Thioether-Functionalized Resorcin[4]arene Cavitan­ds: Electroswitchable Molecular Actuators

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Abstract: The utility of molecular actuators in nanoelectronics requires responsiveness to electric charge by mechanical motion at the interface with conductive surfaces. We hence functionalized redox-active resorcin[4]arene cavitan­ds with thioether groups and investigated their propensity to act as electroswitchable actuators that can adopt two conformations in response to changes in external potential. Molecular design was probed by Density Functional Theory (DFT) calculations that suggest covalent binding of the cavitan­ds to the Au surface in a preferentially upward orientation. The electronic properties were experimentally studied by cyclic voltammetry on Au electrodes, while redox interconversion between the oxidized (quinone, **Q**) and reduced (semiquinone radical anion, **SQ**) state was monitored by UV-Vis spectroelectrochemistry and EPR spectroscopy. It was shown that the reduction to the **SQ** dianions induces a conformational change to a closed form, providing the basis for voltage-controlled molecular actuating devices in the future.

Introduction

Molecular actuators can convert external energy inputs into mechanical motion by performing a switch between two conformations upon exposure to various chemical^[1–4] or physical^[5–8] stimuli, such as chemical agents, pH, temperature, or electrochemical processes.^[1] Resorcin[4]arene cavitan­ds were shown to be potential candidates in the development of molecular actuating devices, primarily owing to their conformational switch between the open (kite) and closed (vase) conformation.^[2,5] These nanosystems are relevant in molecular electronics as switches,^[2] sensors,^[9–12] or elements in nanorobotics,^[5,13] while the magnetic representatives are of interest as components of memory devices.^[14,15] The applications of such systems however mainly require control by physical stimuli, such as voltage or light.^[14,16,17] Furthermore, functionalization of molecular actuators for interfacing with conducting surfaces is a prerequisite to their integration into functional devices.^[18–20] While progress has been made in developing strategies for controlled actuation of resorcin[4]arenes, the functionalization of redox-active analogues remains underexplored. In this regard, the lower rim of resorcin[4]arenes was shown to be functionalizable for assembling onto metallic surfaces,^[21] and thioether chains of

medium length (5–10 carbon atoms) were identified as suitable for covalent binding to Au.^[22] In our recent work, we have demonstrated the first electrochemically switchable resorcin[4]arene cavitan­ds.^[14] These systems were based on quinone (**Q**) moieties and were shown to act as paramagnetic molecular switches upon reduction to the semiquinone (**SQ**) radical anion state (Figure 1a). In order to facilitate their installation into electroswitchable nanodevices, their functionalization remains unexplored. Herein, we present a new generation of thioether-functionalized resorcin[4]arene cavitan­ds comprising naphthoquinone (NQ) and triptycene-quinone (TQ) redox-active walls (Figure 1b). Their optoelectronic and conformational properties were studied in solution on Au electrodes by means of cyclic (CV) and rotating disc voltammetry (RDV), UV-Vis spectroelectrochemistry, and EPR spectroscopy, which was complemented by ab initio calculations, with the aim of evaluating their behavior as electroswitchable actuators.

Figure 1. Top: Schematic representation of a binary switch between an open (kite) form in the oxidized **Q** state, and the closed (vase) conformation in the reduced **SQ** radical dianion state of quinone-based cavitan­ds. Bottom: Structure of thioether-functionalized resorcin[4]arene cavitan­ds **1–2** employed in this study. NQ = naphthoquinone; TQ = triptycene-quinone.

