Bio-Based Mesoporous Materials TP

B^2M^2

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York, 1-11-17

Mesoporous Polysaccharides:
Starch, Pectin, Alginic acid, Hemicellulose

Mesoporous Carbonaceous materials

B^2M^2 TP

Nano-cellulose

Bio-silicates and Silica-Carbons

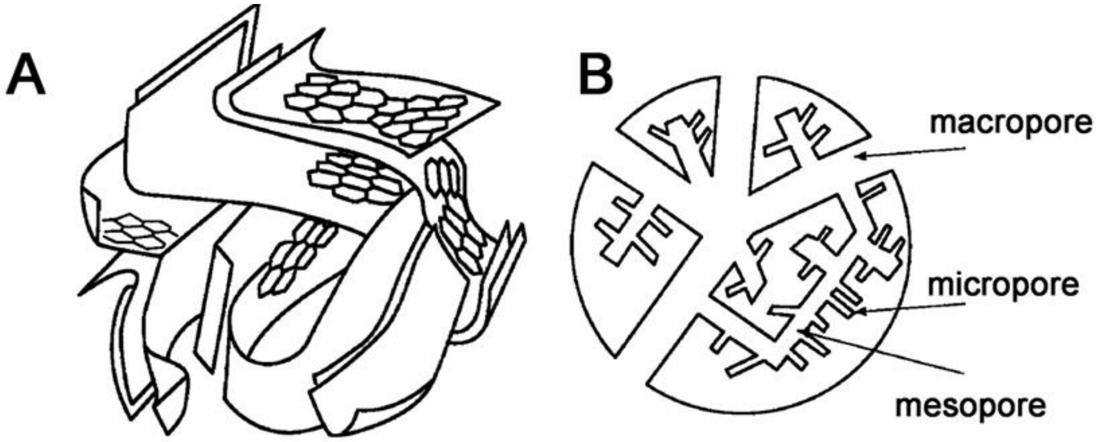
Analysis:
Porosimeter , DRIFT-FTIR, Solid ^{13}C NMR; SEM., TEM

Applications:
Chromatography
Catalysis; Adsorption
Electrochemistry

- 2 postdocs
- 4 PhDs
- More than 25 publications
- 2 patents;
- 1 patent applications

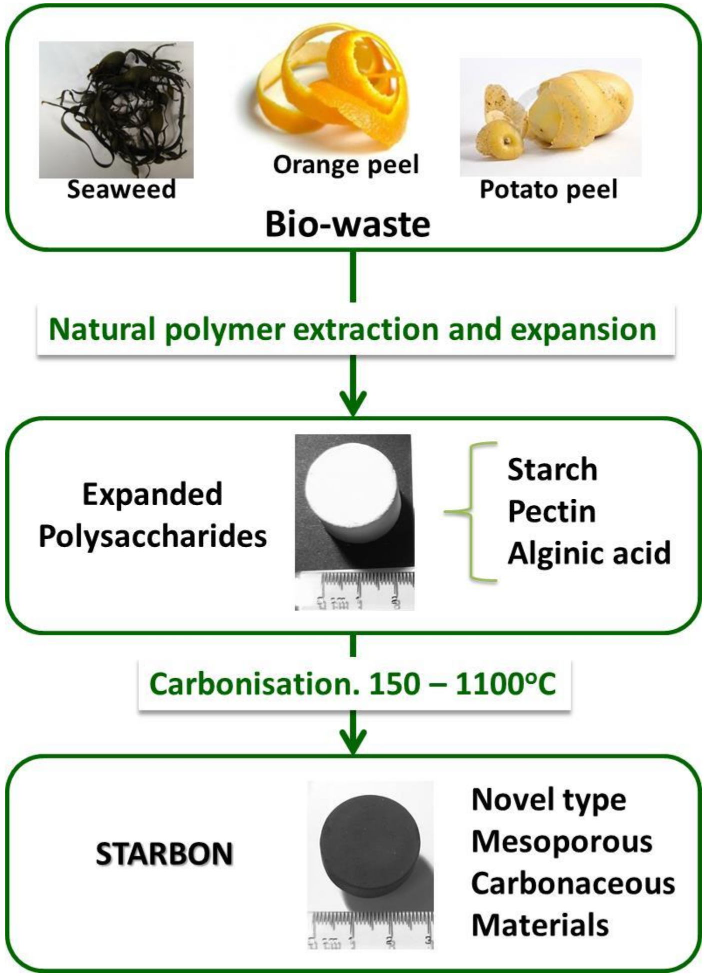
Current project-
Pous4Apps H2020 (1M)
Objective :20 kG/day
Starbon production

