Supplementary Information to the manuscript **"Spin-polarized currents induced in antiferromagnetic polymer multilayered field-effect transistors"** by Shih-Jye Sun, Miroslav Menšík, and Petr Toman.

1) Detail derivation of the spatial distribution of charge density in the vertical direction within the macroscopic limit

For the spatial distribution of charge density in the vertical (z-) direction we take the following ansatz.

$$\delta\rho(z) = q\delta n(z=0)exp(-\frac{q(V(z)-V(z=0))}{k_B T}), \quad \text{(S1)}$$

where $\delta\rho(z) = q\delta n(z)$, δn, and $V(z)$ are the induced charge density, the carrier density, and the potential at height z, respectively. q denotes the positive or negative elementary charge, corresponding to the induced hole or electron, respectively. We can easily see that the ansatz (S1) exactly compensates both diffusion and drift currents in the vertical direction, i.e.,

$$-D\frac{\partial}{\partial z}\delta\rho(z) - qk_B TD\delta\rho(z)\frac{\partial}{\partial z}V(z) = 0. \quad \text{(S2)}$$

We note that in eq. (S2) the Einstein relation between the diffusion coefficient D and the charge mobility $\mu = qk_B TD$ holds true. Thus, the ansatz (S1) is suitable for field-effect transistors (FETs), where the current flows between the source and drain electrodes, i.e. only in the horizontal (x-) direction.

For the FETs, the most dominant divergences of the electric field are controlled by the gate voltage. Hence, the Gauss law for the induced charge density and the potential in the polymer layers can be restricted to the vertical direction, which provides

$$\frac{d^2V(z)}{dz^2} = -\frac{\delta\rho(z)}{\epsilon_s}, \quad \text{(S3)}$$

in which z and ϵ_s are the height and the dielectric constant of the polymer layers. Integrating the Gauss law (S3) step-by-step and utilizing the Ansatz (S1) we get

$$d\left(\frac{dV(z)}{dz}\right) = -\frac{\delta\rho(z)}{\epsilon_s}dz$$

$$\therefore \left(\frac{dV(z)}{dz}\right)d\left(\frac{dV(z)}{dz}\right) = -\frac{\delta\rho(z)}{\epsilon_s}dV(z)$$

$$\therefore \int_z^\infty d\left(\frac{dV(z)}{dz}\right)^2 = -\frac{2q\delta n(0)}{\epsilon_s}\int_z^\infty \exp\left(-\frac{q(V(z)-V(0))}{k_B T}\right)dV(z)$$

Assuming further that at the top layer of the FET $\left.\frac{dV(z)}{dz}\right|_{z\to\infty} \to 0$, while $\left.\frac{q(V(z)-V(0))}{k_B T}\right|_{z\to\infty} \to \infty$ we arrive at

$$\therefore \left(\frac{dV(z)}{dz}\right)^2 = 2\delta n(0)k_B T e^{-q(V(z)-V(0))/k_B T)}$$

$$\therefore \frac{dV(z)}{dz} = \sqrt{2\delta n(0)k_B T/\epsilon_s}\, e^{-q(V(z)-V(0))/2k_B T}$$

$$\therefore \sqrt{\frac{2\delta n(0)k_B T}{\epsilon_s}}\int_0^z dz = \int_{V(0)}^{V(z)} e^{q(\frac{V(z)-V(0)}{2k_B T})} dV(z)$$

$$\therefore e^{q(V(z)-V(0)/2k_B T} = \left(\frac{q}{2k_B T}\right)\sqrt{\frac{2\delta n(0)k_B T}{\epsilon_s}}z + 1$$

$$\therefore\ e^{\frac{-q(V(z)-V(0))}{k_BT}} = \left[\left(\frac{q}{2k_BT}\right)\sqrt{\frac{2\delta n(0)k_BT}{\epsilon_s}}z+1\right]^{-2}$$

∴ From eq. (S1), we obtain

$$\delta n(z) = \delta n(z=0)\left[\left(\frac{q}{2k_BT}\right)\sqrt{\frac{2\delta n(z=0)k_BT}{\epsilon_s}}z+1\right]^{-2} \tag{S4}$$

2) Capacity relation for the FET

Assuming further that the distribution of charge densities and the intensity of the electric field in the FET approaches that of the semi-infinite space, we get also from the Gauss law (S2)

$$\left.\frac{dV(z)}{dz}\right|_{z\to\infty} - \left.\frac{dV(z)}{dz}\right|_{z=0} = E_z(z\to 0^+) = -\frac{1}{\epsilon_s}\int_0^\infty \delta\rho(z)dz \tag{S5}$$

The left-hand side of Eq. S5 is controlled by the vertical component of the electric field at the interface of the FET and the insulating dielectric, i.e.,

$$\epsilon_s E_z(z\to 0^+) = \epsilon_I E_z(z\to 0^-) = \epsilon_I \frac{-(V(z=0)-V_{GS})}{t_{ox}}, \tag{S6}$$

where we took into the account that the electric field inside the insulator of the thickness t_{ox} is given by the potential slope between the FET and the gate voltage V_{GS}. Combining eqs. (S5) and (S6) we arrive at the "capacity relation"

$$\int_0^\infty \delta\rho(z)dz = \frac{\epsilon_I}{t_{ox}}(V(z=0)-V_{GS}), \tag{S7}$$

which couples together the "surface charge" density (volume charge density integrated in the vertical direction) with the capacity of the insulator $\frac{\epsilon_I}{t_{ox}}$ and the gate voltage $(V(z=0)-V_{GS})$. Realizing that we know the spatial profile of $\delta\rho(z)$ due to the eq. (S4), we can also perform the integration in (S7) analytically to get also the relation between the chare density at the bottom of the FET and the gate voltage as follows

$$\delta\rho(z=0) = \frac{q}{2k_BT\epsilon_s}\left(\frac{\epsilon_I}{t_{ox}}(V(z=0)-V_{GS})\right)^2 \tag{S8}$$