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Results and Discussion

Functionalization of resorcin[4]arene cavitands **1** and **2** was performed through an attachment of the corresponding quinone walls **3–4** onto a quinoxaline tetrol platform **5** equipped by thioether chains in the lower rim (Scheme 1, bottom). The installation of the walls followed a common nucleophilic substitution approach^[2,21] under basic reaction conditions employing Cs_2CO_3 as a base, which afforded both cavitands in very good yields. Thioether-functionalized quinoxaline platform **5** was prepared via removal of the two opposite quinoxaline walls in the reaction of the tetraquinoxaline **6** with pyrocatechol as a

nucleophile (Scheme 1, top). The intermediate **6** was accessed via substitution reaction of the quinoxaline wall precursor **7** with resorcin[4]arene octol **8** (crystal structure presented in Figure 2a). The octol **8** was synthesized through condensation of the commercially available resorcinol and the corresponding aldehyde **9**, which was freshly prepared before the reaction by oxidation via pyridinium chlorochromate (PCC) of the alcohol **10**. Preparation of the alcohol involved a synthetic procedure^[22,23] based on the addition of butanethiol onto the terminal olefin bond in presence of 9-borabicyclo(3.3.1)nonane (9-BBN), offering the desired intermediate from pentenol **11** on a multiple gram scale.

Scheme 1. Synthesis of resorcin[4]arene cavitands **1** and **2**. Top: (a) 9-BBN, THF, 20 °C, 3 h, 65% **10**; (b) PCC, CH_2Cl_2 , 20 °C, 5 h, 81% **9**; (c) HCl, EtOH, 0–70 °C, 16 h, 98% **8**; (d) Cs_2CO_3 , DMSO, 50 °C, 16 h, 40% **6**; (e) CsF, DMF, 80 °C, 1.5 h, 55% **3**. Bottom: (a) Cs_2CO_3 , DMF, 70 °C, 2 h, 78% **1**; (b) Cs_2CO_3 , DMF, 50 °C, 72 % **2**. 9-BBN = 9-borabicyclo[3.3.1]nonane; PCC = pyridinium chlorochromate.

DFT calculations of the prospective actuators **1** and **2** on Au(111) surface (Figure 2) indicated that they bind covalently in both redox states, preferentially in an upward orientation, with the thioether groups directly interacting with the surface (for details on the

calculations on the surface refer to Section S8 of the Supporting Information, SI). Moreover, it was shown that the closed conformation in the **SQ** state is energetically more preferred for interaction with the Au(111) surface than the **Q** state.

Figure 2. (a) Crystal structure of quinoxaline cavitaand **6** (*P*-1 space group, for details see Section S3 in the SI) and optimized geometries (DFT B3LYP/6-31G(d)) of the closed conformations of (b) naphthoquinone cavitaand **1** in the **Q** (left) and the **SQ** (right) states, as well as (c) triptycene-quinone cavitaand **2** in the **Q** (left) and the **SQ** (right) states. The thioether groups of the lower rim of cavitaands **1** and **2** are omitted for clarity.

The electronic properties of **1** and **2** were experimentally analyzed by cyclic (CV) and rotating disc (RDV) voltammetry at ambient temperatures. Electrochemical measurements were carried out in CH_2Cl_2 by employing a gold wire (Au) as working electrodes in the presence of ferrocene (Fc^+/Fc) as internal reference. CV of **1** demonstrated three successive reduction waves that were detected at -1.07 V, -1.68 V and -2.21 V (Figure 3a). RDV confirmed that each of the reduction steps occurred as a $2e^-$ processes (Figure 3b). The first reversible $2e^-$ reduction corresponded to the reduction of the two quinone groups and formation of the **SQ** $^{\bullet-}$ radical anions (**2SQ** $^{\bullet-}$) whereas the following quasi-reversible reductions could be attributed to the reduction of the semi-quinone radical anions and the formation of the quinone dianions (**2Q** $^{2-}$) and the quinoxaline reduction, respectively.^[14] The redox properties of the triptycene-quinone **2** were comparable to those of the naphthoquinone **1** (Figure 3c–d), with reduction potentials shifted to more positive values (for more details refer to Section S4 in the SI).

