CAPACITIVE SENSORS BASED ON SPIN COATED MACROCYCLIC COMPOUNDS FOR DETERMINATION OF AMINO ACIDS

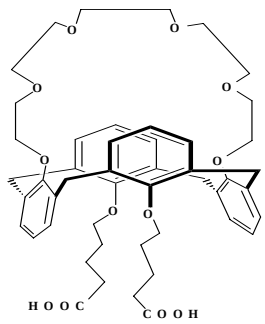
V. S. Ijeri[a, c], F. Vocanson[b], C. Martelet[a], N. Jaffrezic-Renault[a]

a) CEGELY, Ecole Centrale de Lyon, Ecully cedex 69134, France
b) LACE, UMR CNRS, 5634, Université Lyon I, Villeurbanne 69622, France
c) Department of Chemistry, Langelandsgade 140, University of Aarhus, Aarhus 8000, Denmark

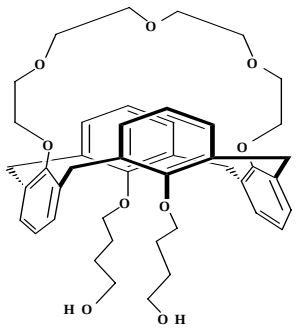
Motivation for the work: **Electrode surfaces can be modified with suitable receptor or catalytic molecules to enhance the specificity and / or reactivity to give electrochemical sensors. Electrochemical sensors form the largest group of chemical sensors[1], but there are hardly any sensors for amino acids. Most of the electrochemical sensors reported are for the easily oxidisable amino acids like tryptophan, tyrosine and cysteine, and a few enzyme based electrodes[2,3]. The possibility of using capacitive sensors for determining amino acids that are neither electroactive nor with strong UV / VIS absorption has been explored.**

Procedure: **The sensors were fabricated by spincoating calixarene derivatives on Si / SiO_2 / Si_3N_4 transducers or the so-called EIS (electrolyte – insulator – semiconductor) structures. The capacitance measurements were made in sulphuric acid media of pH ~ 1 and in physiological buffer of pH 7.4 at 10 kHz frequency over the range of – 500 to + 2800 mV vs. SCE.**

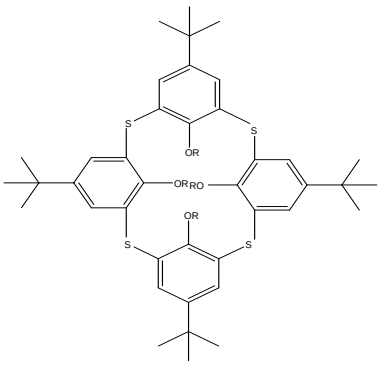
Macrocyclic compounds synthesized for the study



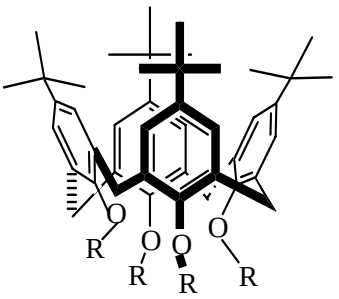
(1)
1,3-(Diethyl-5-oxavaleric Acid)-calix[4]arenecrown-6



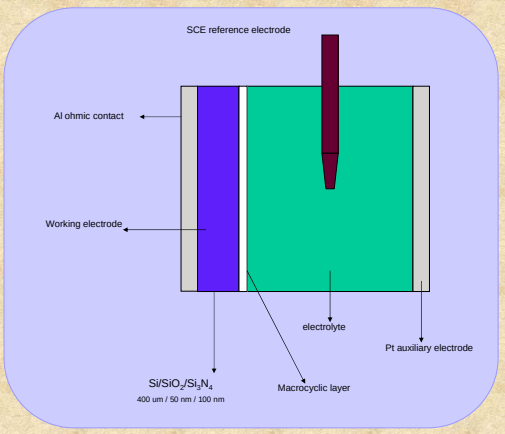
(2)
1,3-(Di-4-oxabutanol)-calix[4]arene-crown-5



(3)
Tetraethyl *p-tert*-butylthiacalix[4]arene tetraacetate



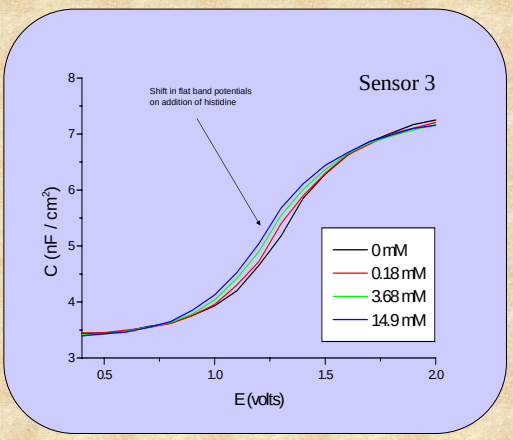
$R = CH_2COOCH_2CH_3$
(4)
Tetraethyl *p-tert*-butylcalix[4]arene tetraacetate



Both calixarenes, as well as crown ethers are known to form complexes with organic amines in solutions[4,5].

The shift in the flat band potentials with the addition of amino acids is indicative of charge effects and correlated with the complexation phenomena which can be used quantitatively.

Sensors with compounds 1, 2 and 4 showed negligible response to change in concentrations of amino acids in physiological buffer due to competition from Na and K ions, but fairly good responses in sulphuric acid media. But sensor 3 with sulphur atoms was less sensitive to interference from Na and K ions, hence proved to be best among the four sensors here.

