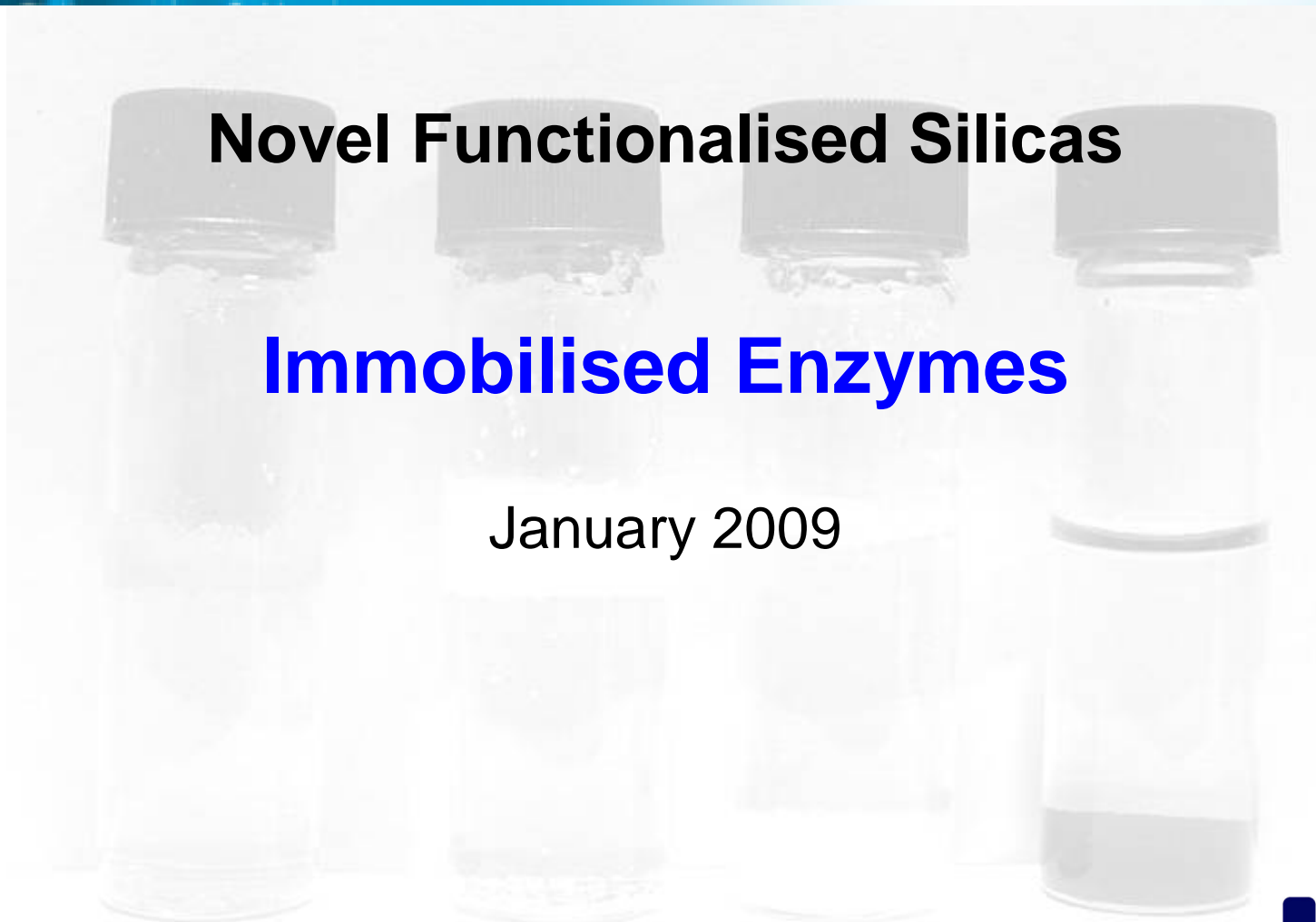




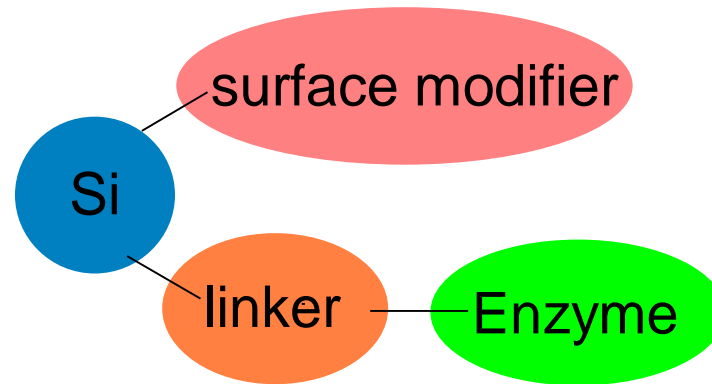
Novel Functionalised Silicas

Immobilised Enzymes

January 2009



PhosphonicS™ Technology



- Expertise in immobilisation onto **functionalised silicas**
- **Scalable, cost-effective** technology
- **Track record at scale:** Process to Manufacture – scavenging & catalysis
- **High performance & stability** under **broad process conditions**