This redox interconversion of thioether-functionalized cavitaands **1–2** between the oxidized quinone (**2Q**) and reduced semiquinone (**2SQ** $^{\bullet-}$) radical anion states was anticipated to induce a change of geometry owing to stronger noncovalent interactions between the neighboring walls in the **SQ** state.^[14] Such conformational properties can be monitored by NMR

spectroscopy^[24] and UV-Vis-NIR spectroelectrochemistry.^[4,14] The geometry of resorcin[4]arene cavitaands in the oxidized **Q** state can be probed by ^1H NMR spectroscopy through observing the chemical shifts of the methine protons, which indicate the open (kite) form by the appearance in the area between 3.5–4.5 ppm, whereas its occurrence at 5.5–6.5 ppm was shown to be indicative of the closed (vase) conformation.^[5,9–11,24] Both cavitaands **1** and **2** in the **Q** state were shown to adopt kite conformations in CDCl_3 at ambient temperatures (for details see Section S2 in the SI). Paramagnetic properties of the cavitaands in the reduced **SQ** radical dianion state were shown to prevent using NMR to evaluate the properties due to fast relaxations in presence of free electrons that lead to disappearance of proton resonances.^[14,15] UV-Vis spectroscopy was thus demonstrated as an alternative method to evaluate conformational properties of quinoxaline-based cavitaands.^[4,14,18,20] Changes in the absorbance in the domain between 300–350 nm, which arise from the absorption of the quinoxaline wall, were shown to be indicators of conformational changes. This absorption band undergoes a hypo-hypochromic shift upon the conformational change from the open to the closed form, which can be used to monitor the actuating motion.^[14,21,22] We thereby relied on UV-Vis-NIR spectroelectrochemistry to monitor the changes in

geometry of the cavitands **1** and **2** in the **SQ** radical anion state (Figure 4).

Figure 3. CV of cavitands (a) **1** and (c) **2** in 0.1 M *n*-Bu₄NPF₆/CH₂Cl₂ at scan rates of 0.1 Vs⁻¹, along with RDV of (b) **1** and (d) **2** on Au electrodes. Ferrocene (Fc⁺/Fc) is used as internal standard.

Figure 4. UV-Vis-NIR spectroelectrochemical study of (a) **1** and (c) **2** at ambient temperature upon electrochemical reduction in 0.1M *n*-Bu₄NPF₆/CH₂Cl₂ in the potential region of the first reduction step at scan rate of 10 mVs⁻¹. Inset shows the corresponding CV at scan rate of 0.01 Vs⁻¹. Differential UV-Vis spectra of (b) **1** and (d) **2** recorded during the reduction in CH₂Cl₂. Disappearance of the absorption at 250 nm corresponds to the **Q** consumption (blue), whereas appearance of

the band with the maximum at 440 nm reflects **SQ** radical anions formation (red). The changes of the Qx absorption at 300–350 nm indicates conformational changes of the cavitand from the open (blue) to the closed (red) conformation.^[14]