Porous materials



Pore type	Pore Size	Condensation mechanism	Type of Adsorption
Micropore	*< 2 nm*	Three-dimensional	Non-specific
Mesopore	*≥ 2 ≤ 50 nm*	Capillary	Specific
Macropore	*> 50 nm*	No condensation	-

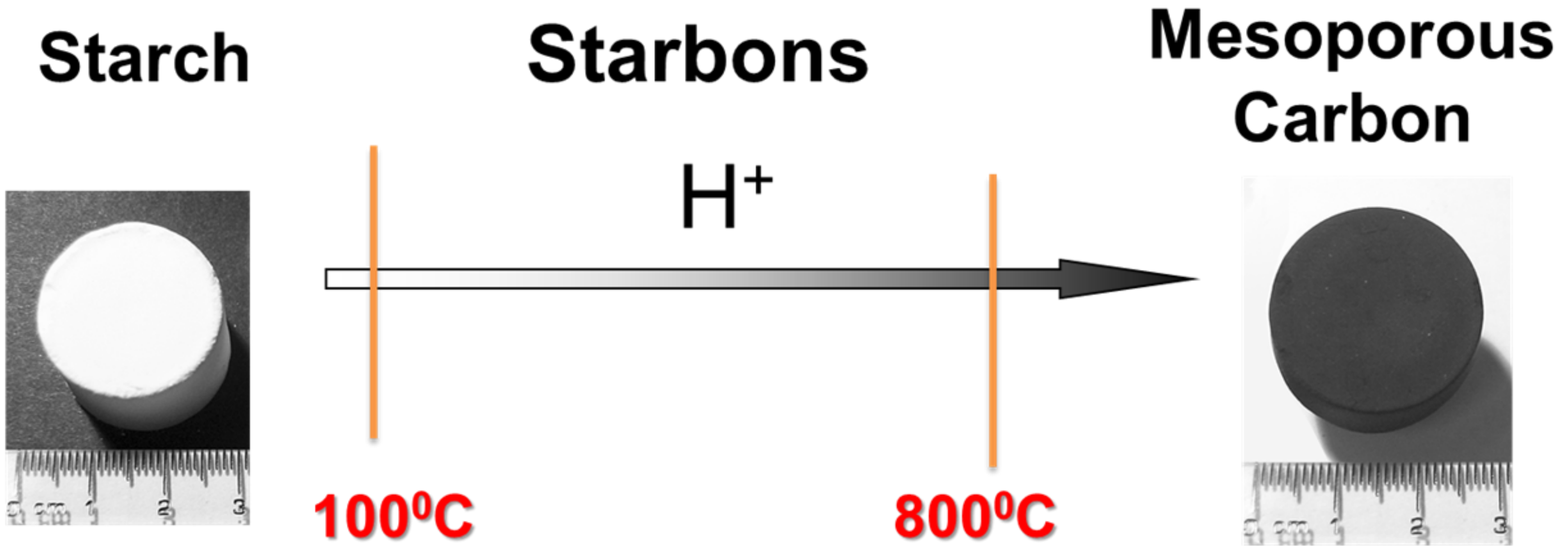
Starbon® technology



- **Patented** (2 patents)
- **Well-established** (26 papers published)
- **Sustainable** (polysaccharides are renewable and widely available)
- **Inexpensive feedstock** (starch, alginic acid, pectin)
- **Simple** (two stages process)
- **Green** (avoiding use of harmful chemicals; uses green solvents (water, ethanol))