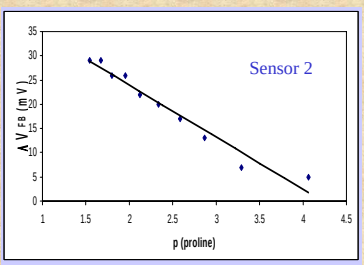


Amino acids	Sensor 1 In H_2SO_4 Slope (mV/decade) Linear range (M)	Sensor 2 In H_2SO_4 Slope (mV/decade) Linear range (M)	Sensor 3 In PBS Slope (mV/decade) Linear range (M)	Sensor 3 In H_2SO_4 Slope (mV/decade) Linear range (M)	Sensor 4 In H_2SO_4 Slope (mV/decade) Linear range (M)
Glycine	11.9 $1.7 \times 10^{-2} - 1.3 \times 10^{-4}$	13.8 $1.5 \times 10^{-2} - 2.7 \times 10^{-4}$	20.3 $2.1 \times 10^{-2} - 2.6 \times 10^{-4}$	35.8 $1.5 \times 10^{-2} - 3.6 \times 10^{-4}$	32.9 $1.8 \times 10^{-2} - 3.6 \times 10^{-4}$
Lysine	*	9.3 $1.8 \times 10^{-2} - 1.3 \times 10^{-4}$	27.5 $3.7 \times 10^{-3} - 1.8 \times 10^{-4}$	43.2 $1.5 \times 10^{-2} - 1.7 \times 10^{-4}$	45.7 $1.3 \times 10^{-2} - 1.4 \times 10^{-4}$
Proline	*	12.9 $2.1 \times 10^{-2} - 5.1 \times 10^{-4}$	19.8 $1.7 \times 10^{-2} - 2.6 \times 10^{-4}$	22.3 $1.7 \times 10^{-2} - 1.4 \times 10^{-4}$	21.3 $1.7 \times 10^{-2} - 1.4 \times 10^{-4}$
Histidine	*	12.8 $2.5 \times 10^{-2} - 2.7 \times 10^{-4}$	24.8 $1.5 \times 10^{-2} - 1.8 \times 10^{-4}$	33.8 $1.8 \times 10^{-2} - 1.4 \times 10^{-4}$	31.8 $1.8 \times 10^{-2} - 1.4 \times 10^{-4}$
Asparagine	7.7 $1.5 \times 10^{-2} - 6.8 \times 10^{-4}$	10.8 $1.3 \times 10^{-2} - 1.4 \times 10^{-4}$	17.0 $7.7 \times 10^{-3} - 2.3 \times 10^{-4}$	50.5 $1.3 \times 10^{-2} - 1.4 \times 10^{-4}$	48.3 $1.3 \times 10^{-2} - 1.4 \times 10^{-4}$
Aspartic acid	4.8 $5.6 \times 10^{-3} - 6.4 \times 10^{-5}$	5.2 $5.1 \times 10^{-3} - 9.4 \times 10^{-5}$	137.6 $7.7 \times 10^{-3} - 6.3 \times 10^{-4}$	38.4 $5.5 \times 10^{-3} - 5.4 \times 10^{-5}$	32.4 $5.9 \times 10^{-3} - 5.4 \times 10^{-5}$
Glutamine	7.9 $1.5 \times 10^{-2} - 2.3 \times 10^{-4}$	8.9 $1.1 \times 10^{-2} - 1.4 \times 10^{-4}$	17.1 $8.8 \times 10^{-3} - 4.6 \times 10^{-5}$	53.2 $1.6 \times 10^{-2} - 1.4 \times 10^{-4}$	51.4 $1.4 \times 10^{-2} - 1.6 \times 10^{-4}$
Glutamic acid	6.9 $1.4 \times 10^{-3} - 5.2 \times 10^{-5}$	9.6 $1.2 \times 10^{-3} - 1.0 \times 10^{-5}$	127.8 $9.3 \times 10^{-3} - 3.4 \times 10^{-4}$	41.7 $4.1 \times 10^{-3} - 5.5 \times 10^{-5}$	31.5 $4.2 \times 10^{-3} - 5.5 \times 10^{-5}$
Albumin	*	*	103.2 $2.2 \times 10^{-5} - 3.4 \times 10^{-7}$	11.6 $2.2 \times 10^{-5} - 2.1 \times 10^{-7}$	10.6 $2.2 \times 10^{-5} - 2.1 \times 10^{-7}$

The different sensors showed varying levels of selectivity and sensitivity for the different amino acids as shown in the table.

The EIS structures could be reused after alternate washings with dilute sulphuric acid and distilled water.

Between repeated uses, they can be stored in airtight containers at 4 °C for about 2 months.



Conclusions and future prospects

This preliminary study has revealed the possibility of using the calixarene coated EIS structures for determination of non-electroactive and non-absorbing amino acids by capacitance measurements. The only common method used till now for such amino acids was chromatography or derivatization. Designing of suitable receptors can further improve the selectivity and / or sensitivity of such sensors. As the responses are non Nernstian, further studies at different pH will lead to a better understanding of the sensing phenomena and could lead to commercially useful sensors.

References

1) Bakker, E., Diaz, M. T. *Anal. Chem.*, **2002**, *74*, 2781.
2) Jin, G. P., Lin, X. Q. *Electrochem. Comm.*, **2004**, *6*, 454.
3) Alaejos, M. S., Montelongo, F. J. G. *Chem. Rev.*, **2005**, *104*, 3239.
4) Gokel, G. W., Leevy, W. M., Weber, M. E. *Chem. Rev.*, **2005**, *104*, 2723.
5) Abraham, W. *J. Inclusion Phenomena and Macrocyclic Chem*., **2002**, *43*, 159.

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