UV-Vis-NIR spectra at the first reduction wave of **1** and **2** confirmed the formation of the **SQ** radical anions (**2SQ•**) (Figure 4) through the appearance the absorption in the visible 400–500 nm domain that can be attributed to the SOMO-LUMO transitions.^[14,21,25–27] Furthermore, inspection of the spectroscopic changes in the quinoxaline (Qx) absorption domain at 300–350 nm revealed a hypo-hypsochromic shift of the absorption at 300–350 nm for both cavitands **1** and **2** (Figure 4a–b), which suggested that the conformational change to the closed (vase) form took place, consistent with the behavior of quinone-based cavitands.^[14,23] The complementary information on the geometry in the **SQ** state can be deduced from its paramagnetic properties owing to zero field splitting (ZFS) arising from the interaction of the two unpaired electrons that is a function of the distance between them.^[23] In accordance with the previous reports, the continuous wave (CW) EPR spectrum of the reduced quinone-based cavitands (Figure 5a; for details see Section S6 in the SI) represents a composite signal corresponding to the presence of two paramagnetic species in solution.^[23] The central singlet line can be assigned to the quinone-semiquinone radical monoanion (**Q** - **SQ•**; where only one of the two quinone groups reduced; spin state $S = \frac{1}{2}$), while the signals at the edges of the spectrum to the triplet **2SQ•**; semiquinone radical anions where the two quinone were reduced ($S = 1$). Accordingly, the signal of the **2¹(•)** was simulated using the rhombic g tensor (g_x 2.0073, g_y 2.0053, g_z 2.0019) with principal values determined in accordance with our previous study (green line in Figure 5a; for further details see Section S6, SI). The spectrum of the **2²(•)** semiquinone radical anions can be well reproduced using a rhombic g tensor (g_x 2.0070, g_y 2.0052, g_z 2.0020) and a slightly rhombic, almost axial ZFS tensor characterized by the parameter $D = 79.7$ MHz and $E = 3.9$ MHz (blue line in Figure 5a), which are compatible with analogous systems reported previously. Assuming a dominantly dipolar character of the ZFS tensor and using the point-dipole approximation,^[23] the distance of 9.9 ± 0.5 Å between the two unpaired electrons can be estimated. This value is in good agreement with the distance between the two quinone rings in the closed conformation of the functionalized cavitand, confirming the closed geometry in the triplet dianion state.

This finding suggested that the actuating motion took place upon redox interconversion to the **SQ** radical anions state (**2SQ•**). Reversibility of this process was assessed by monitoring the evolution of the **SQ** absorption in the UV-Vis spectrum (Figure 5b). Reversible changes of the absorption at 456 nm, 340 nm, and 247 nm over several reduction-oxidation cycles confirmed that the redox interconversion between the **Q** and **SQ** states ensued with remarkable reversibility, particularly in the case of triptycene-quinone **2**. Cavitand **1** demonstrated two stepwise changes of the absorption at 340 nm and 247 nm (for details see Section S5 in the SI), which was likely to indicate that the conformational change took place on a slower timescale compared to the redox interconversion. This was not evident for the triptycene-quinone **2** (Figure 5b), presumably as the

conformational switch occurred at a faster rate. This finding further suggests the potential of such host molecules to act as molecular grippers,^[5,14,28–30] whose assembly on Au surfaces is a subject of an ongoing research in our group. These studies promise to provide the basis for designing molecular actuators for conductive surfaces towards development of future nanoactuators in molecular electronics.

Figure 5. (a) X-band (9.4 GHz) cw EPR spectrum of 0.5 mM **2** in CH_2Cl_2 reduced with two-fold excess of CoCp_2 at 100K (black). Red dotted lines show the simulation. The green and the blue lines show the contributions of the monoanionic ($S = \frac{1}{2}$) and dianionic ($S = 1$) species in the simulated spectra, respectively. (b) Evolution of the UV-Vis-NIR spectra of **2** over several switching cycles upon electrochemical reduction in the potential region of the first reduction step illustrating the reversibility of the **Q-SQ** interconversion. For the corresponding details on cavitand **1**, please refer to the Supporting Information.

Conclusions

In summary, this study presents an investigation of thioether-functionalized cavitands **1** and **2**, whose electronic and actuating properties were probed by DFT calculations on Au surfaces and evaluated via electrochemical and UV-Vis-NIR spectroelectrochemical studies on Au electrodes complemented by EPR spectroscopy. Furthermore, high reversibility of the redox interconversion between the **Q** and **SQ** state was shown to be accompanied by a conformational change from an open to a closed conformation upon electrochemical reduction for both **1**

and **2** in the **SQ** state. These findings revealed the capacity of these functionalized systems to act as electroswitchable molecular actuators at the interface with conductive surfaces, which sets the stage for the development of molecular actuating devices in the future.