ANGEWANDTE , 2006, 45,3782-3786

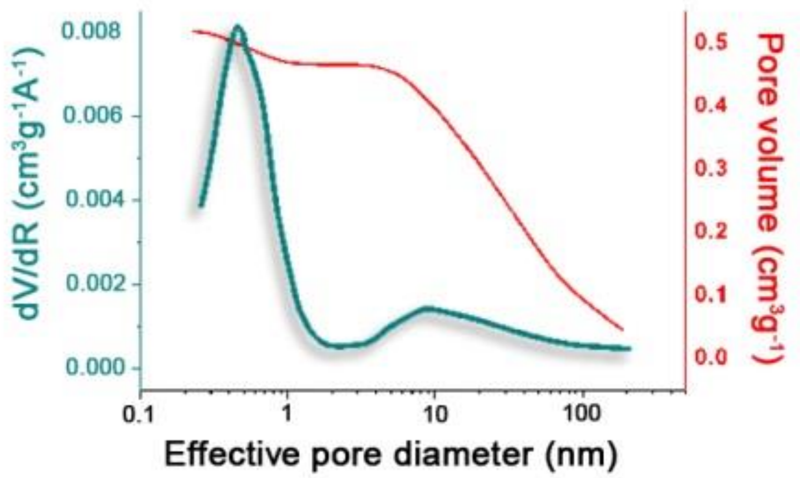
Starbonisation

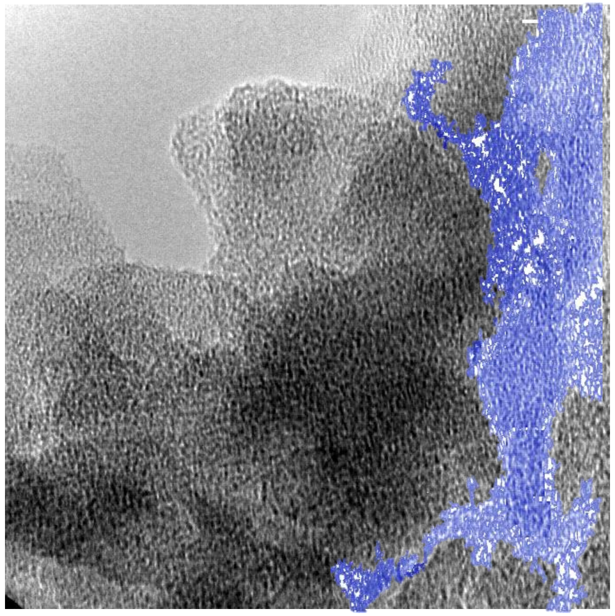


Starbon Properties :

- Tuneable surface functionality
- High mesoporosity (up to 2.0 cm^3/g)
- High surface areas (up to 500 m^2/g)
- Controllable electrical conductivity
- Particulate / monolithic forms

Starbon® Micro- and Mesoporosity (HTEM , Porosimeter)





