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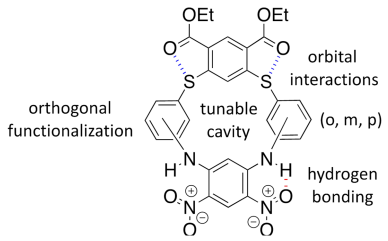

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Versatile synthesis of tunable *N,S*-bridged-[1.1.1.1]-cyclophanes promoted by ester functions

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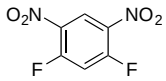
ABSTRACT

We report herein a powerful and highly adaptable metal-free organic synthetic route to functionalized *N,S*- bridged-[1.1.1.1]-cyclophanes using an ester-promoted macrocyclisation step. The newly synthesized cyclophanes are obtained in good yields exhibiting *(i)* high solubility, allowing the possibility to enlarge the scope and chemistry for such macrocycles, (*ii*) a tunable cavity and *(iii)* orthogonal functional groups.

1. Introduction

Cyclophanes[1] are natural or synthetic strained cage-like structures that play a prominent role in host-guest chemistry and supramolecular assemblies. Cyclophanes architectures encompass among others, pillararenes[2] and calixarenes[3] derivatives. They are widely used in a variety of applications including analytical detection or sensing,[4] catalysis,[5] medicine[6] and materials technology.[7] Although these macrocycles can be readily obtained in good yields from commercially available starting materials, their synthesis suffer oftenly of a lack of compatibility with functionalized monomers due to the harsh synthetic conditions used. Indeed, in several cases, it appears difficult to avoid the formation of by-products that render their purifications somewhat tricky and tedious.[8] Therefore, a peculiar attention has to be paid in order to develop efficient synthetic protocols leading to cyclophanes with high yields and under mild conditions.

In this respect, nucleophilic aromatic substitution reactions (S_NAr) appeared to be an attractive synthetic approach that has been successfully applied for the preparation of heteracalix[4]arenes.[9] The reaction requires two entities namely a nucleophile and an electron-poor aromatic ring (acting as an electrophile). A rapid literature survey shows that in most cases, the involved electrophile corresponds to a triazine ring or an aromatic ring bearing electron-withdrawing groups such as CN, SO_3H or NO_2. Among them, the dinitrobenzene derivative **1** has been widely used as electrophile.[9] However the lack of solubility of the obtained macrocycles prevents the possibility to extend their scope and chemistry, as they are only soluble in solvent such as DMF or DMSO. Nevertheless the simplicity, versatility and efficiency of these reactions led us to extend this strategy by widening it to innovative molecular scaffolds that could overcome those drawbacks. For this purpose, aromatic rings substituted with carbonyl groups (C=O); such as ketones, aldehydes, esters and so on; could be envisioned as interesting alternatives. Surprisingly, solely one example, based on a diketo substituted benzene, has been described for the synthesis of soluble symmetrical thiacalix[n]arenes.[10] Moreover, the scarcity of functional groups on these macrocycles can limit considerably their uses. Therefore, the insertion of orthogonal functional groups or atoms either on the aromatic subunits or in the bridges is of great of importance and interest. For all of these reasons, we turned out our attention on the use of the diethyl 4,6-dibromoisophthalate **2** derivative that fulfills all required criteria for the well-established synthetic pathway. Furthermore, to the best of our knowledge, this molecule is hitherto unknown in the macrocyclic chemistry field.



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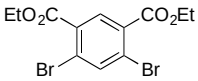