Experimental Section

General Information. Synthesis of compounds **1–2** was performed by using precursors **3–9** that were prepared according to modified literature procedures by using commercially available resorcinol, 4-penten-1-ol, 1-butanethiol, 2,3-dichloroquinoxaline, and 2,3-dichloronaphthoquinone. The procedures and characterization of the compounds are reported in the Supporting Information, which also contains the information on NMR, EPR, spectroscopy, crystal structure data, electrochemistry, UV-Vis spectroelectrochemistry, and DFT calculations.

Electroswitching Studies. Electronic properties were analysed by cyclic (CV) and rotating disc voltammetry (RDV) in conjugation with UV-Vis spectroelectrochemistry (SEC) and EPR spectroscopy. Electrochemical measurements were carried out in CH₂Cl₂ containing 0.1 M *n*-Bu₄NPF₆ in a classical three-electrode cell by employing either a glassy carbon disk (GC, 3 mm in diameter) or a gold wire (Au) electrode as a working electrode, Pt wire as an auxiliary, and another Pt wire as a pseudo reference electrode. Ferrocene (Fc⁺/Fc) was used as internal reference. UV-Vis spectroelectrochemical experiments were performed in situ with 1–2 mM sample solution in degassed CH₂Cl₂ and 0.2 M *n*-Bu₄NBF₄ as the supporting electrolyte. A three-electrode arrangement with Pt mesh as WE, glassy carbon CE and Ag wire as pseudoreference electrode was used in a thin layer optical cell with KBr windows. Further details can be found in the Supporting Information.

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Keywords: molecular actuators • electroswitch • supramolecular chemistry • host-guest systems • molecular devices

