Supporting Information

Spin Filtering Along Chiral Polymers
Suryakant Mishra, Amit Kumar Mondal, Eilam Z. B. Smolinsky, Ron Naaman,* Katsuhiko Maeda,* Tatsuya Nishimura,* Tsuyoshi Taniguchi, Takumu Yoshida, Kokoro Takayama, and Eiji Yashima

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Materials:
All reagents were obtained from commercial suppliers and used without further purification. 4-Mercaptophenylboronic acid and [RhCl(nbd)]₂ were purchased from Sigma-Aldrich (St. Louis, MO, USA). Tetrabutylammonium hydroxide solution (40% in water) (TBAOH), diphenylacetylene, benzoyl chloride, and pinacol were obtained from Tokyo Chemical Industry (TCI, Tokyo, Japan). Sodium sulfate (Na₂SO₄), triethylamine, and potassium hydroxide (KOH) were purchased from FUJIFILM Wako Pure Chemical (Osaka, Japan). Triphenylphosphine (PPh₃) was available from Nacalai Tesque (Osaka, Japan). 4-Ethynylbenzoyl-L-alanine decyl ester (1L),[S¹] 4-ethynylbenzoyl-D-alanine decyl ester (1D),[S¹] and (4-((1-decyloxycarbonyl-1-methylethyl)carbamoyl)phenyl)acetylene (2)[S²] were prepared according to the reported method.

Instruments:
NMR spectra were taken on a JNM-ECA 500 (JEOL, Tokyo, Japan) (500 MHz for ¹H and 125 MHz for ¹³C) spectrometer in CDCl₃ using TMS (for CDCl₃, H and C) as the internal standard. Melting points were recorded on a Yanako melting point apparatus, which was not corrected. IR spectra were recorded with a JASCO (Hachioji, Japan) Fourier Transform IR-460 spectrophotometer. IR-RAS spectra were obtained with Nicolet 6700 FTIR equipped with a
PEM-90 photoelastic modulator (Hinds Instruments, Hillsboro, OR). The size exclusion chromatography (SEC) measurements were performed with a JASCO PU-4180 liquid chromatograph equipped with a UV-vis (JASCO MD-4010). The temperature was controlled with a JASCO CO-4060 column oven at 40 °C. Three columns (Tosoh (Tokyo, Japan) TSKgel G4000HXL (30 cm) + G3000HXL (30 cm) + G3000HXL (30 cm)) were connected in a series for the SEC measurements using tetrahydrofuran (THF) as the eluent at flow rate of 1.0 mL/min. Polystyrene standards (Tosoh) were used for the molecular weight calibration.

**Experimental details:**

**Hall device fabrication:** Hall devices are fabricated on the AlGaN/GaN wafer which is composed of nucleation layer of thickness 1800 nm, intrinsic-GaN (i-GaN), a 20-nm-thick intrinsic-AlGaN (i-AlGaN) layer on top of it and finally a 2 nm thick capping layer again of GaN. The advantage of this geometry is 2-dimentional electron gas (2DEG) layer at the interface of the AlGaN and GaN. Devices were prepared by standard optical photolithography in a class 1000 clean room. These devices are combined by six electrodes, arrange in a standard Hall geometry: source (S) and drain (D) electrodes are to flow constant charge carrier, and two set of Hall probes to measure the Hall potential. Ohmic contacts of the electrodes were made with 2DEG by annealing (at 850 °C) multilayers of metals, i.e. Ti (20 nm)/Al (100 nm)/Ni (40 nm)/Au (40 nm). Extra layer of gold (100 nm) on top of these electrode was placed to ease the wire-bonding. After etching the device, it breaks the inter-electrode electrical contact, area of (500 µm × 40 µm) which is the active area of the channel, was coated with 2 nm-Ti and 5 nm-Au for immobilization of the molecule by thiol gold bond. After adsorption of the polymers (poly-1L and poly-1D) (method in the next section), the device chip glued to a chip holder and device electrodes were connected to the chip holder pads using wire bonding. In addition, a high-quality RTV silicone glue was used to insulate all the connections and pads of the device to avoid charge leakage. To maintain the aqueous environment during the measurements, we prepared a PDMS (polydimethylsiloxane) cell with a 200 µL capacity that was glued on top of the device on the chip holder.
**Figure S1:** (A) Optical image of the device along with (B) layers underneath of the channel.