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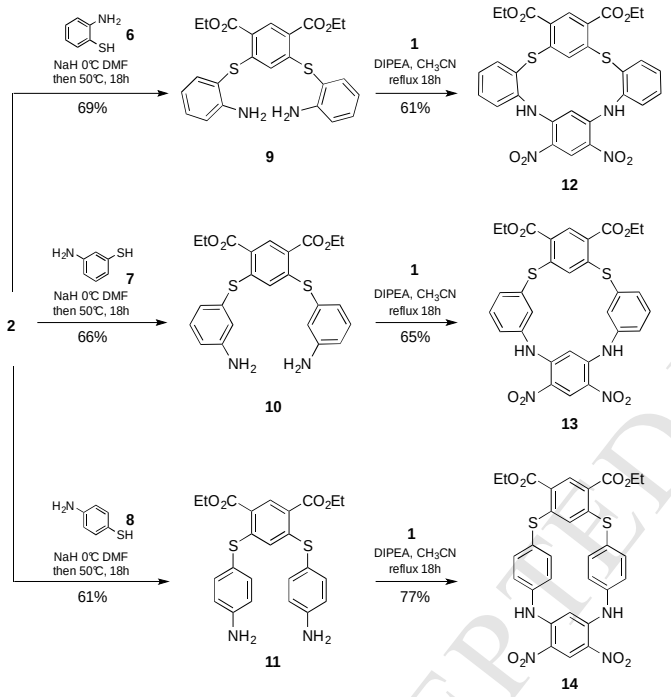
Thus, we describe herein a simple intuitive, iterative and modular synthetic strategy, based on SN_{Ar} reactions of **1** and **2**, that one may give easy access to asymmetric structures in which the orthogonal chemical groups, the sizes cavities and the heteroatoms positions can be finely controlled. For this aim, we have focused our work on the synthesis of mixed *N,S*-[1.1.1.1]-heteraphanes that are at the cross-road of two major classes of macrocycles, namely the thia- and aza-[1.1.1.1]-cyclophanes, in order to combine their concomitant properties.

2. Results and discussion

2.1 Synthesis

Diethyl 4,6-dibromoisophthalate **2** was readily synthetized from *m*-xylene in three steps according to reported literature procedures.[11]

The key intermediate **2** was then further reacted, in presence of NaH in DMF, with 2 equiv. of 3-aminothiophenol **6** leading to the symmetrical triaryl **9** as an off-white solid in 69% yield after purification by column chromatography over SiO_2. Similarly, intermediates **10** and **11** have been prepared by condensation of **2** and 2-aminothiophenol **7** or 4-aminothiophenol **8** to furnish **10** and **11** in 66% and 61% yield, respectively (Scheme 1). The ring closure step was achieved by condensation of the triaryl units **9**, **10** and **11** with 1,5-difluoro-2,4-dinitrobenzene **1** in CH_3CN under reflux over 18 h in presence of N(*i*Pr)$_2$Et. The target *N*,*S*-[1.1.1.1]-heteraphanes precipitated in the reaction medium and were isolated by filtration as orange-yellow solids in 61-77%. All obtained macrocycles have been thoroughly characterized by ^{1}H NMR, ^{13}C NMR, mass spectrometry and elemental analysis.



Scheme 1. Synthesis of mixed *N*,*S*-[1.1.1.1]-heteraphanes **12-14.**

2.2 Crystallographic analysis of intermediates

The macrocyclization step was performed at high concentrated solution. As previously demonstrated for mixed heteracalix[4]arenes,[9i] a pre-organized intermediate controlled by electrostatic interactions[12] between the d orbitals of the sulfur atom (δ^+, due to its conjugation with the diethyl isophthalate ring) and the p orbitals of the oxygen atom (δ^-, of the carbonyl in the adjacent CO_2Et group), might be formed during the course of the reaction, favoring the macrocyclisation step.

This hypothesis is clearly supported in each case by the analysis of the crystallographic structure of the single crystals of **9**, **10** and **11** (Figure 1). Indeed, all crystal structures display a non-planar architecture and the examination of the S--O=C distances (ranging from 2.668 Å < d(S---O=C-OEt) < 2.780 Å) shows that these distances are significantly shorter than the sum of the van der Waals radii of oxygen and sulfur (3.25 Å) which evidences the occurrence of strong intramolecular interactions. This behavior indicates that esters functions are seemingly suitable to replace the nitro group in the engineering of novel cyclophanes even if these intramolecular interactions are slightly weaker comparing to the nitro counterparts.