 - pH (up to 10)
 - high temperatures
 - aqueous or organic solvents
- **Enzyme immobilisation applications now developed & successfully tested externally**

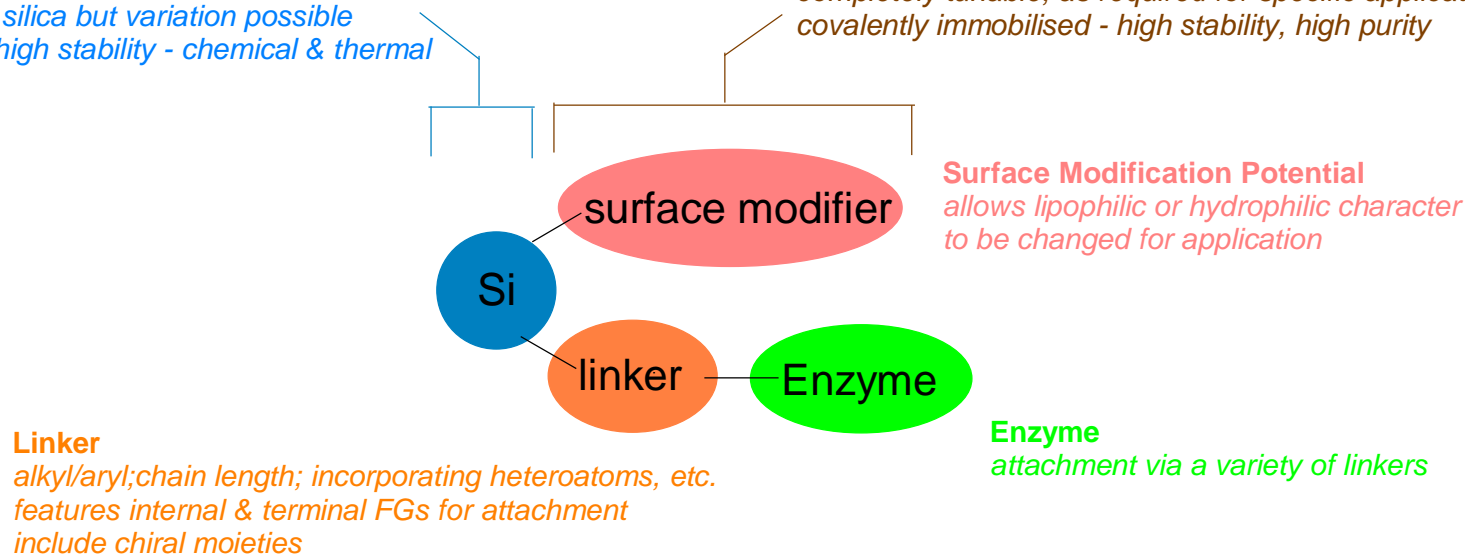
PhosphonicS™ IE Technology

Inorganic Support

*tunable properties e.g. particle size & pore size
typically silica but variation possible
imparts high stability - chemical & thermal*

Organic Fragment for Task (Surface Modifier & Linker)