Alternatively, we can reformulate potential calibration with respect to the top of the FET structure and write

$$\delta\rho(z=0) = \frac{q}{2k_BT\epsilon_s}(C_p(V(z=n_Lu_z)-V_{GS}))^2, \tag{S9}$$

where C_p is the total capacitance, $C_P^{-1} = C_s^{-1} + C_I^{-1}$, where $C_s = \frac{\epsilon_s}{z_L}$ and $C_I = \frac{\epsilon_I}{t_{ox}}$ are the capacitances of the polymer and insulator layers per unit area, respectively. z_L and t_{ox} are the thickness of the polymer and insulator, respectively. We note that while the "surface charge" density scales linearly with the gate voltage in eq. (S7), the charge density at the bottom of the FET scales quadratically with the gate voltage in eq. (S8). Such property is related to the mean thickness $\langle Z\rangle$ of the conducting channel of FET

$$\langle Z\rangle \equiv \frac{\int_0^\infty \delta\rho(z)dz}{\delta\rho(z=0)} = \frac{2k_BT}{q(V(z=0)-V_{GS})\epsilon_I}\frac{\epsilon_s}{}t_{ox} \qquad \text{(S10)}$$

We see that with increasing gate voltage the mean thickness $\langle Z\rangle$ decreases. Namely, when the gate voltage difference $(V(z=0)-V_{GS}) \gg \frac{2k_BT}{q} \approx 0.05\ V$ at the room temperature, the mean thickness $\langle Z\rangle$ of the conducting channel becomes significantly thinner than the thickness of the insulating dielectrics t_{ox}. Hence, the applied gate voltage effectively decreases the thickness of the conducting channel, and therefore, we speak about the thin film FET model.

(3) Eigensolution, matrix representation

The spin-dependent total Hamiltonian H_σ in the matrix form in the basis $\{|m,\sigma\rangle\}$ can be written as

$$[H]_\sigma = \begin{bmatrix} a_{11} & a_{12} & 0 & & & & \\ a_{12} & a_{22} & a_{23} & \cdots & & 0 & \\ 0 & a_{23} & a_{33} & & & & \\ & \vdots & & \ddots & & \vdots & \\ & & & & a_{N-2N-2} & a_{N-2N-1} & 0 \\ & 0 & & \cdots & a_{N-2N-1} & a_{N-1N-1} & a_{N-1N} \\ & & & & 0 & a_{N-1N} & a_{NN} \end{bmatrix}_{N\times N} \qquad \text{(S11)}$$

The matrix element $a_{ij} = (\epsilon_0 + Un_{i\bar{\sigma}} + \frac{1}{2}\sigma(J_s(\langle S_{i-1}^z\rangle + \langle S_{i+1}^z\rangle)) + V(k,i))\delta_{ij} + t_{ij}$, where $V(k,i)$ is the potential voltage on the *i*-th site of the k-th polymer layer, biased and driven by the drain-source and gate voltages, and t_{ij} is the transfer integral from eq. (7). Note that $V(k,i)$ can be solved self-consistently from eqs. (2-5) in the main text. The matrix form (S11) can be obtained from the temperature-dependent Hartree-Fock Hamiltonian

$$H^{\mathrm{HF}}_{k,i\sigma_i;k,j\sigma_j} = \delta_{k,\sigma_i;k,\sigma_j}\{\delta_{k,i;k,j}[(H_{\mathrm{P}})_{k,i;k,i} + \frac{U}{2}\langle\hat{n}_{k,i\bar{\sigma}_i}\rangle + \frac{\sigma_{k,i}J_s}{2}(\langle S_{k,i-1}^z\rangle + \langle S_{k,i+1}^z\rangle)] + (\delta_{k,i;k,j+1} + \delta_{k,i;k,j-1})[(H_{\mathrm{T}})_{k,i;k,j} - \left(\frac{1}{4}J_s\right)\rho_{k,i\sigma_i;k,j\sigma_i}]\},$$
(S12)

where the density matrix $\rho_{k,i\sigma_i;k,j\sigma_i}$ satisfies

$$\rho_{k,i\sigma_i;k,j\sigma_j} \equiv \sum_{k,\sigma_k}\langle k,i\sigma_i\,|\,k,\mu\sigma_\mu\rangle f\left(E_{k,\mu\sigma_\mu}\right)\langle k,\mu\sigma_\mu\,|\,k,j\sigma_j\rangle \rightarrow \delta_{k,\sigma_i;k,\sigma_j}\cdot\rho_{k,i\sigma_i;k,j\sigma_i} \qquad \text{(S13)}$$

Here, $f(E_{k,\mu\sigma_\mu})$ is the Fermi-Dirac distribution of the eigenstates $|k,\mu\sigma_\mu\rangle$ (with the eigenenergies $E_{k,\mu\sigma_\mu}$) obtained as the solution to the Hartree-Fock (mean-field) Hamiltonian (S12), delocalized along the *k*-th chain. If we neglect in the Hartree-Fock Hamiltonian in eq. (S12) the off-diagonal coherences $\rho_{k,i\sigma_i;k,j\sigma_i}$ for $i \neq j$, which only "effectively" renormalize the "hopping term", we obtain the "mean-field" Hamiltonian (S11).