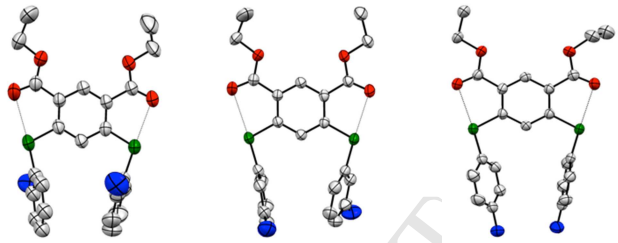
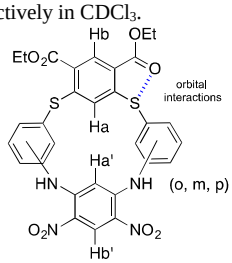


Figure 1. ORTEP view of the pre-organized intermediates **9**, **10** and **11** (black: C; blue: N; green: S and red:O, for clarity H are omitted).

2.3 ^{1}H NMR analysis

In addition, the survey of the ^{1}H NMR spectra reveals that all macrocycles **12-14** adopt preferably the 1,3-alternate conformation as evidenced by the chemical shift observed for the intra-annular protons Ha and Ha' (Table 1). Moreover the inner protons (Ha and Ha') experiencing the diamagnetic shielding of the adjacent aromatic rings can act as internal probes for the size cavity. In addition, the inner proton Ha is slightly outside of the area of maximum shielding comparatively to the Ha' protons located on the nitrogenated part of the *N*,*S*-[1.1.1.1]-heteraphanes which is in accordance with previous results.[9i, 13]

Table 1. Relative chemical shift (ppm) of the inner and outer protons Ha, Ha' and Hb, Hb' respectively in $CDCl_3$.



Chemical shift δ (ppm) in $CDCl_3$ of inner and outer H_x

	δ_{Ha}	$\delta_{Ha'}$	δ_{Hb}	$\delta_{Hb'}$
12	6.31	4.86	8.17	8.99
13	6.34	4.96	8.67	9.25
14	6.91	5.77	8.66	9.29

These data are also consistent with both the presence that limit the conformation changes at the NMR timescale (electrostatic interactions coming from the S atom (δ^+, due to its conjugation with the dinitrobenzene ring) and the oxygen atom (δ^-, in the adjacent C=O group) and hydrogen bonding coming from the N–H----O_2N intramolecular H-bonds) and a strong push-pull conjugation-type effect developed between the bridges (acting as a donor) and the ester or nitro groups (acceptor part). Indeed the measured S-C bond lengths (from crystallographic data of the derivatives **9**,**10**, **11** $d_{(C-S)}$ 1.82Å > $d_{(C-S)o,m,p}$ 1.768-1.778Å > $d_{(C=S)}$ 1.61Å) are comprised between a single and double bond and the measured angles are nearly about 120° (119.22° < θ < 120.32°) suggesting a sp^2 character which induces a quasi-planar geometry of the bridges. These two effects contribute conjointly to restrict thermodynamically the internal rotation.

2.4 Optical and electrochemical properties

The optical properties of these new macrocycles **12-14** have been investigated by UV-Visible spectroscopy in $CHCl_3$ (Figure 2, Table 2) and interesting features can be deduced from their optical spectra. The three novel *N*,*S*-[1.1.1.1]-heteraphanes present the same appearance characterized by three main absorbance bands that are red-shifted from the ortho to the para-substituted derivative. Thus, the lowest energy band corresponding to the charge transfer band, related to the intrinsic push-pull effect of these structures, is almost centered at the same wavelenght for all compounds. Indeed, only a slight red-shift is observed because the push-effect involves only the heteratoms linked to the electron deficient rings which are the same in all cases. However, the main bathochromic shift is observed for the principal π-π* absorbance band originating from the substitution pattern. Therefore the highest red-shift is observed for the para-substituted derivative **14**. Interestingly, depending on the substitution pattern, the macrocycles show a more constrained character resulting in the emergence of a fine vibronic structure. Hence, the most constraintd macrocycle in this series appears to be the heteraphane **12** having the smallest cavity.