*completely tunable, as required for specific applications
covalently immobilised - high stability, high purity*



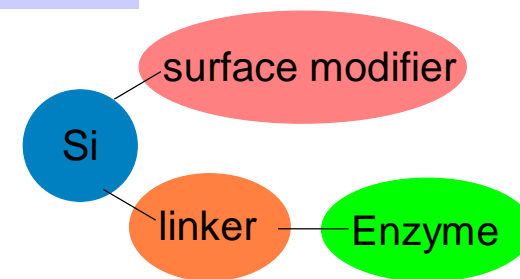
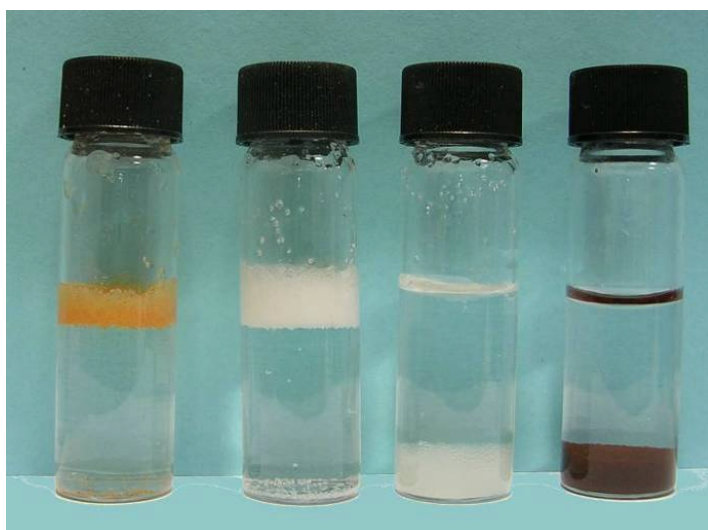
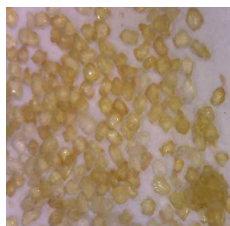
Provides high performance by offering...

- **Microenvironment control** through surface modifier & linker = **high selectivity**
- **Highly stable** covalent binding approach = **no enzyme leaching**
- Application optimisation – reactor (fixed bed or stirred slurry), silica properties

Allows...

- Design & optimisation of IE around process not other way round
- Consistent approach - reducing trial & error in finding an effective IE
- Focus on main IE performance parameters – activity, stability & selectivity

Silica Surface Modification



Enzyme Attachment

After Before Before After

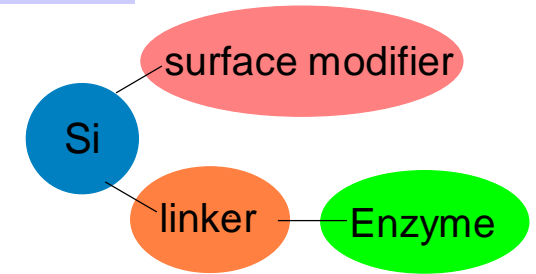
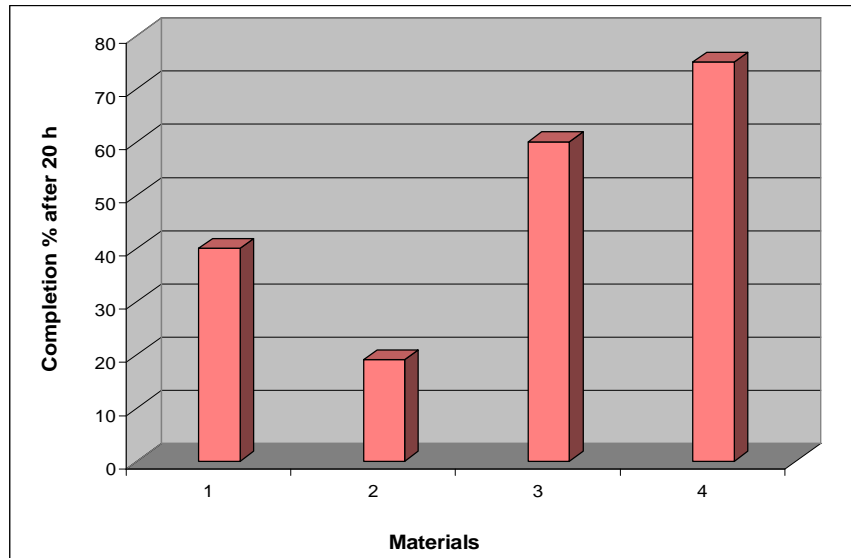
Functionalised silicas shown in aq. solution