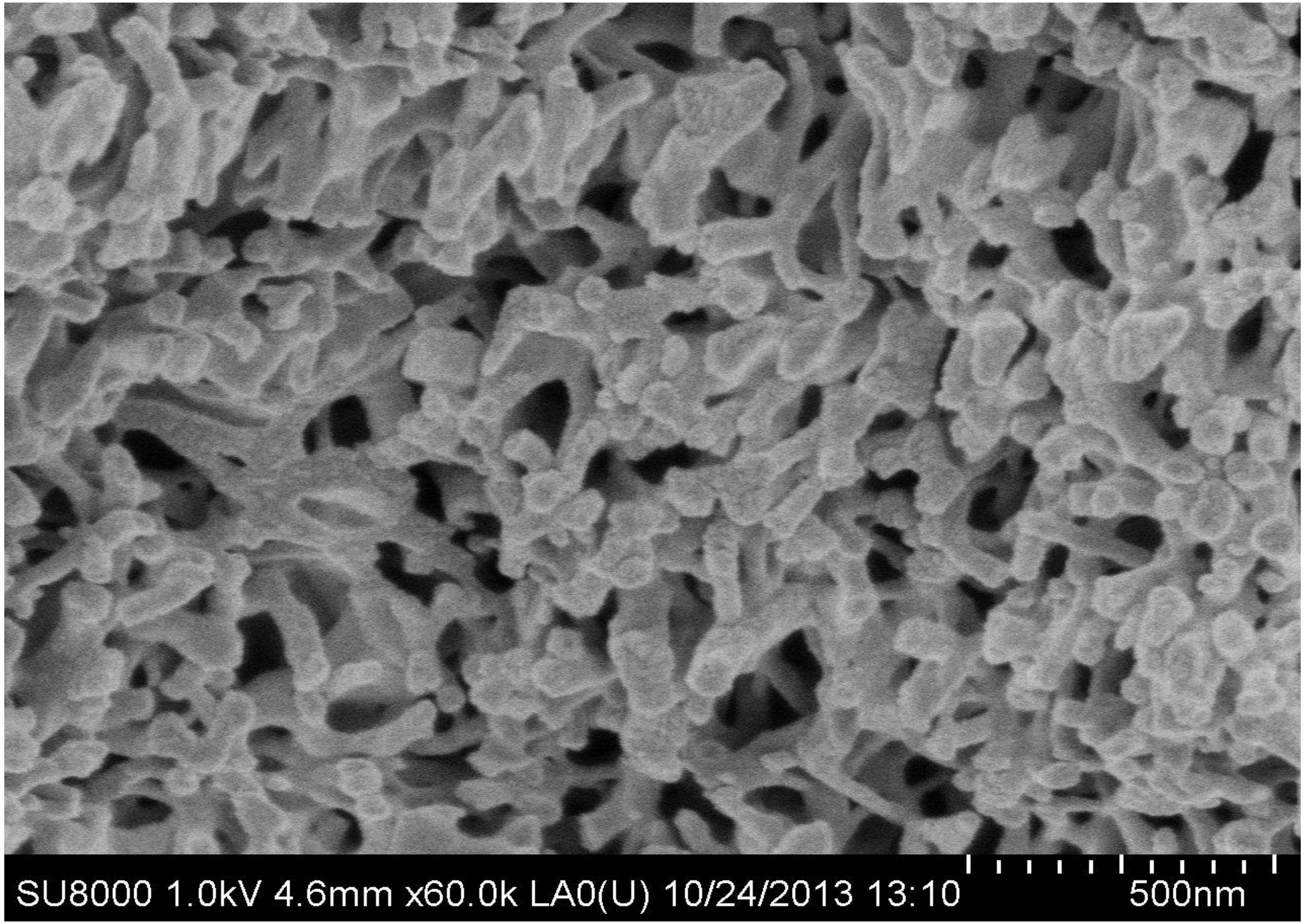
1 nm

Micropore

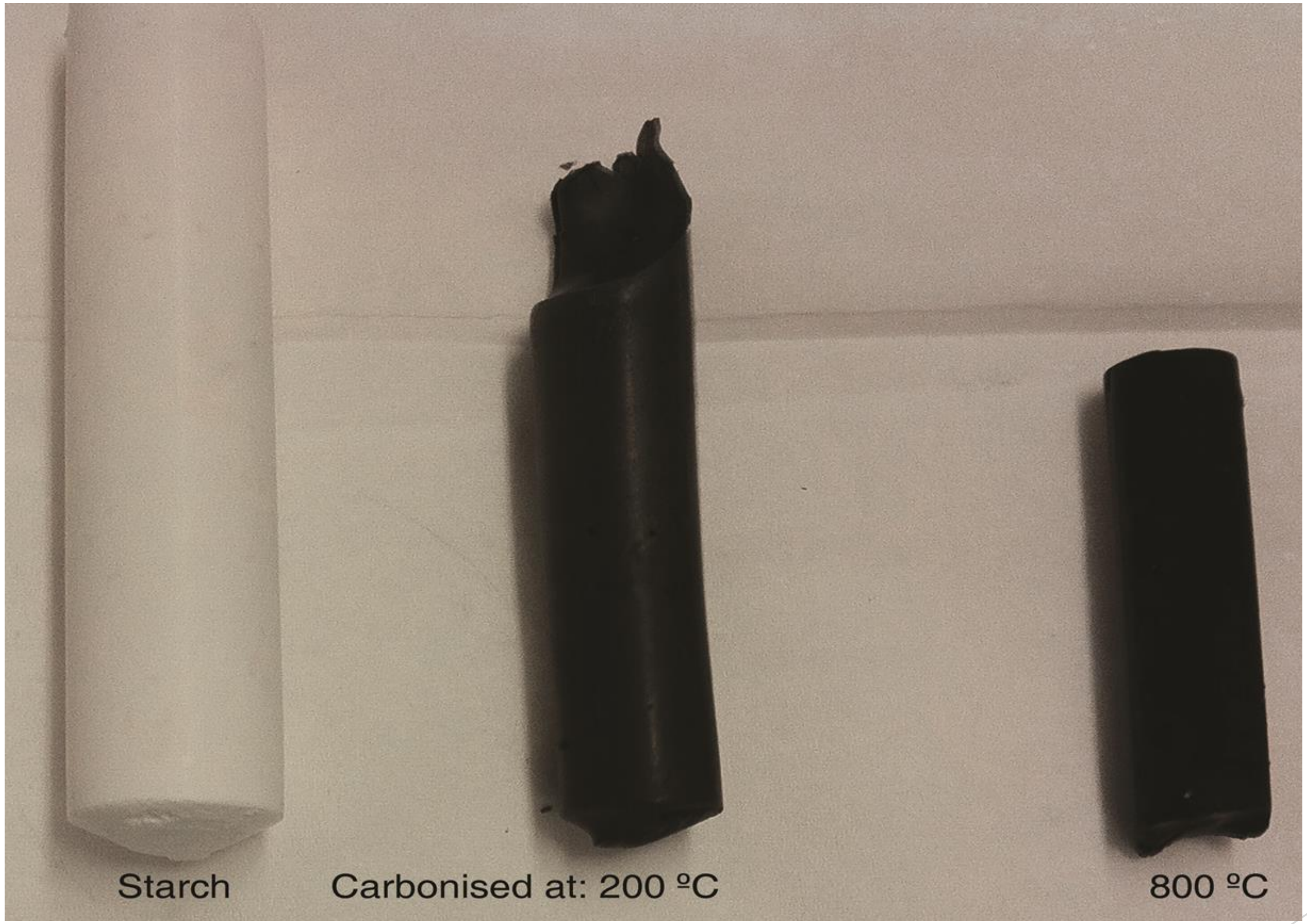
Mesopore

10 nm

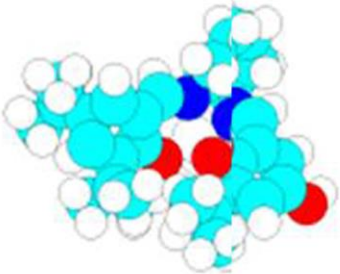
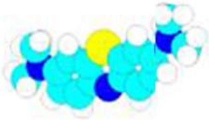
Starbon® Macroporosity (SEM)

