**Donor–π–acceptor heterojunctions constructed from the rGO network and redox-active covalent organic frameworks for high-performance supercapacitors†**

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To overcome the bottleneck of low energy density in graphene-based supercapacitors and endow them with advanced properties such as ultralong life cycles, a key rational strategy is to couple graphene sheets with multielectron, redox-reversible, and structurally stable organic compounds. This work demonstrates the synthesis and characterization of hybridizing redox-active covalent organic frameworks (COFs) with nickel bis(dithiolene) units and graphene via covalent linkages to form heterostructures for high-performance supercapacitors. Efficient electron transfer between COFs and rGO is observed which results from the orderly assembled Ni-bis(dithiolene) units with unique electronic structure, as well as the unique design of COF/rGO morphology. The obtained Ni-TAPP/rGO and Ni-TAP/rGO heterojunctions display a gravimetric capacitance of 346.0 F g\(^{-1}\) and 367.5 F g\(^{-1}\) at a current loading of 0.5 A g\(^{-1}\), volumetric/gravimetric specific energy densities up to 48.1 W h kg\(^{-1}\) and 51.04 W h kg\(^{-1}\), and power densities up to 1.81 kW kg\(^{-1}\) and 1.78 kW kg\(^{-1}\), as well as exceptional rate capability and cycling stability (capacitance retention of 97.01% after 10 000 cycles).

**Introduction**

Supercapacitors hold significant promise for the development of new-generation, zero-carbon-emission electric vehicles, portable, smart, and wearable electronics, etc. due to their advantageous features of high power density, ultrafast charging/discharging rate, and remarkable operation stability (up to tens of thousands of electrochemical cycles).\(^1\)-\(^3\) Two major working mechanisms include electrochemical double-layer capacitance (EDLC) where energy is stored through reversible electrolyte-ion adsorption and desorption at the electrode/electrolyte interfaces, and pseudo capacitance where electricity is reserved through reversible redox transitions of electrode materials.\(^4,5\) The real capacitance generally falls between dozens and 300 F g\(^{-1}\) for a synthetic graphene material.\(^6-9\) Therefore, flexible, lightweight, and cost-effective conducting polymers have been identified as important materials for pseudo-capacitor electrodes. As a new type of polymer prestigious representative, covalent organic framework (COF) materials have sparked intensive research interest recently. However, the inferior electrochemical tolerances of COFs, due to structural depolymerization and collapse during electrochemical cycling tests call for the development of structurally sturdy, well-defined, and redox-active framework materials, while being able to afford attractive positive performances when applied in electrodes.\(^10\)-\(^11\)

Metal-bis(dithiolene) units have π-conjugated electronic structures and rich redox activity,\(^12\)-\(^14\) and they can be regarded as inorganic analogs of the famous electron donor, tetrathiafulvalene (TTF). Notably, TTF has been widely used as a building unit to fabricate COFs for electrical conductors\(^15\)-\(^18\) and electrochemical devices.\(^19\)-\(^21\) Considering the structural similarity between Ni-bis(dithiolene) and TTF, we expect to obtain Ni-bis(dithiolene)-based COFs that are isostructural to TTF-based ones. Taking advantage of the unique electronic structure and redox activity of Ni-bis(dithiolene) centers, the resulting Ni-bis(dithiolene)-COFs are expected to exhibit combined characteristics of high surface area, good electronic conductivity and redox activity, affording attractive capacitance performances from Ni-bis(dithiolene)-COFs. Moreover, the ordered pores in COFs can form efficient ion transport pathways, enabling rapid ion diffusion. To date, a critical issue of COF-based supercapacitors remains as they exhibit poor cycling stability and low actual capacity owing to insufficient electrical conductivity and limited active sites.\(^22\) To this end, morphology control on COF materials could be an effective strategy to address this issue for...
considerable performance enhancement. The achievement of low-dimensional COF materials, especially two-dimensional (2D) nanosheets with short channels, would increase exposure to active sites within the porous structure for electrochemical reactions.24