'Large' hydrophobic modification **'Small' hydrophobic modification**

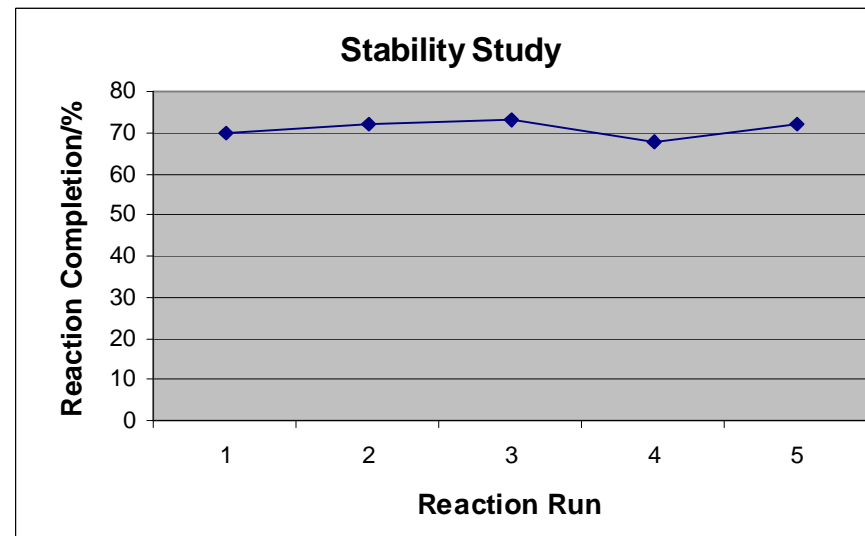
- Silica surface modification – upon attachment of the linker & surface modifier
- Controls physical properties of functionalised silica & ultimately IE
- Allows lipophilic character of IE to be tailored for application
- Linker allows distance from support to be optimised for application

High Performance, No Loss of Activity

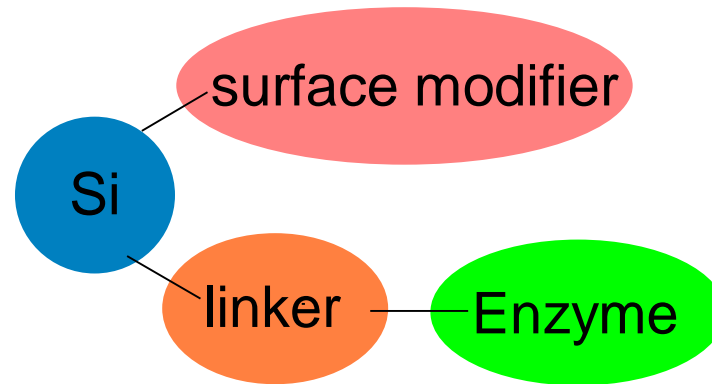


- Hydrolysis reaction
- Four PhosphonicS™ IEs screened
- Each with different surface modification
- Used under continuous flow conditions

- Hydrolysis reaction at elevated T
- Each reaction run over 20 hours
- Recyclable, reproducible
- No enzyme leaching



Working with PhosphonicS™ IE Technology



From...

- **Product supply to client** – as activated silica supports for enzyme attachment
- IE Screening plates – allow variation of number of key parameters
- Initial 'Identification' plate matrix includes IEs with variation of linker, surface modifier enzyme loading
- Follow-on 'Optimisation' plate matrix addresses key variables from 'Identification' plate plus silica & other properties as appropriate
- Format as preferred by client for testing

To...

- **Fully collaborative work programs** – focused to client requirements, including IE preparation and associated analytical work