

Controlling Performance of Lipase Immobilised on Bioinspired Silica

Supporting Information

Claire Forsyth and Siddharth V Patwardhan^{*}

Department of Chemical and Process Engineering, University of Strathclyde, 75
Montrose Street, Glasgow G1 1XJ, U.K.

^{*}E-mail: Siddharth.Patwardhan@strath.ac.uk, Telephone: +44-141-548-5786

Table S1. Comparison of Methods for Silica synthesis

Method/ product	Reagents	Steps	t /min	T /°C	Ref.
Bioinspired (reported herein)	Na-silicate Ethyleneamine ^a Water HCl	Synthesis + immobilisation	5	20	1, 2
		Centrifugation and washing	45	20	
		Vacuum drying	300	40	
		Total synthesis time	5		
MCM-41	Na-silicate Sulphuric acid Surfactant Water	Gel Formation	120	20	3, 4
		Aging	8640	100	
		Filtration and washing	60	20	
		Drying	960	20	
		Calcination	480	550	
		Enzyme Immobilisation	~1440 ^c		
		Total synthesis time	8760		
Stöber	TEOS ^b Alcohol Ammonia ^b	Mixing and Condensation	15	20	5, 6
		Reaction	720	20-80	
		Centrifugation and washing	30	20	
		Drying	720	70	
		Enzyme Immobilisation	~1440 ^c		
		Total synthesis time	735		
SBA-15	P-123 CTAB TEOS ^b Amine ^b Ethanol HCl, Water	Solution preparation	60	20	7, 8
		Stirring	120	40	
		Aging	1440	80	
		Calcination	360	550	
		Functionalisation	1440	20	
		Filtration and washing	60	20	
		Drying	720	80	
		Enzyme Immobilisation	~1440 ^c		
		Total synthesis time	1620		
Sponge Mesoporous Silicas	TEOS ^b Dodecylamine ^a Lecithin, Lactose Ethanol, Water	Reagent mixing	15	20	9
		Synthesis + immobilisation	1440	20	
		Drying	1440	50	
		Total synthesis time	1455		

TEOS: tetraethyl orthosilicate; P-123: non-ionic triblock copolymer; CTAB: Cetyltrimethylammonium Bromide. ^a Low toxicity. ^b Highly toxic, TEOS can cause blindness by depositing silica in eyes. ^c Post-synthetic enzyme immobilisation typically takes up to 24 hours either by chemical tethering or adsorption. N.B. slight variations occur within methods

Table S2- Data obtained from SLS/DLS

Method	Decay Rate (ms ⁻¹)	Diffusion Coefficient (m ² /s)	Average Hydrodynamic Radius (nm)	Mean Intensity (a.u.)
PEHA	0.035	1.00E-13	2400 ±100	4700
TEPA	0.043	1.43E-13	1700 ±100	2000
TETA	0.061	1.74E-13	1400 ±100	1300
DETA	0.070	2.00 E-13	1200 ±100	1000

Table S3- BET analyses of gas adsorption results

Method	Surface Area [m ² /g]	Pore Volume [cm ³ /g]	Pore Diameter [nm]
PEHA	15.6 ± 0.1	0.06	13
TEPA	13.2 ± 0.1	0.05	16
TETA	12.8 ± 0.2	0.04	22