So far, conventional post-processing methods heavily rely on physical or chemical exfoliation to acquire 2D COF nanosheets by the top to bottom approach, which suffers from cumbersome operation and uncontrollability.24–28 The facile realization of 2D COF nanosheet fabrication is still challenging yet of high significance, and heterojunctions hold great potential to improve reaction kinetics by adjusting the interface electric field while enabling a redistribution of contact interface charges,29,30 which is beneficial for accelerating ion transfer rate and enhancing electrochemical kinetics, ultimately optimizing electrochemical performance.31,32 However, there is still a lack of an effective fabrication strategy to design heterostructures possessing particular morphology or facets for improving the accessibility of active interfaces. As an alternative to metal oxides, redox-active polymers offer mechanical flexibility,33–35 low-cost, and scalability relevant for small and large scale applications.36,37 In redox-active coordinate polymers, due to the insulating nature of the backbone and low conductivity, devices based on these materials require blending with additional conductive materials for electron transport, ultimately lowering the electrode energy density.38 Polymers that were n-doped have also been explored as negative electrodes, but the high charge transfer resistance negatively impacts the performance, and rapid degradation occurs due to instability associated with strong charge localization.39 The relatively more localized redox states can be attributed to the inherent disorder in these materials.40 Overall, the aforementioned technologies lead to poor coulombic efficiency and rapid degradation with redox cycling, exhibiting a low capacitance retention of <80% at 1000 cycles.41 To this end, π–π conjugation, a prevalent interaction among organic molecules, has been reported to effectively drive the loading of COFs on carbonaceous materials such as carbon nanotubes,31,42–44 which would easily facilitate the growth of COFs into 2D structures leveraging their inherent 2D morphology, and is expected to be an effective solution to obtain high-performance 2D COF electrodes.

Herein, two-dimensional (2D) graphene with extremely abundant π-electrons was employed as an electron-donating partner given its high conductivity as well as favorable EDLC contribution. Following this design principle, we synthesized a graphene oxide (GO) monolayer (as the graphene precursor) to couple with Ni-bis(dithiolene)-COFs. The intermolecular hydrogen bonding and the preferred D–A π–π stacking between GO and COFs drove the COF agglomerates to a more isolated morphology toward the formation of a homogeneous COF/rGO hybrid, i.e., the COF/rGO D–A heterojunctions. Hierarchically porous structure obtained in COF/rGO facilitates the entry of electrolyte ions leading to high bulk conductivity. More importantly, the unique D–A interactions favor effective electron transfer from the conductive rGO scaffold to the redox COFs. With these synergetic merits, eventually, the COF/rGO heterojunctions demonstrate excellent electrochemical energy-storage characteristics, including gravimetric specific capacitance (CV) values as high as 367.5 F g⁻¹, and volumetric/gravimetric specific energy densities and power densities as large as 51.0 W h kg⁻¹ and 1.78 kW kg⁻¹, as well as exceptional rate capability and cycling stability (capacitance retention of ≈97.01% after 10 000 cycles).

Results and discussion

The solvothermal reaction of GO in mesitylene/dioxane solutions of TAP and TAPP results in covalent anchoring of TAP or TAPP molecular “pillars” to the surface of GO. The morphologies of GO, TAP-GO, and TAPP-GO were determined by scanning electron microscopy (SEM) and transmission electron microscopy (TEM) (Fig. S1–S3†). TAP-GO and TAPP-GO showed a thin-sheet morphology with slight wrinkles, the same as that of GO. Fourier transform infrared (FT-IR) spectra of GO, TAP-GO, and TAPP-GO were collected and the results are shown in Fig. S4.† The FT-IR spectrum of GO exhibits peaks at 3400, 1725, 1625, 1400, and 1075 cm⁻¹ corresponding to the C–OH group stretching vibrations, the C═O stretching vibrations of the carboxyl group situated at the edges, aromatic C＝C stretching vibrations, O–H deformation vibrations and C–O–C stretching vibrations in epoxide groups, respectively. The three new peaks at 1265, 1515, and 810 cm⁻¹ in the spectrum of TAP/TAPP-GO should be attributed to the C–N stretching vibration, N–H bending, and wag deformation vibration, respectively, which confirm the successful grafting of TAP and TAPP onto the surface of graphene oxide.