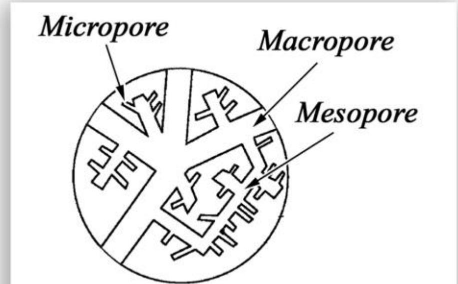


Starbon® Monoliths



Starbon –activated carbon comparison

Typical size of molecules		Activated Carbon	Starbon®
Metal complex *(Catalyst)*		-	√
Methylene Blue *(Dye)*		-	√
Sucrose *(bio-product)*		-	√
Succinic acid *(bio-product)*		√	√
		0.5nm	5.0nm

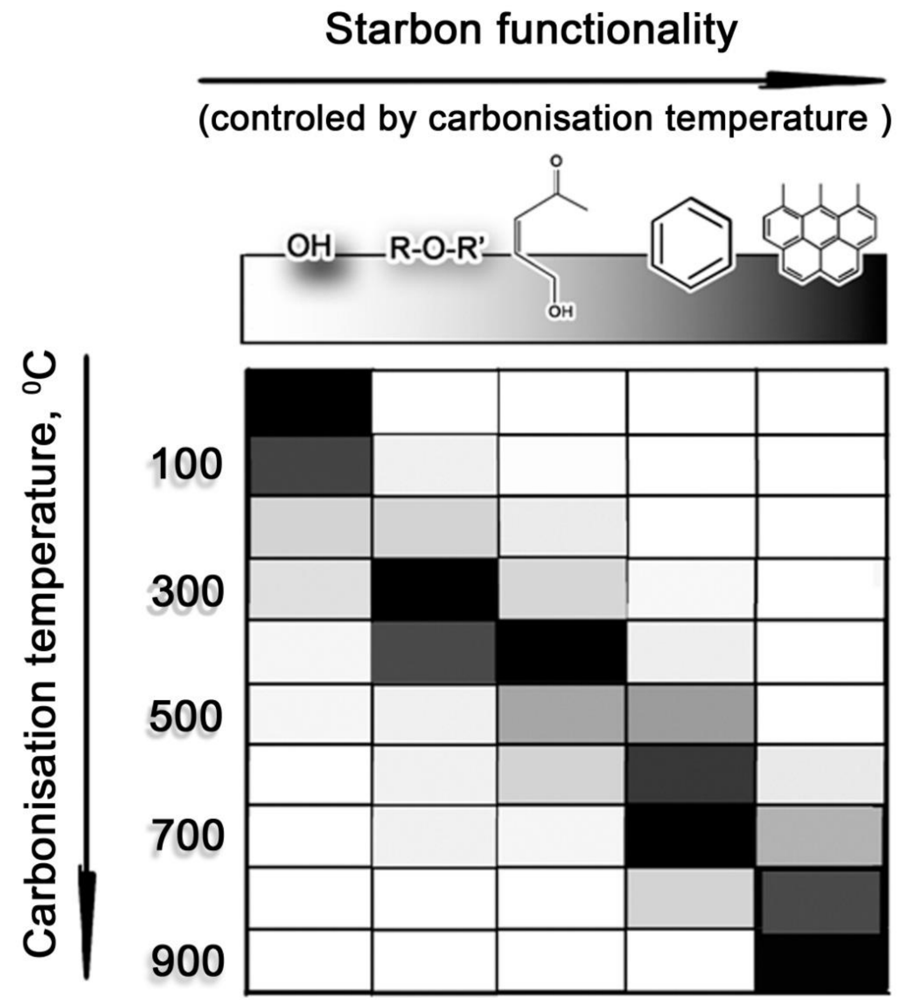


