

Nanographene Spin Chains

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Recent advances in on-surface synthesis have enabled the fabrication of prototypical open-shell nanographenes that can be covalently assembled into well-defined quantum spin systems. This presentation focusses on the realization of antiferromagnetically coupled nanographene spin chains, where the choice of the building block and the covalent coupling motif allows for the design of three emblematic quantum spin models: **i)** a spin-1/2 Heisenberg chain based on olympicenes [1], **ii)** a spin-1 Haldane chain based on triangulenes [2], and **iii)** an spin-1/2 alternating exchange Heisenberg chain based on Clar's goblets [3].

On-surface synthesis and *in situ* scanning probe-based characterization allows testing theoretical predictions for the different quantum systems. This includes length-dependent decay of the magnetic excitation gap in the spin-1/2 Heisenberg chain proving the quantum nature of the realized Heisenberg chain, gapped bulk excitations and fractional edge excitations for the spin-1 triangulene chains and gapped magnetic excitations in the spin-1/2 alternating exchange Heisenberg that depend on the ratio of J_1 to J_2 ($a = J_1/J_2$).

We employ atomic hydrogen to passivate the spin sites via CH_2 group formation, followed by tip-induced reactivation to precisely define chain lengths and control terminal coupling motifs in the alternating exchange Heisenberg chains. This approach enables manipulation of the chain's topological phase and the corresponding selective induction or suppression of topology-dependent end states. Bulk excitations in alternating exchange chains are identified as triplons, and Fourier analysis of inelastic standing wave patterns reveals their energy-momentum dispersion of these spin-1 bosonic quasiparticles. These results establish on-surface synthesis as a powerful route to engineer and explore fundamental quantum spin models with strong exchange interactions at the molecular scale.

References

- [1] C. Zhao et al., Spin excitations in nanographene-based antiferromagnetic spin-1/2 Heisenberg chains, *Nat. Mater.* **1** (2025).
- [2] S. Mishra et al., Observation of fractional edge excitations in nanographene spin chains, *Nature* **598**, 287 (2021).
- [3] C. Zhao et al., Tunable topological phases in nanographene-based spin-1/2 alternating-exchange Heisenberg chains, *Nat. Nanotechnol.* **19**, 1789 (2024).

Figures

Figure 1: On-surface synthesized spin-1/2 alternating exchange Heisenberg chain based on Clar's goblet with gapped bulk excitations and topology-derived end states.