Raman analyses were performed to confirm the structures of the obtained graphene materials. The change of $I_D/I_G$ is an important parameter for evaluating the content of graphene defects and the degree of graphitization. The Raman results show that the $I_D/I_G$ of TAP-GO (1.92), TAPP-GO (2.02), and GO (1.58), respectively (Fig. S5†). The higher $I_D/I_G$ of TAP/TAPP-GO than that of rGO indicates that grafting amino groups into GO induced more defects than the graphene surface of GO. FTIR results further confirm the existence of surface –NH₂ groups on TAP/TAPP-GO. Therefore, two unreacted –NH₂ groups on the other side of the TAP and TAPP molecules can be used as molecular nucleation sites and starting points to produce Ni-TAP and Ni-TAPP polymers. As a result, COFs were covalently attached and oriented perpendicular to the graphene surface (Fig. 1a). Taking advantage of the unique electronic structure and redox activity of Ni-bis(dithiolene) centers, Ni-TAP and Ni-TAPP were anticipated to be attractive active materials for supercapacitor electrodes. A facile oxygen-free solvothermal method was adopted with TAP, TAPP, and a Ni-bis(dithiolene)-based linker containing four aldehyde groups (Ni(bded)₂), to synthesize stable polyimide Ni-TAP, and Ni-TAPP materials via Schiff-base condensation, which is illustrated in Fig. 1b. Ni-TAP and Ni-TAPP were synthesized by reacting Ni[bded]₂ with TAP or TAPP in a mixture of o-DCB/n-BuOH in the presence of acetic acid (6 M) at 120 °C for 3 days, which afforded green microcrystalline solids. The resulting metal-containing Ni-TAP and Ni-TAPP exhibit high surface area, good electrical conductivity, regular structure, high crystallinity, and excellent chemical
Their structures were confirmed by PXRD analysis combined with structural simulations using Materials Studio. Pawley refinements gave a PXRD pattern that matched well with the experimental data, as reflected by their negligible differences (Fig. S6†). When synthesizing Ni-TAP and Ni-TAPP with rGO, analogical crystallization behavior in Ni-TAP/rGO or Ni-TAPP/rGO is found (Fig. S7a†), consistent with the theoretical model of AA or AB stacking. Fourier Transform Infrared (FT-IR) spectra were used to characterize the components in the COFs and derived COFs with the introduction of rGO. As shown in Fig. S7b,† the FT-IR spectra of both Ni-TAP/rGO and Ni-TAPP/rGO composites and pristine COFs show a characteristic absorption peak at 1618 cm\(^{-1}\) derived from the vibration of C\(=\)N bonds. Meanwhile, Fig. S8† depicts the FT-IR spectra of pristine COFs and the corresponding monomers (TAP, TAPP). The amidation reaction renders the disappearance of reactive functional groups including amidogen (\(-\text{NH}_2\)) or anhydride (O\(=\text{C}-\text{O}-\text{C}=\text{O}\)), which also demonstrates the formation of the frame structure in the as-prepared products.

In a traditional process without external intervention, structure units of COFs would stack easily face to face due to \(\pi-\pi\) conjugation, as shown in the corresponding SEM images (Fig. 2a–d and S9†). The apparent dispersity and micro-morphologies of Ni-TAP and Ni-TAPP feedstocks stayed almost unchanged even after the ultrasonic procedure (Fig. S10†), indicative of the strong hydrophobicity and the inter-molecular affinity of large \(\pi\)-conjugated Ni-TAP and Ni-TAPP. With the addition of NH\(_2\)-rGO in the solvothermal system, the \(\pi-\pi\) interactions between rGO and the structure units of COFs lead them into single layers of COFs covalently attached and oriented perpendicular to the graphene surface (Fig. 2 and S11, S12†). The coupled energy dispersive spectroscopy (EDS) elemental mapping readily identified the homogeneous presence of the N elements absent in GO (Fig. 2f-i and S13, S14†), implying that Ni-TAP and Ni-TAPP are molecularly distributed throughout the rGO scaffolds via the D–A attraction. In addition, as shown in Fig. S15† Ni TAP/rGO and Ni TAPP/rGO exhibit better hydrophilicity than pure COFs. Unlike large-scale deposition of pure COFs with disordered orientation, in this case, the functional groups in the COF stack are difficult to be fully utilized, which greatly reduces ion mobility. Achieving fewer layers of 2D COF nanosheets will fully expose the active centers inside the COF and shorten the ion diffusion path, which is beneficial for improving the performance of supercapacitors. Unlike the massive deposition of pure COFs with disordered orientation, where the functional groups in COF stacks are difficult to be fully utilized, which greatly reduces the ion mobility, the achievement of few-layered 2D COF nanosheets will make efficient exposure of active centers inside COFs and shorten the ion diffusion paths, beneficial for desirable electrode materials for supercapacitors.