Stracture of porous materials

Micropore
D < 2nm

Mesopore
2nm < D < 50nm

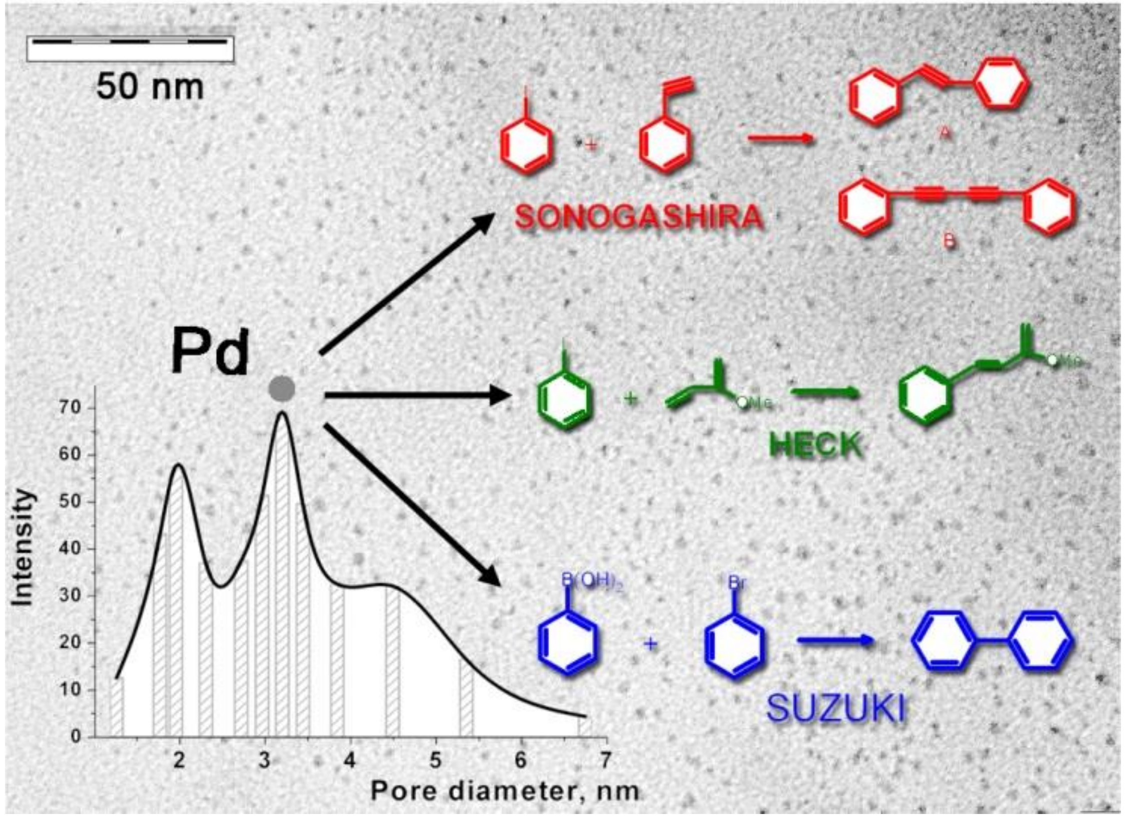
Starbon® functionality



Applications

Nanotechnology	Chromatography	Acid catalysis	Organic adsorption	Metal adsorption
✓✓				
✓✓				
✓✓				
✓		✓	✓	
✓		✓	✓	
✓	✓	✓✓	✓✓	✓
✓	✓	✓✓	✓	✓
	✓	✓	✓	✓
	✓✓		✓	✓✓
	✓✓		✓	✓✓