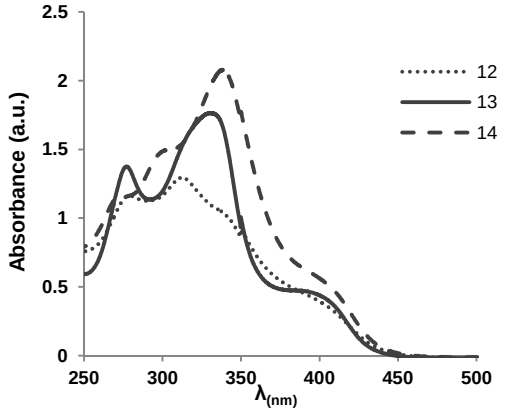


Figure 2. Optical properties for compounds **12**, **13** and **14.**

Table 2. Absorption maximum ($\lambda_{abs,}$ nm) and molar extinction coefficient (log (ε) $L.mol^{-1}.cm^{-1}$) of compounds **12-14** in $CHCl_3$.

12		**13**		**14**	
λ_{abs}	Log ε	λ_{abs}	Log ε	λ_{abs}	Log ε
397	3.95	398	3.99	403	4.06
312	4.44	330	4.56	340	4.64
279	4.40	277	4.48	301	4.51

Analysis of the cyclic voltammograms (CV) of macrocycles **12-14** has revealed similar characteristics. They display two irreversible one-electron reduction redox system corresponding to the formation of the radical anion on each electron poor rings present on the molecular scaffold (Figure 3 - Table 3). All compounds exhibit close values for $E_{1/2}(red_1)$ and $E_{1/2}(red_2)$ as well as for $E_{1/2}(ox_1)$ and $E_{1/2}(ox_2)$ suggesting that both geometric and/or steric parameters as well as the nature of the heteroatoms contribute to these small changes. Indeed, the small variations observed for the reduction potentials can be correlated to the angle formed between the two aromatic rings bearing the ester and nitro electron withdrawing groups. These features are also in agreement with the spectral behaviors.

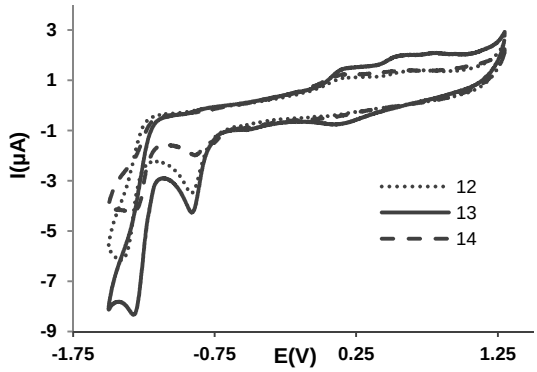


Figure 3. Cyclic voltammograms for compounds **12**, **13** and **14**.

Table 3. Oxidation and reduction potentials for compounds **12**, **13** and **14** 10^{-3} M in DMF, 0.1 M Bu_4NPF_6, Pt (WE) Ag/AgCl v= 100 mV/s.

	$E_{1/2}(ox_1)^{[a]}$	$E_{1/2}(ox_2)^{[a]}$	$E_{1/2}(red_1)^{[a]}$	$E_{1/2}(red_2)^{[a]}$
12	0.14	0.60	-0.92	-1.42
13	0.13	0.51	-0.92	-1.33
14	0.11	0.46	-0.90	-1.33

[a] E (V) vs Ag/AgCl obtained from the deconvulated voltammograms

3. Conclusion

In conclusion, we have herein established a powerful and highly adaptable route to functionalized heteraphanes. Indeed, three novel mixed *N*,*S*-bridged [1.1.1.1]-cyclophanes **12-14** have been effortlessly synthesized via a simple intuitive and modular synthesis based on nucleophilic aromatic substitution reactions (S_NAr). Importantly, we have clearly demonstrated that the ester fragment constitutes a very promising alternative relative to the nitro group, since the newly designed *N*,*S*-diethylcarboxlate-dinitro-heteraphanes compounds are much more soluble compared to their tetranitro analogues. As shown, the CO_2R fragment is able to promote macrocyclisation in high concentrated medium due to the presence of intramolecular interactions. Finally, following the adopted strategy, unprecedented mixed -heteraphanes, associated with various functional groups have been obtained. The methodology has been shown to be valuable and worth to be pursued with the emergence of a novel class of mixed *N*,*S*-heterophanes. Undoubtedly this feature opens new perspectives in cyclophane's chemistry and chemical modifications on esters and nitro functions are now under investigations.