**Hall Experiments:** Two sets of measurement have been performed on the theses Hall devices, one is polarization and other one is electrochemical Hall. In polarization, a glass coverslip coated with 100 nm of gold was used as the gate electrode, and was placed on top of the PDMS cell that contained a 0.4 M PBS buffer solution, with the gold-coated side facing away from the solution. Constant potential pulses of different magnitudes were applied to the gold-coated coverslip (with respect to the device channel), providing the electric field that polarized the polymers. During the experiment, a constant current of 10 µA was maintained between the source (S) and drain (D) electrodes. The varying gate voltages and the constant S-D current were applied using a dual channel Keithley 2636A source measuring unit and Hall signal were probed by Keithley 2182A nanovoltmeter. All measurements were performed in a dark Faraday cage. In the second experiment, electrochemical Hall signal were probed using electrochemistry within the PDMS cell. The 3-electrode electrochemical setup was composed of the Hall device-channel as the working electrode, Ag/AgCl reference electrode (0.1 M NaCl), and a platinum wire counter electrode. A potentiostatic (PalmSens4) electrochemical workstation was used to make the cyclic voltammetry measurements. Similar to the polarization experiment, a constant current of 10 µA was maintained between the source and drain electrodes. The buffer used during the electrochemical experiments contained 0.4 M PBS and ferrocene as redox probe. All cyclic voltammetry measurements were performed at a scan rate of 100 mV/s unless stated otherwise.

**Magnetic conducting AFM experiment:** Magnetic field-dependent current vs. voltage (I-V) characteristics of poly-1L, poly-1D and poly-2 were obtained using a multimode magnetic scanning probe microscopy (SPM) system built with Beetle Ambient AFM and an electromagnet equipped with R9 electronics controller (RHK Technology). Voltage spectroscopy for I-V measurements were performed by applying voltage ramps on a platinum tip (DPE-XSC11, μmasch with spring constant 3-5.6 Nm⁻¹) in contact with the sample at an
applied force of 3 nN. At least ~80, $I$–$V$ curves were scanned in an applied magnetic field of 0.50 T for both UP and DOWN magnetic field orientations.

**Hall device calibration using external magnetic field:** Hall device calibration was done using a superconducting electromagnet, by varying the magnetic field from $-500$ Oe to $+500$ Oe and measuring the corresponding Hall potential across the probes when constant current ($10 \, \mu$A) flowed between S and D.

**Magnetoresistance device fabrication and characterization in SQUID:** Magnetoresistance measurement were performed in crossbar geometry on SiO$_2$ wafer, where 2 $\mu$m bottom electrode composes of 40 nm gold (Au) and 10 nm titanium (Ti), prepared by optical lithography. This bottom electrode is used to grow self-assembled monolayer (SAM) of given polymers. On top of the closely packed monolayer of the polymers, insulating buffer layer of 1.5 nm magnesium oxide (MgO) were grown by e-beam evaporation and then the final top electrode composed of nickel (Ni) and Au having thickness of 40 nm and 20 nm evaporated using shadow mask with line width of 50 $\mu$m. Top most Au layer is to protect Ni from the environmental oxidation. All the electrical measurements were carried out within the SQUID-MPMS3 made by Quantum Design. Magnetic field of up to 0.6 T was applied out-of-plane to the device and resistance was measured by standard 4-probe method by flowing constant current of 1 mA. Keithley SMU model 2400, used as current source and Keithley nanovoltmeter model 2182A, used to measure voltage across the junction.

**Monolayer formation:** Before growing monolayer of the poly-1 on top of the surfaces mentioned in all above measurements, we clean surface in boiling acetone and boiling ethanol for 10 minutes each. After this treatment we kept them in UV Ozone plasma cleaner for 5 minutes which help to remove all organic residues. Then after the surfaces were incubated in normal ethanol for 30 minutes, finally in the polymer solution for overnight. In this study we use two type of chiral polymers poly-1L and poly-1D in THF with the molarity of 10 mM.

**Molecular synthesis and their characterization:**

**Step1:** Synthesis of 4-mercaptophenylboronic acid pinacol ester was carried out according to the previous report.$^{[S3]}$ To a solution of 4-mercaptophenylboronic acid (700 mg, 4.6 mmol) in diethyl ether (14 mL) were added pinacol (806 mg, 6.8 mmol) and $\text{Na}_2\text{SO}_4$ (2.0 g) and then the mixture was stirred for 16 hours at room temperature under nitrogen. The precipitated product was collected by filtration and then purified by chromatography with silica gel (AcOEt/hexane = 1/4) to give 4-mercaptophenylboronic acid pinacol ester as a white solid (1.08 g, 100% yield).
**Step2:** To a solution of 4-mercaptophenylboronic acid pinacol ester (245 mg, 1.0 mmol) (obtained in the previous step) in dichloromethane (5.2 mL, 0.2 M) were added triethylamine (188 μL, 1.4 mmol) and benzoyl chloride (134 μL, 1.1 mmol) at 0 °C and then the mixture was stirred for 17 hours at room temperature. The reaction mixture was washed with 1 M HCl, saturated NaHCO₃, and H₂O in the separatory funnel. The obtained crude product was purified by recrystallization from ethanol to give 4-benzoylthiophenylboronic acid pinacol ester as a white crystal (141 mg, 40% yield).

