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Carbon-based materials for room temperature single-electron devices (and why it pays to know a chemist)

Jan Mol

Single electron transistors





Total energy of the dot:

$$U(N) = \frac{1}{2} \frac{\left[-|e|(N-N_0) + C_s V_s + C_d V_d + C_g V_g\right]^2}{C_s + C_d + C_g}$$



Single electron transistors



$$U(N) = \frac{1}{2} \frac{\left[-|e|(N-N_0) + C_s v_s + C_d v_d + C_g\right]}{C_s + C_d + C_g}$$



Single electron transistors

Energy difference (single-particle energy level):

 $\epsilon_N = \left(N - N_0 - \frac{1}{2}\right) E_C - \frac{E_C}{|e|} \left(C_s V_s + C_d V_d + C_g V_g\right)$ with

 $E_C = \frac{e^2}{C_s + C_d + C_g} \qquad N$







Quantum electrometer





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Vigneau, et al. Appl. Phys. Rev. 10, (2023)

Measuring quantum transport



Understanding resonant charge transport through weakly coupled single-molecule junctions.

Thomas et al.

Nat. Commun. **10**, 4628 (2019)

Exceptionally clean singleelectron transistors from solutions of molecular graphene nanoribbons.

Niu et al.

Meas

Nat. Mater. 22, 180–185 (2023)

Measuring quantum *entropy*



Electronic measurements of entropy in meso- and nanoscale systems.

Pyurbeeva et al.

Chem. Phys. Rev. **3**, 041308 (2022)

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Lau et al. Phys. Chem. Chem. Phys. 16, 20398–20401 (2014)

Single-molecule transistors





Thomas et al. Nat. Commun. 10, 4628 (2019)

Single-molecule transistors





Thomas et al. Nat. Commun. 10, 4628 (2019)

Non-equilibrium vibrations

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Bian, X. et al. Phys. Rev. Lett. 129, 207702 (2022)

Non-equilibrium vibrations







Bian, X. et al. Phys. Rev. Lett. 129, 207702 (2022)

Engineering quantum properties

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Thomas *et al.*, *Chem* Sci. **12**, 11121–11129 (2021)

12

Engineering quantum properties





Chen, Z. et al.. Nat. Nanotechnol. (just accepted) arXiv:2304.08535

Engineering quantum properties





Pei, T. et al. Nat. Commun. 13, 1–8 (2022)

Scaling up



10 nm – 400 nm



Niu, W. et al. Nat. Mater. 22, 180–185 (2023)

Scaling up

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Phase exchange & monolayer assembly





Degousée, T. et al. J. Mater. Chem. C 11, 16518–16526 (2023)

Scaling up





Graphene quantum dots

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Gehring et al. Nano Lett. 16, 4210-4216 (2016)

Single-electron charge sensing





Puczkarski et al. ACS Nano 12, 9451–9460 (2018)

Single-electron charge sensing

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Riccardi, E. et al. Nano Lett. 20, 5408–5414 (2020)

Room temperature operation





Fried et al. Nanoscale **12**, 871–876 (2020)

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