4. Experimental section

4.1 General

All commercially available products and reagents were purchased from Alfa Aesar (mercaptoaniline derivatives; acetonitrile; *N*,*N*-diisopropylethylamine) or Sigma-Aldrich (NaH (60% in mineral oil); anhydrous dimethylformamide; ethanol, cyclohexane, ethylacetate) and used as received. Mercaptoaniline derivatives may be hazardous; handle with care and read the MSDS. Reactions were performed in air unless otherwise specified. TLC analysis was performed on E. Merck silica gel 60 F_{254} precoated plates (0.25 mm) and flash chromatography was performed with the indicated solvent systems using silica gel grade 60 (230-400 mesh). All spectra ^1H and ^{13}C NMR spectra were recorded at 21°C in the indicated solvent with a Jeol spectrometer, operating

at 400 and 101 MHz, respectively. Chemical shifts are reported in δ units, in parts per million (ppm) and the resonance multiplicity in the ^{1}H and ^{13}C NMR were described as s (singlet), d (doublet), t (triplet), m (multiplet). Elemental and MS analyses were performed at the Spectropole of Marseille. Compound **2** was synthetized in three steps as follow: the first step has consisted in the brominating of the m-xylene **3** affording the 1,3-dibromo-4,6-dimethylbenzene **4** in 82% yield as a white solid. The latter one was successfully oxidized using conventional methodology with $KMnO_4$ in a mixture of H_2O/tert-BuOH leading to the 4,6-dibromoisophthalic acid **5** as a white solid in 69% yield. Finally the obtained 4,6-dibromoisophthalic acid **5** was esterified following the procedure described by Wong et al affording diethyl 4,6-dibromoisophthalate **2** in 93% yield as a white solid.

4.2 Synthesis

Bis-1,3-(2-phenyleneamino sulphide) 4,6-diethylisophthalate (9). 2-aminothiophenol **6** 0.550 g (4.40 mmol) was dissolved in 10 mL of dry DMF under an argon atmosphere. To the ice-cooled solution was added portionwise 0.176 g (4.40 mmol) of sodium hydride (60% in mineral oil). The solution was further stirred 10 min. and 0.760 g (2.00 mmol) of diethyl 4,6-dibromoisophthalate **2** was added in one portion. The reaction was allowed to warm up to room temperature and then heated at 50°C for 18 hours. Then the solvent was removed under reduced pressure and the viscous oil obtained was taken up into 100 mL of $CHCl_3$ and the organic phase was washed with 100 mL of water. The organic phase was dried over $MgSO_4$ affording a 1.10 g of crude solid. The crude product was purified by column chromatography over SiO_2 using cyclohexane: ethyl acetate (6:4 then 5:5) affording 648 mg (69%) of an off-white solid. ^{1}H NMR ($CDCl_3$, δ ppm): 8.65 (s, 1H), 7.14 (dd, J = 7.70, 1.50 Hz, 2H), 7.10 (ddd, J = 8.90, 7.60, 1.60 Hz, 2H), 6.56 (td, J = 7.40, 1.10 Hz, 2H), 6.50 (dd, J = 8.10, 1.10 Hz, 2H), 6.28 (s, 1H), 4.43 (q, J = 7.10 Hz, 4H), 3.90 (s, 4H), 1.44 (t, J = 7.10 Hz, 6H). ^{13}C NMR ($CDCl_3$, δ ppm): 165.84, 149.10, 146.99, 137.21, 134.48, 132.06, 123.13, 122.68, 119.10, 115.90, 112.13, 61.54, 14.53. Mp (°C): >193, decomposition. ESI-MS(+): 469.1 ($[M+H]^+$), 491.1 ($[M+Na]^+$), 507.0 ($[M+K]^+$); ESI-MS(-): 467.0 ($[M-H]^-$), 527.1 ($[M+Ac]^-$). EA calc. (%): C 61.52, H 5.16, N 5.98, S 13.69; found (%): C 62.29, H 5.47, N 5.72, S 12.83.

