

**Figure S2| Bit-depth scaling for the discrete (QAOA/QUBO) encoding and projected accuracy gains.** (a) Total qubit requirement as the discretization resolution increases from 3 to 6 bits per parameter for the 7-parameter MXene EIS model ( $N_{qubits}=7\times\text{bits/parameter}$ ), illustrating the linear growth in quantum resources. (b) Quantization error in the normalized coordinate  $u$  versus bits/parameter, reported as RMS and MAE across the discretized grid, showing systematic reduction of discretization error with increasing bit depth. (c) Projected surrogate-gap improvement  $\Delta F$  (mean and 95th percentile) as bit depth increases, indicating that finer discretization is expected to reduce the mismatch between the discrete surrogate optimum and the underlying continuous objective, at the expense of additional qubits and a larger combinatorial search space.

