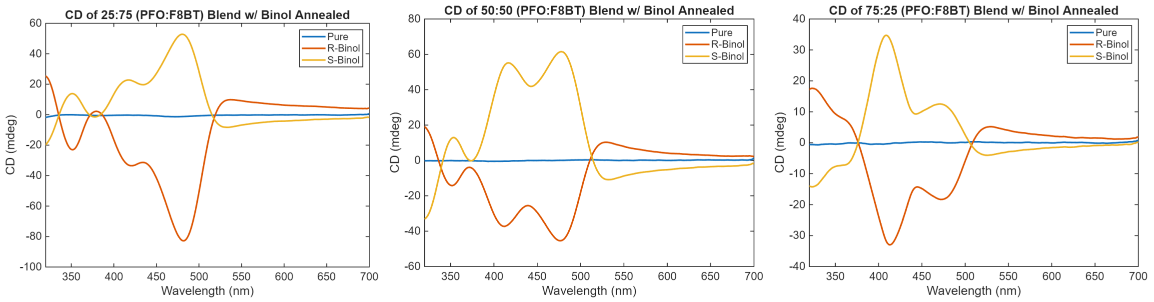

Figure 3.7 CD Spectrum of the blends with R/S Binol.

3.3 Interpretation of Findings

The results highlight the dopant-specific efficacy in inducing chirality: Binol proved optimal for F8BT, yielding strong CD signals, whereas BN was optimal for PFO, achieving peak intensities of -550 mdeg with S-BN and 325 mdeg with R-BN. These differences underscore the importance of molecular matching between dopant and polymer, where structural similarities likely enhance non-covalent interactions such as π-π stacking or hydrogen bonding, leading to more pronounced helical structures in the polymer chains.

In the context of polymer blends, varying the PFO:F8BT ratios, the CD spectrum's chiral features, with peaks correlating to the dominant polymer's absorption bands. The unexpectedly strong signal in the 50:50 blend indicates a cooperative effect. This tunability suggests that blend composition can be leveraged to tailor the wavelength-specific chirality for applications in optoelectronic devices, such as chiral sensors or circularly polarized light emitters.

Overall, these findings contribute to the understanding of chirality induction in conjugated polymers, demonstrating that both dopant selection and blend formulation are key parameters for optimization. Future work could explore additional dopants or processing conditions to further enhance signal strength and stability, paving the way for practical implementations in chiral photonics and materials science.

Chapter 4

Conclusion

Chiality can be induced in conjugated polymers, specifically poly(9,9-dioctylfluorene-alt-benzothiadiazole) (F8BT) and poly(9,9-dioctylfluorene) (PFO), through the incorporation of chiral dopants 1,1′-Bi-2-naphthol (R/S-BINOL) and 1,1′-Binaphthyl-2,2′-diamine (R/S-BN). By investigating the effects of dopant type, polymer blend ratios, and processing conditions. The results demonstrate that chirality can be successfully induced in F8BT and PFO through the use of chiral dopants, with dopant-specific efficacy playing a critical role. Binol was found to be the most effective dopant for F8BT, producing robust circular dichroism (CD) signals, while BN exhibited superior performance with PFO, achieving peak intensities of -550 mdeg for S-BN and 325 mdeg for R-BN. These differences highlight the importance of structural compatibility between the dopant and the polymer, likely driven by non-covalent interactions such as π-π stacking or hydrogen bonding, which promote helical ordering in the polymer chains.

The study of PFO:F8BT polymer blends revealed that chirality induction is highly tunable through blend composition. A 50:50 PFO:F8BT blend doped with Binol yielded the strongest CD signals, reaching approximately 60 mdeg for S-Binol and -

45 mdeg for R-Binol, suggesting a cooperative effect that enhances chiral organization. The wavelength-specific chiral signatures correlated with the dominant polymer's absorption bands, with higher F8BT content producing peaks around 500 nm and higher PFO content shifting peaks toward 400 nm.

Processing conditions were also critical to achieving chirality. Thermal annealing at 180°C for 10 minutes significantly enhanced CD signals, with annealed samples showing increases compared to non-annealed counterparts. This enhancement is attributed to improved molecular ordering during annealing. Additionally, spin-coating at 1000 rpm was identified as optimal for producing uniform thin films, ensuring consistent chiral responses across samples.

The ability to induce and tune chirality in conjugated polymers opens new avenues for the design of advanced materials with tailored optical and electronic properties. The strong CD signals observed in this study suggest that chiral conjugated polymers could be integrated into next-generation photonic devices, such as circularly polarized light emitters and detectors, which are critical for applications in displays, optical communication, and sensing. The observed chirality-induced spin selectivity (CISS) effect, enabled by helical polymer structures, holds promise for spintronic devices, where spin-polarized currents can be manipulated without magnetic materials.

While this study provides a foundation for understanding chirality induction in conjugated polymers, further exploration is needed. Expanding the study of polymer blends to include extreme ratios, such as 99:1 or 1:99 PFO:F8BT, may reveal whether chirality can be maintained or enhanced in highly skewed compositions, potentially optimizing material properties for specific applications.

Future work could also explore alternative processing techniques, such as solvent annealing or varied annealing temperatures, to further enhance CD signal strength and stability. Incorporating advanced characterization techniques, such as X-ray diffraction or scanning probe microscopy, could provide deeper insights into the nanoscale organization of chiral polymer chains.

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