Bis-1,3-(3-phenyleneamino sulphide) 4,6-diethylisophthalate (10). 3-aminothiophenol **7** 0.550 g (4.40 mmol) was dissolved in 10 mL of dry DMF under an argon atmosphere. To the ice-cooled solution was added portionwise 0.176 g (4.40 mmol) of sodium hydride (60% in mineral oil). The solution was further stirred 10 min. and 0.760 g (2.00 mmol) of diethyl 4,6-dibromoisophthalate **2** was added in one portion. The reaction was allowed to warm up to room temperature and then heated at 50°C for 18 hours. Then the solvent was removed under reduced pressure and the viscous oil obtained was taken up into 100 mL of $CHCl_3$ and the organic phase was washed with 100 mL of water. The organic phase was dried over $MgSO_4$ affording a 1.10 g of crude solid. The crude product was purified by column chromatography over SiO_2 using cyclohexane: ethyl acetate (6:4 then 5:5) affording 620 mg (66%) of an off-white solid. ^{1}H NMR ($CDCl_3$, δ ppm): 8.59 (s, 1H), 6.99 (t, J = 7.70 Hz, 2H), 6.62 (m, 6H), 6.42 (s, 1H), 4.41 (q, J = 7.20 Hz, 4H), 2.30 (s, 4H), 1.43 (t, J = 7.20 Hz, 6H). ^{13}C NMR ($CDCl_3$, δ ppm): 165.79, 149.30, 147.45, 133.74, 130.78, 130.47, 125.69, 124.97, 121.75, 116.85, 61.48, 14.52. Mp (°C): >170, decomposition. ESI-MS(+): 469.1 ($[M+H]^+$), 486.1 ($[M+NH_4]^+$), 491.1 ($[M+Na]^+$); ESI-MS(-): 467.1 ($[M-H]^-$), 527.0 ($[M+Ac]^-$). EA calc. (%): C 61.52, H 5.16, N 5.98, S 13.69; found (%): C 61.22, H 5.16, N 5.73, S 12.94.

Bis-1,3-(4-phenyleneamino sulphide) 4,6-diethylisophthalate (11). 4-aminothiophenol **8** 0.550 g (4.40 mmol) was dissolved in 10 mL of dry DMF under an argon atmosphere. To the ice-cooled solution was added portionwise 0.176 g (4.40 mmol) of sodium hydride (60% in mineral oil). The solution was further stirred 10 min. and 0.760 g (2.00 mmol) of diethyl 4,6-dibromoisophthalate **2** was added in one portion. The reaction was allowed to warm up to room temperature and then heated at 50°C for 18 hours (brownish solution). Then the solvent was removed under reduced pressure to afford a brownish residue. The latter was taken into $CHCl_3$ and the organic phase was washed with water. The organic layer was dried over MgSO4, filtered and the solvent was removed under reduced pressure. The crude solid was purified by column chromatography over SiO_2 using cyclohexane: ethyl acetate to afford 573 mg (61%) as an off-white solid. ^{1}H NMR ($CDCl_3$, δ ppm): 8.59 (s, 1H), 7.02 (d, *J* = 8.40 Hz, 4H), 6.56 (d, *J* = 8.40 Hz, 4H), 6.37 (s, 1H), 4.41 (q, *J* = 7.10 Hz, 4H), 1.40 (s, 4H) 1.42 (t, *J* = 7.10 Hz, 6H). ^{13}C NMR ($CDCl_3$, δ ppm): 165.88, 137.24, 134.00, 124.01, 121.20, 117.84, 116.73, 61.37, 14.53. Mp (°C): > 155, decomposition. ESI-MS(+): 469.1 ($[M+H]^+$), 491.1 ($[M+Na]^+$); ESI-MS(-): 467.1 ($[M-H]^-$), 527.1 ($[M+Ac]^-$). EA calc. (%): C 61.52, H 5.16, N 5.98, S 13.69; found (%): C 61.14, H 5.11, N 5.82, S 13.00.