To gain more insights into the D–A interactions between rGO and Ni-TAP or Ni-TAPP, we carried out UV-vis diffuse reflectance spectroscopy (UV-vis DRS). As shown in Fig. 3a, the bulk Ni-TAP and Ni-TAPP powders exhibited absorption peaks at 513 and 617 nm. When assembling into the rGO–\(\pi\)-IDT heterojunctions, a stronger absorption peak appeared at 700 nm, ascribed to the D–A interactions of rGO and COFs.
Fig. 2  (a) SEM image of Ni-TAP; (b) TEM images of Ni-TAP, and corresponding TEM and elemental mapping of single COFs; (c) SEM image of Ni-TAPP; (d) TEM image of Ni-TAPP, and corresponding TEM and elemental mapping of single COFs; (e) SEM image of Ni-TAP/rGO; (f) TEM image of Ni-TAP/rGO; (g) SEM image of Ni-TAPP/rGO; (h) TEM image of Ni-TAPP/rGO; (i and j) HRTEM image of Ni-TAPP/rGO, and the corresponding inverse FFT patterns of HRTEM; (k and l) STEM images of Ni-TAP/rGO and Ni-TAPP/rGO.

Fig. 3  (a) UV–vis DRS spectra; (b) simulated differential charge density of Ni-TAP/rGO, and Ni-TAPP/rGO; XPS spectra of (c) N 1s; (d) C 1s; (e) the conductivity test of Ni-TAP, Ni-TAP/rGO and Ni-TAPP, Ni-TAPP/rGO; (f) N₂ adsorption–desorption isotherms.
Importantly, the unique D–A interactions allowed efficient electron transfer from the redox Ni-TAP and Ni-TAPP molecules to the conductive rGO scaffolds. The charge differential density of COF/rGO from density functional theory (DFT) calculations is depicted in Fig. 3b, where charge re-distribution exists between the COF and rGO. The blue regions on graphene and yellow regions on the COF indicate charge transfer from rGO to the COF via conjugation of π–π stacking, which enhances the stability and promotes electron conduction of COF/rGO. X-ray photoelectron spectroscopy (XPS) spectra of Ni-TAP, Ni-TAPP, Ni-TAP/rGO, and Ni-TAPP/rGO are displayed in Fig. 3c and d. Their elemental compositions are exhibited in wide-scan XPS spectra in Fig. S16.† In the N 1s spectra of Fig. 3c, the N–C peak of Ni-TAP/rGO, and Ni-TAPP/rGO shifts to lower binding energy, implying π–π stacking and electron transfer between the phenyl groups of PIBN and six-member carbon rings of graphene. This is in good agreement with the DFT calculations in Fig. 3b. The emergence of a π–π* satellite peak in Fig. 3d further confirms that Ni-TAP and Ni-TAPP molecules are strongly interacting with rGO in Ni-TAP/rGO and Ni-TAPP/rGO.

The macroscopic conductivity of the material is shown in Fig. 3e (for details see ESI†). After the compounding of rGO, the electrical conductivities of Ni-TAP and Ni-TAPP increased by 2.16 and 2.63 times, respectively. The porous structure of COF hybrids, which decides their practical electrochemical performance, was evaluated by nitrogen adsorption–desorption measurements at 77 K (Figs. 3f and S17†). The Brunauer–Emmett–Teller (BET) surface areas of Ni-TAP, Ni-TAPP/rGO, Ni-TAP, and Ni-TAPP/rGO were determined to be 243 m$^2$ g$^{-1}$, 219 m$^2$ g$^{-1}$, 346 m$^2$ g$^{-1}$, and 306 m$^2$ g$^{-1}$ respectively. In comparison to the parent Ni-TAP and Ni-TAPP, the decreased BET surface areas of Ni-TAP/rGO and Ni-TAPP/rGO can be attributed to the introduction of nonporous rGO, which also supports the successful synthesis of these composite materials. According to the thermogravimetric (TG) profiles (Fig. S18†), the pristine Ni-TAP begins its rapid weight loss at 400 °C, and the final Ni-containing ash has been obtained at 500 °C, whereas weight loss at temperatures higher than 600 °C can still be observed for all the Ni-TAP/rGO samples. The same phenomenon can also be observed when comparing between Ni-TAP and Ni-TAP/rGO, indicating that the strong interaction between COFs and rGO enhances the stability of the composite. To further reflect the increased utilization of COFs in COF/rGO compared to pure COFs, the dispersion of Ni was tested using H$_2$–TPR at temperatures below 400 °C. As shown in Table S1,† whether it is Ni-TAP or Ni-TAPP, the dispersion of Ni is higher when combined with rGO, indicating a higher utilization rate of COFs after composite formation. A series of concrete structural characterization tests combined with morphological observations revealed that the COF/rGO heterojunctions materialized with multiple remarkable advantages suitable for supercapacitors as the central electrode component.