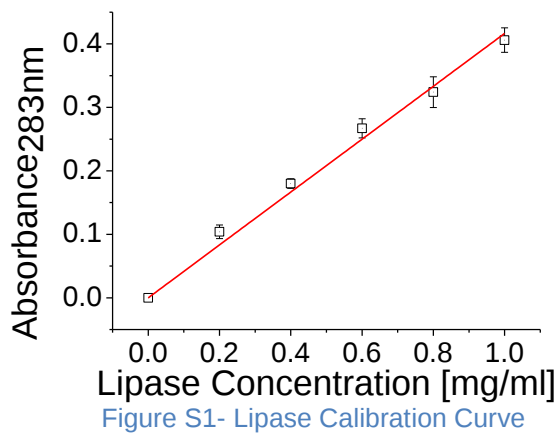


Figure S1- Lipase Calibration Curve

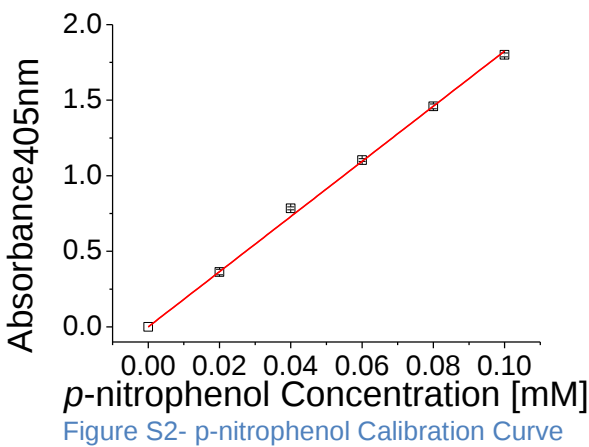


Figure S2- p-nitrophenol Calibration Curve

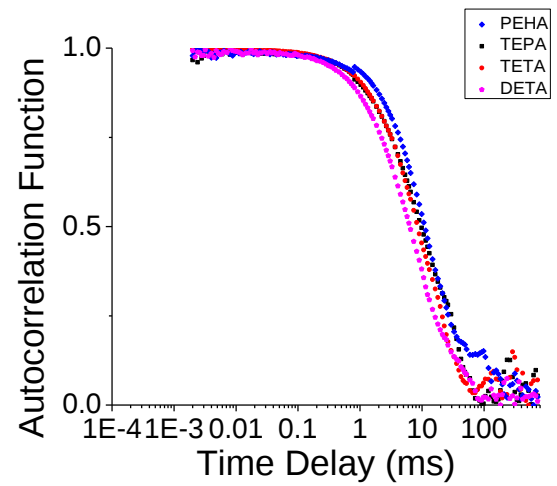


Figure S3- DLS Autocorrelation Functions for Immobilised Enzymes

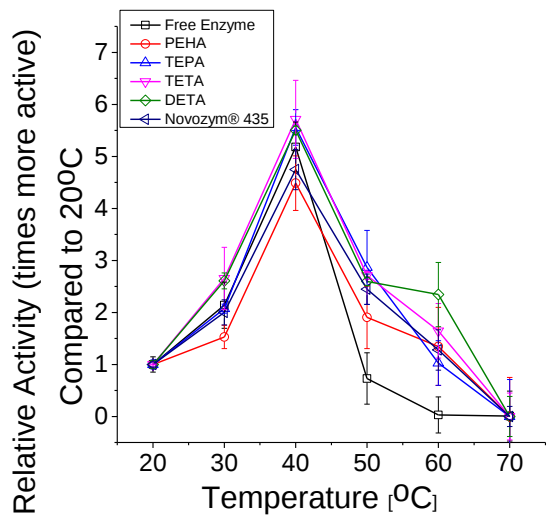


Figure S4- Relative Activity at Various Temperatures

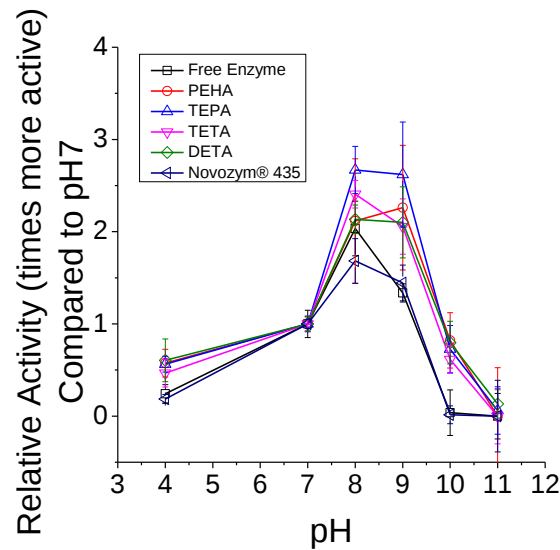


Figure S5- Relative Activity at Various pH Conditions

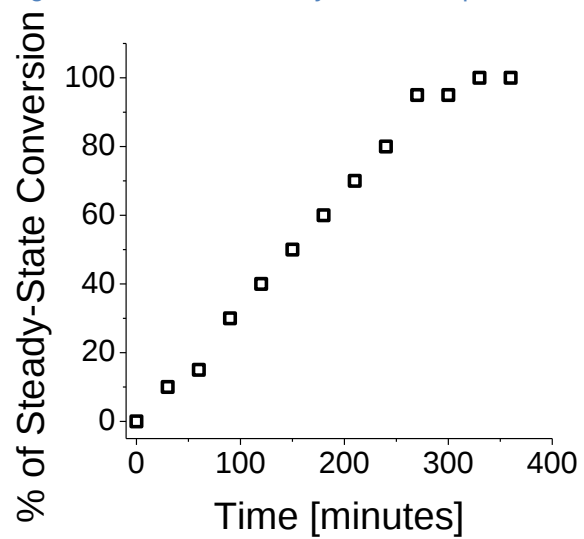


Figure S6- Enzyme activity in a reactor relative to the steady state activity as a function time.

References:

1. D. J. Belton, S. V. Patwardhan, V. V. Annenkov, E. N. Danilovtseva and C. C. Perry, *Proceedings of the National Academy of Sciences of the United States of America*, 2008, **105**, 5963-5968.
2. C. Perry and S. Patwardhan, *Silicon*, 2010, **2**, 33-39.
3. J. S. Beck, J. C. Vartuli, W. J. Roth, M. E. Leonowicz, C. T. Kresge, K. D. Schmitt, C. T. W. Chu, D. H. Olson, E. W. Sheppard, S. B. McCullen, J. B. Higgins and J. L. Schlenker, *Journal of the American Chemical Society*, 1992, **114**, 10834-10843.
4. C. T. Kresge, M. E. Leonowicz, W. J. Roth, J. C. Vartuli and J. S. Beck, *Nature*, 1992, **359**, 710-712.
5. W. Stober, A. Fink and E. Bohn, *Journal of Colloid and Interface Science*, 1968, **26**, 62-&.
6. K. Nozawa, H. Gailhanou, L. Raison, P. Panizza, H. Ushiki, E. Sellier, J. P. Delville and M. H. Delville, *Langmuir*, 2005, **21**, 1516-1523.
7. M. Vinoba, M. Bhagiyalakshmi, S. K. Jeong, Y. I. Yoon and S. C. Nam, *Colloids and Surfaces B-Biointerfaces*, 2012, **90**, 91-96.
8. H. Jaladi, A. Katiyar, S. W. Thiel, V. V. Gulians and N. G. Pinto, *Chemical Engineering Science*, 2009, **64**, 1474-1479.
9. A. Galarneau, M. Mureseanu, S. Atger, G. Renard and F. Fajula, *New Journal of Chemistry*, 2006, **30**, 562-571.