mp = 99.5~100.5 °C

**Step3:** Benzo-poly-1L, benzo-poly-1D, and benzo-poly-2 were synthesized by the living polymerization of 1L, 1D, and 2, respectively, by using the rhodium-based multicomponent catalytic system. A solution of [RhCl(nbd)]₂ (18.5 mg, 0.04 mmol), 4-benzoylthiophenylboronic acid pinacol ester (40.8 mg, 0.06 mmol) (obtained in step2) and diphenylacetylene (57.0 mg, 0.32 mmol) in THF (0.8 mL) was prepared and cooled down to 0 °C. The solution was stirred immediately after addition of a 10% aqueous solution of KOH (112 μL) for 4.5 minutes at 0 °C. Colour of the solution was changed from yellow to brown and finally the orange solution of the active catalyst was formed after rapid addition of PPh₃ (63.0 mg, 0.24 mmol). To each monomer (1L, 1D, 2) solution (0.57 mmol/L) in THF, the
prepared stock solution of catalyst was added (160 µL). The concentration of the resultant red solution was around 0.5 M. Then it was stirred for one hour at 30 °C. A few drops of acetic acid were added to the polymerization solution for termination of the reaction. Then it was poured into excess hexane (for benzo-poly-1) or methanol (for benzo-poly-2). The precipitated polymer was collected by centrifugation, washed with hexane (for benzo-poly-1) or methanol (for benzo-poly-2), and dried in vacuo at room temperature to give benzo-poly-1L (159.3 mg, $M_n = 10,100$, $M_d/M_w = 1.08$), benzo-poly-1D (162.0 mg, $M_n = 10,300$, $M_d/M_w = 1.08$), and benzo-poly-2 (113.3 mg, $M_n = 14,000$, $M_d/M_w = 1.11$) as yellow powders.
**Step 4**: Deprotection of the terminal thioester in benzo-poly-1 and benzo-poly-2 was carried out as follows. To the solution of the corresponding polymers (120.0 mg for benzo-poly-1 or 113.3 mg for benzo-poly-2) in THF (1.0 mL), a 40% (w/v) aqueous solution of TBAOH was added and the mixture was stirred for 3 hours at room temperature. After addition of acetic acid to the reaction mixture, the solution was poured into excess hexane, and the precipitated polymer was collected by centrifugation, washed with hexane, and then dried in vacuo at room temperature to give poly-1L (109 mg, 91% yield), poly-1D (108.3 mg, 90% yield), and poly-2 (113.0 mg, 100% yield). All the polymers maintained a cis-transoidal structure as confirmed by $^1$H NMR spectra.
PMIRAS Characterization: Polarization modulation-infrared reflection-absorption spectroscopy (PM-IRRAS) was used to characterize the polymer monolayers. Nicolet 6700 FTIR equipped with a PEM-90 photoelastic modulator (Hinds Instruments, Hillsboro, OR) at an incidence angle of 80° was used for this measurement.

**Figure S2:** IR spectra recorded (A) for the monolayers of the poly-1D, poly-1L and poly-2 on gold surfaces in reflection mode and (B) for their drop-cast films on KBr plate in transmission mode.
Optical activity (Circular Dichroism):
The circular dichroism (CD) measurements were carried out using a Chirascan™-plus spectrometer equipped with an Avalanche Photodiode Detector, made by Applied Photophysics, England. Measurements were done at a scan range of 500 to 230 nm; ~2 sec time per point; 1 nm step size; and a 1 nm bandwidth. The polymer was dissolved in THF and concentration was about 0.22 mM. The spectra were taken using a 0.2 cm light path length cuvette, THF serving as a background. The concentration of polymers was calculated based on the monomer units.

Figure S3: CD and absorption spectra of poly-1L (red line), poly-1D (blue line), and poly-2 (black line) in THF (0.1 mg/mL) at 25 °C.
SEC analysis of the polymers
The number-average molar mass ($M_n$) and molar-mass dispersity ($M_w/M_n$) of benzo-poly-1L and benzo-poly-1D (SH-protected polymer) were $1.0 \times 10^4$ and 1.08, respectively, as determined by SEC with THF as an eluent. The SEC chromatograms (Figure S4) of poly-1L and poly-1D showed bimodal distribution ($M_n$ (peak 1) = $1.1 \times 10^4$, $M_n$ (peak 2) = $2.0 \times 10^4$) (Figure S4). The high molecular weight fraction (peak 2) is probably due to the formation of the -S-S- bond between the two polymer chains at the chain end.

Figure S4: SEC chromatograms of the protected benzo-poly-1L and benzo-poly-1D (left), and the deprotected poly-1L and poly-1D (right), which have thiol group in the end terminus.
Figure S5: Magnetic cp-AFM measurement of poly-1L and poly-1D in magnetic north pole Up and Down direction. Black line represents the average value.

Figure S6: Magnetic cp-AFM measurement of achiral polymer (poly-2) in magnetic north pole Up and Down direction.
Figure S7: Hall device calibration using a standard magnetic field.

References:
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