1,21-dithia-8,14-diaza-10,12-dinitro-23,25-diethylcarboxylatecyclophane (12). A mixture of **9** (0.200 g, 0.42 mmol) and 4,6-difluoro-1,3-dinitrobenzene **1** (0.087 g, 0.42 mmol) in 10 mL of dry CH_3CN was heated to reflux until complete dissolution of the materials. Then 0.300 mL (2.76 mmol) of *N*,*N*-diisopropylethylamine was added dropwise. The solution became slightly orange and maintained under reflux over 48h. The reaction mixture was cooled, diluted with dichloromethane, washed with water and brine, dried under $MgSO_4$ and the solvents were removed under reduced pressure. The product was recrystallized from mixture DCM/EtOH, filtered and dried affording 161 mg of the titled macrocycle (61% yield) as an orange solid. ^{1}H NMR ($CDCl_3$, δ ppm): 9.00 (s, 2H), 8.99 (s, 1H), 8.17 (s, 1H), 7.70 (dd, J = 7.60, 1.50 Hz, 2H), 7.37 (td, J = 7.60, 1.50 Hz, 2H), 7.30 (td, J = 7.70, 1.40 Hz, 2H), 7.19 (d, J = 7.70 Hz, 2H), 6.31 (s, 1H), 4.86 (s, 1H), 4.37 (q, J = 7.10 Hz, 4H), 1.41 (t, J = 7.10 Hz, 6H). ^{13}C NMR ($CDCl_3$, δ ppm): 165.21, 147.91, 144.39, 141.47, 138.98, 133.12, 131.64, 131.59, 131.38, 129.23, 128.18, 125.34, 124.98, 99.02, 62.03, 14.37. Mp (°C): > 175, decomposition. ESI-MS(+): 633.1 ($[M+H]^+$), 650.1 ($[M+NH_4]^+$); ESI-MS(-): 631.1 ($[M-H]^-$). EA calc. (%): C 56.95, H 3.82, N 8.86, S 10.14; found (%): C 56.46, H 3.81, N 8.73, S 9.71. FTIR: 3348 cm^{-1}, 2982 cm^{-1}, 2930 cm^{-1}, 2361 cm^{-1}, 2324 cm^{-1}, 1701 cm^{-1}, 1624 cm^{-1}, 1570 cm^{-1}, 1288 cm^{-1}, 1077 cm^{-1}. UV-vis ($CHCl_3$): λ_{max} = 312 nm, $\varepsilon = 2.8 \cdot 10^4$ $L \cdot mol^{-1} \cdot cm^{-1}$.

1,19-dithia-7,13-diaza-9,11-dinitro-21,23-diethylcarboxylatecyclophane (13). A mixture of **10** (0.200 g, 0.42 mmol) and 4,6-difluoro-1,3-dinitrobenzene **1** (0.087 g, 0.42 mmol) in 10 mL of dry CH_3CN was heated to reflux until complete dissolution of the materials. Then 0.300 mL (2.76 mmol) of *N*,*N*-diisopropylethylamine was added dropwise. The solution became slightly orange and maintained under reflux over 18h (after 1 hour a yellow precipitate started to form in the medium). The solution was cooled in the fridge and then filtered off, washed with 20 mL of hot water followed by 30 mL of