- [1] (a) C. Song, T. M. Swager, *Org. Lett.* **2008**, *10*, 3575–3578. (b) V. J. Chebny, R. Shukla, S. V. Lindeman, R. Rathore, *Org. Lett.* **2009**, *11*, 1939–1942; (c) H. J. Shepherd, I. Gural'skiy, C. M. Quintero, S. Tricard, L. Salmon, G. Molnar, A. Bousseksou, *Nat. Commun.* **2013**, *4*, 2607.
- [2] V. A. Azov, A. Beeby, M. Cacciarini, A. G. Cheetham, F. Diederich, M. Frei, J. K. Gimzewski, V. Gramlich, B. Hecht, B. Jaun, T. Latychevskaia, A. Lieb, Y. Lill, F. Marotti, A. Schlegel, R. R. Schlittler, P. J. Skinner, P. Seiler, Y. Yamakoshi, *Adv. Funct. Mater.* **2006**, *16*, 147–156.
- [3] M. Frei, F. Marotti, F. Diederich, *Chem. Commun.* **2004**, 1362–1363.
- [4] P. J. Skinner, A. G. Cheetham, A. Beeby, V. Gramlich, F. Diederich, *Helv. Chim. Acta* **2001**, *84*, 2146–2153.
- [5] I. Pochorovski, F. Diederich, *Acc. Chem. Res.* **2014**, *47*, 2096–2105.
- [6] R. Kakavandi, S.-A. Savu, A. Caneschi, M. B. Casu, *J. Phys. Chem. C* **2013**, *117*, 26675–26679.
- [7] O. B. Berryman, A. C. Sather, J. Rebek Jr., *Chem. Commun.* **2010**, *47*, 656–658.
- [8] J. R. Moran, S. Karch, D. J. Cram, *J. Am. Chem. Soc.* **1982**, *104*, 5826–5828.
- [9] M. Suman, M. Freddi, C. Massera, F. Ugozzoli, E. Dalcaneale, *J. Am. Chem. Soc.* **2003**, *125*, 12068–12069.
- [10] M. Melegari, M. Suman, L. Pirondini, D. Moiani, C. Massera, F. Ugozzoli, E. Kalenius, P. Vainiotolo, J. C. Mulatier, J. P. Dutasta, E. Dalcaneale, *Chem. Eur. J.* **2008**, *14*, 5772–5779.
- [11] F. Bertani, N. Riboni, F. Bianchi, G. Brancatelli, E. S. Sterner, R. Pinalli, S. Geremia, T. M. Swager, E. Dalcaneale, *Chem. Eur. J.* **2016**, *22*, 3312–3319.
- [12] L. Pirondini, E. Dalcaneale, *Chem. Soc. Rev.* **2007**, *36*, 695–706.
- [13] I. Pochorovski, M.-O. Ebert, J.-P. Gisselbrecht, C. Boudon, W. B. Schweizer, F. Diederich, *J. Am. Chem. Soc.* **2012**, *134*, 14702–14705.
- [14] J. Milic, M. Zalibera, I. Pochorovski, N. Trapp, J. Nomrowski, D. Neshchadin, L. Ruhlmann, C. Boudon, O. S. Wenger, A. Savitsky, W. J. Phys. Chem. Lett. **2016**, *7*, 2470–2477.
- [15] S. Nakatsuji, *Chem. Soc. Rev.* **2004**, *33*, 348–353.
- [16] T.-H. Shin, J. Cheon, *Acc. Chem. Res.* **2017**, *50*, 567–572.
- [17] J. Wang, K. M. Manesh, *Small* **2010**, *6*, 338–345.
- [18] D. Xiang, X. Wang, C. Jia, T. Lee, X. Guo, *Chem. Rev.* **2016**, *116*, 4318–4440.
- [19] L. Sun, Y. A. Diaz-Fernandez, T. A. Gschneidner, F. Westerlund, S. Lara-Avila, K. Moth-Poulsen, *Chem. Soc. Rev.* **2014**, *43*, 7378–7411.
- [20] E. Moulin, J.-J. Cid, N. Giuseppone, *Adv. Mater.* **2012**, *25*, 477–487.
- [21] V. A. Azov, P. J. Skinner, Y. Yamakoshi, P. Seiler, V. Gramlich, F. Diederich, *Helv. Chim. Acta* **2003**, *86*, 3648–3670.
- [22] Y. Yamakoshi, R. R. Schlittler, J. K. Gimzewski, F. Diederich, *J. Mater. Chem.* **2001**, *11*, 2895–2897.
- [23] Y. Masuda, M. Hoshi, Y. Nukawa, A. Arase, *J. Chem. Soc., Chem. Commun.* **1991**, 1444–1445.
- [24] V. A. Azov, B. Jaun, F. Diederich, *Helv. Chim. Acta* **2004**, *87*, 449–462.
- [25] T. N. V. Karsili, D. Tuna, J. Ehrmaier, W. Domcke, *Phys. Chem. Chem. Phys.* **2015**, *17*, 32183–32193.
- [26] Q. A. Huchet, B. Kuhn, B. Wagner, N. A. Kratochwil, H. Fischer, M. Kansy, D. Zimmerli, E. M. Carreira, K. Müller, *J. Med. Chem.* **2015**, *58*, 9041–9060.
- [27] N. Van Anh, R. M. Williams, *Photochem. Photobiol. Sci.* **2012**, *11*, 957–961.
- [28] I. Pochorovski, J. Milic, D. Kolarski, C. Gropp, W. B. Schweizer, F. Diederich, *J. Am. Chem. Soc.* **2014**, *136*, 3852–3858.
- [29] I. Pochorovski, C. Boudon, J.-P. Gisselbrecht, M.-O. Ebert, W. B. Schweizer, F. Diederich, *Angew. Chem. Int. Ed.* **2012**, *51*, 262–266; *Angew. Chem.* **2012**, *124*, 269–273.
- [30] S. R. Miller, D. A. Gustowski, Z.-H. Chen, G. W. Gokel, L. Echegoyen, K. E. Angel, *J. Electroanal. Chem.* **1988**, *60*, 2021–2024.

COMMUNICATION

Thioether-functionalized quinone-based resorcin[4]arene cavitands act as electroswitchable molecular actuators at the interface of conductive surfaces by reversibly contracting upon electrochemical reduction. Their conformational and optoelectronic properties reveal a promising platform for molecular actuating devices.

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