For the electrochemical tests, carbon paper with an area of 1 cm$^{-2}$ with a COF loading of 1 mg was used as the working electrode, a Pt sheet with an area of 1 cm$^{-2}$ was used as the counter electrode, and 6 M KOH was used as the electrolyte, and the potential was referenced against a Hg/HgO electrode internally charged with 1 M KOH. During cyclic voltammetry (CV) analysis, the scan rate was set from 5 mV s$^{-1}$ to a maximum of 100 mV s$^{-1}$. The CV profiles feature a quasi-rectangular shape even at an ultrahigh scanning rate of 100 mV s$^{-1}$, indicating high-rate capability as well as ideal electric double-layer capacitance (EDLC) behavior (Fig. 4a and S19†). The symmetry-shaped GCD profiles of Ni-TAPP/rGO at 0.5–10 A g$^{-1}$ are shown in Fig. 4b, showing a specific capacitance ($C_p$) of 367.5 F g$^{-1}$ at a current loading of 0.5 A g$^{-1}$, and rate capability with 62.94% capacitance retention at 0.5–10 A g$^{-1}$, as shown in Fig. 4c and S20 (ESI†). It can be clearly found that after the compounding of rGO, the specific capacitances of Ni-TAPP/rGO are increased from 318.5 F g$^{-1}$ (0.5 A g$^{-1}$) and 191.9 F g$^{-1}$ (10 A g$^{-1}$) to 367.5 F g$^{-1}$ and 231.3 F g$^{-1}$ compared with that of the non-compounded Ni-TAPP, respectively. The Ni-TAPP/rGO shows more excellent supercapacitor performance in organic frame-like materials, as shown in Fig. 4d. The Ni-TAPP/rGO heterojunctions display specific energy densities and power densities as large as 51.04 W h kg$^{-1}$ and 1.78 kW kg$^{-1}$. We also tested pure GO samples and control samples without covalent structures. The control experiment was conducted under the same solvent thermal reaction conditions, where the COF precursor was reacted with the precursor GO that was not functionalized with TAPP. These composite materials will be named Ni-TAPP-GO to emphasize the absence of covalent bonds between Ni-TAPP and GO. As shown in Fig. S21 and S22,† the results show that GO essentially does not contribute to supercapacitor performance, and heterojunctions constructed lead to supercapacitor performance enhancement. The kinetic analysis and electrochemical storage mechanism of the Ni-TAPP/rGO were analyzed using CV curves measured at different scan rates determined by the power–law relation ($i = a \cdot v^b$, where $i$ and $v$ stand for the current and the scan rate, respectively). The $b$ values of the anodic peak and cathodic peak are determined to be 0.82 and 0.74, suggesting that the capacitance of Ni-TAPP/rGO is predominantly due to capacitance behavior, and supplemented by an internal diffusion process (Fig. 4e). The capacitance contributions of electric double-layer capacitance (EDLC) and pseudocapacitance can be uncovered by the equation of $i = k_1 \cdot v + k_2 \cdot v^{1/2}$, where $k_1 \cdot v$ stands for the fast-kinetics process (EDLC) and $k_2 \cdot v^{1/2}$ represents a low-kinetics process (pseudo-capacitance) (Fig. 4f). The capacitance behavior (EDLC) contributed by the fast-kinetics process dropped from 47.4% to 79.9% with increasing the scan rates from 10 to 200 mV s$^{-1}$ (Fig. 4g). For Ni-TAPP/rGO, its supercapacitor performance is similar to that of Ni-TAPP, and detailed information is shown in Fig. S23.† The Ni-TAP/rGO heterojunctions show a gravimetric capacitance of 346.0 F g$^{-1}$ at 0.5 A g$^{-1}$, and specific energy densities and power densities as large as 48.1 W h kg$^{-1}$ and 1.81 kW kg$^{-1}$, which demonstrates the universality of the heterogeneous synthesis method.