ethanol. The obtained solid was dried affording 176 mg of the titled macrocycle (65 % yield) as a yellow solid. ^{1}H NMR ($CDCl_3$, δ ppm): 9.25 (s, 1H), 9.19 (s, 2H), 8.67 (s, 1H), 7.47 (d, J = 7.80 Hz, 2H), 7.39 (t, J = 7.80 Hz, 2H), 7.30 (t, J = 1.60 Hz, 2H), 7.14 (d, J = 7.90 Hz, 2H), 6.34 (s, 1H), 4.96 (s, 1H), 4.44 (q, J = 7.00 Hz, 4H), 1.44 (t, J = 7.20 Hz, 6H). ^{13}C NMR ($CDCl_3$, δ ppm): 165.55, 148.94, 148.57, 139.37, 136.49, 134.28, 132.54, 131.34, 131.07, 128.53, 125.04, 122.92, 122.26, 99.01, 61.80, 14.49. Mp (°C): > 280, decomposition. ESI-MS(+): 633.1 ($[M+H]^+$), 650.1 ($[M+NH_4]^+$), 655.0 ($[M+Na]^+$); ESI-MS(-): 631.1 ($[M-H]^-$). EA calc. (%): C 56.95, H 3.82, N 8.86, S 10.14; found (%): C 56.79, H 3.76, N 8.86, S 10.20. FTIR: 3359 cm^{-1} (δ N-H), 2981 cm^{-1} (δ C-H), 2360 cm^{-1}, 2334 cm^{-1}, 1707 cm^{-1}, 1628 cm^{-1}, 1569 cm^{-1}, 1292 cm^{-1}, 1074 cm^{-1}. UV-vis ($CHCl_3$): λ_{max} = 330 nm, $\varepsilon = 3.7 \cdot 10^4$ $L \cdot mol^{-1} \cdot cm^{-1}$.

1,17-dithia-6,12-diaza-8,10-dinitro-19,21-diethylcarboxylatecyclophane (14). A mixture of **10** (0.200 g, 0.42 mmol) and 4,6-difluoro-1,3-dinitrobenzene **1** (0.087 g, 0.42 mmol) in 10 mL of dry CH_3CN was heated to reflux until complete dissolution of the materials. Then 0.300 mL (2.76 mmol) of *N*,*N*-diisopropylethylamine was added dropwise. The solution became slightly orange and maintained under reflux over 18h (after 30 min a yellow precipitate starts to form in the medium). The reaction mixture was cooled down with an ice bath then filtered off. The obtained yellow solid was washed several times with ethanol and dried affording 0.210 g of the expected macrocycle (77% yield) as a yellow solid. ^{1}H NMR ($CDCl_3$, δ ppm): 9.32 (s, 2H), 9.29 (s, 1H), 8.66 (s, 1H), 7.53 (d, J = 8.40 Hz, 4H), 7.15 (d, J = 8.40 Hz, 4H), 6.91 (s, 1H), 5.77 (s, 1H), 4.45 (q, J = 7.10 Hz, 4H), 1.46 (t, J = 7.10 Hz, 6H). ^{13}C NMR ($CDCl_3$, δ ppm): 147.52, 138.48, 136.34, 128.95, 125.39, 61.86, 14.51. Mp (°C): > 300, decomposition. ESI-MS(+): 633.1 ($[M+H]^+$), 650.1 ($[M+NH_4]^+$), 655.0 ($[M+Na]^+$); ESI-MS(-): 631.1 ($[M-H]^-$). EA calc. (%): C 56.95, H 3.82, N 8.86, S 10.14; found (%): C 56.92, H 3.75, N 8.92, S 10.14. FTIR: 3300 cm^{-1} (δ N-H), 2985 cm^{-1}, 2354 cm^{-1}, 2329 cm^{-1}, 1696 cm^{-1}, 1624 cm^{-1}, 1577 cm^{-1}, 1560 cm^{-1}, 1276 cm^{-1}, 1071 cm^{-1}. UV-vis ($CHCl_3$): λ_{max} = 338 nm, $\varepsilon = 4.4 \cdot 10^4$ $L \cdot mol^{-1} \cdot cm^{-1}$.

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Supplementary data

Supplementary data (Tables of crystallographic data for **9**, **10** and **11**. Copies of NMR spectra) related to this article can be found, in the online version at http://dx.doi.org/xx.xxxx/j.tet.xx.xx.xxx.

Notes and references

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