The cycle stability of supercapacitors is a crucial parameter for their practical applications. As shown in Fig. 4h, Ni-TAPP/rGO was subjected to 10,000 consecutive required cyclic charge/discharge tests @ 10 A g$^{-1}$, and Ni-TAPP/rGO showed excellent stability and still maintained a specific capacitance of 97.01%. XRD (Fig. S24†) analyses were performed to characterize the sample
recovered after the reusability test. These results further confirm the excellent stability of Ni-TAP/rGO and Ni-TAPP/rGO for supercapacitors. These preliminary results well supported that the D–A interaction strategy was effective in chemically exfoliating COF acceptor bulks using the giant π-donor of rGO, and the reassembled COF/rGO D–A heterojunctions showed a colossal potential in the energy-storage area.

Conclusions

In summary, we have successfully assembled redox-active Ni-bis(dithiolene)-based COFs and rGO by covalent linkages to form a series of highly efficient heterostructures for high-performance supercapacitors. The obtained Ni-TAP/rGO and Ni-TAPP/rGO heterostructures exhibit an unprecedented specific capacitance \( C_s \) of 367.5 F g\(^{-1}\) at a current loading of 0.5 A g\(^{-1}\). The in situ growth of redox COFs on the surface of rGO and the formation of heterojunctions at the interface greatly promote COF utilization and charge transfer. More importantly, the vertical growth of COFs on the surface of rGO can result in faster ion diffusion. DFT calculations indicate that electrons are rapidly transferred from highly conductive rGO to vertically growing COFs. The above advantages collectively contribute to the outstanding supercapacitor performance of Ni-TAP/rGO and Ni-TAPP/rGO. These results demonstrate that composites with both redox metal-containing COFs and rGO may have potential applications in highly efficient supercapacitors.

Experimental

Experimental section/methods

Synthesis of Ni-TAP/rGO. Ni(bded)_2 (13.1 mg, 0.02 mmol), 2,3,6,7-tetra(4-aminophenyl)pyrene (12.6 mg, 0.02 mmol), and TAP/rGO were charged into a 10 ml Pyrex tube. Then, a mixture of n-BuOH 6 M HOAc (1.2 ml, 1/0.2 by vol) was added to the tube, and the mixture was sonicated for 10 min. The resulting mixture was degassed by freeze–pump–thaw cycles and sealed under vacuum. The sealed tube was heated at 120 °C for 3 days. The solid was collected by centrifugation and washed with methanol and THF. Ni-TAP was then washed with THF in a Soxhlet extractor overnight. The resulting powder was dried at 100 °C under vacuum to yield Ni-TAP (16.7 mg, 65% yield).

Synthesis of Ni-TAPP/rGO. A Pyrex tube (18 × 9 mm outer diameter × inner diameter) was charged with 2H-TAPP (0.02 mmol, 13.5 mg), Ni(bded)_2 (0.02 mmol, 13.1 mg), and TAPP/rGO, 1,4-dioxane (0.75 ml), mesitylene (0.25 ml), and aqueous acetic acid (6 M, 0.2 ml), and the mixture was sonicated for 15 min. After three freeze–pump–thaw cycles, the Pyrex tube was sealed under vacuum and heated at 120 °C for 72 hours. The dark purple precipitate was isolated by filtration and washed with CH₃OH and THF. The dark solid was further washed with THF via Soxhlet extraction for 24 hours. Last, the product was dried at 100 °C under vacuum to yield Ni-TAP (16.7 mg, 65% yield).

Data availability

All relevant data are within the manuscript and its additional files.

Author contributions

The original idea was conceived by J.-L. Z., M.-N. D., and A.-Q. Z.; experiments and data analysis were performed by A.-Q. Z., P. R., X. H., S.-W. K., C.-Q. Q., Z.-D. Z. and Y. L. Structure characterization was performed by A.-Q. Z. and P. R., and the manuscript was drafted by J.-L. Z., M.-N. D., P. R., and A.-Q. Z. All authors have approved the manuscript.
Conflicts of interest
There are no conflicts to declare.

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Notes and references