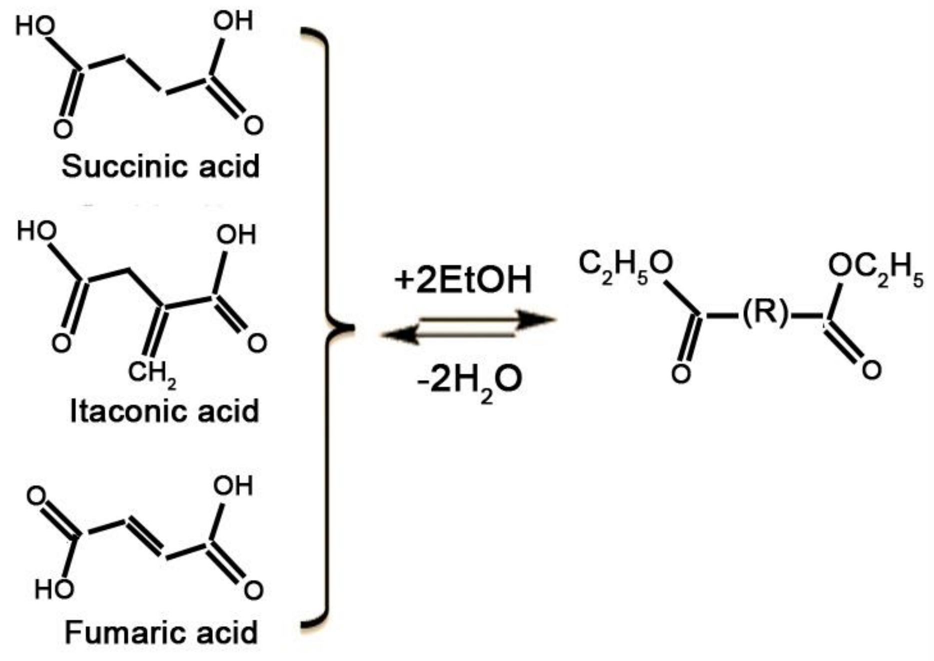
Expanded starch application: Synthesis of nanoparticles

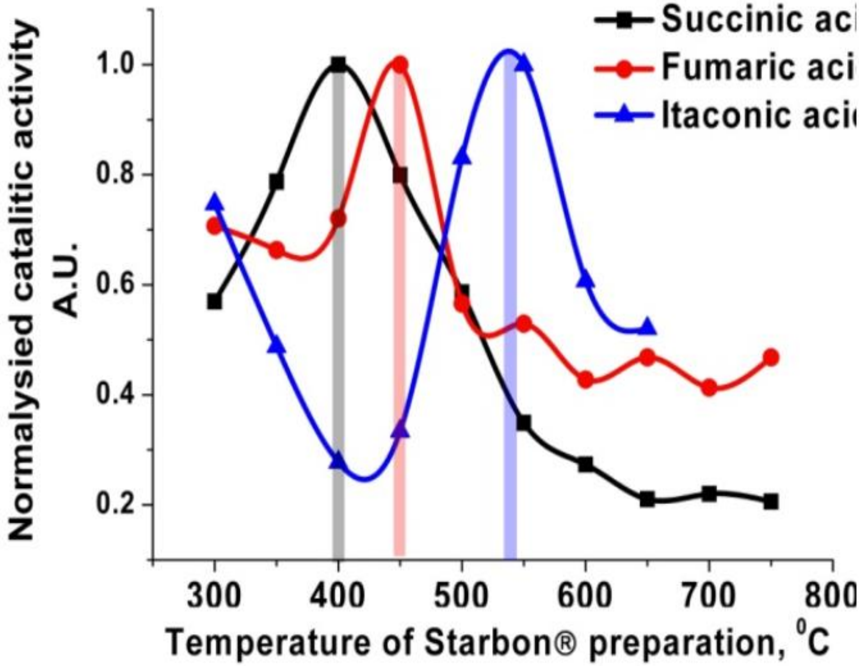


- **The nanoparticle size distribution was controllable by pore structure of Expanded Starch**

Green chemistry , 2008, Vol.10(4), p.382-387

Starbon® application: acid catalysis

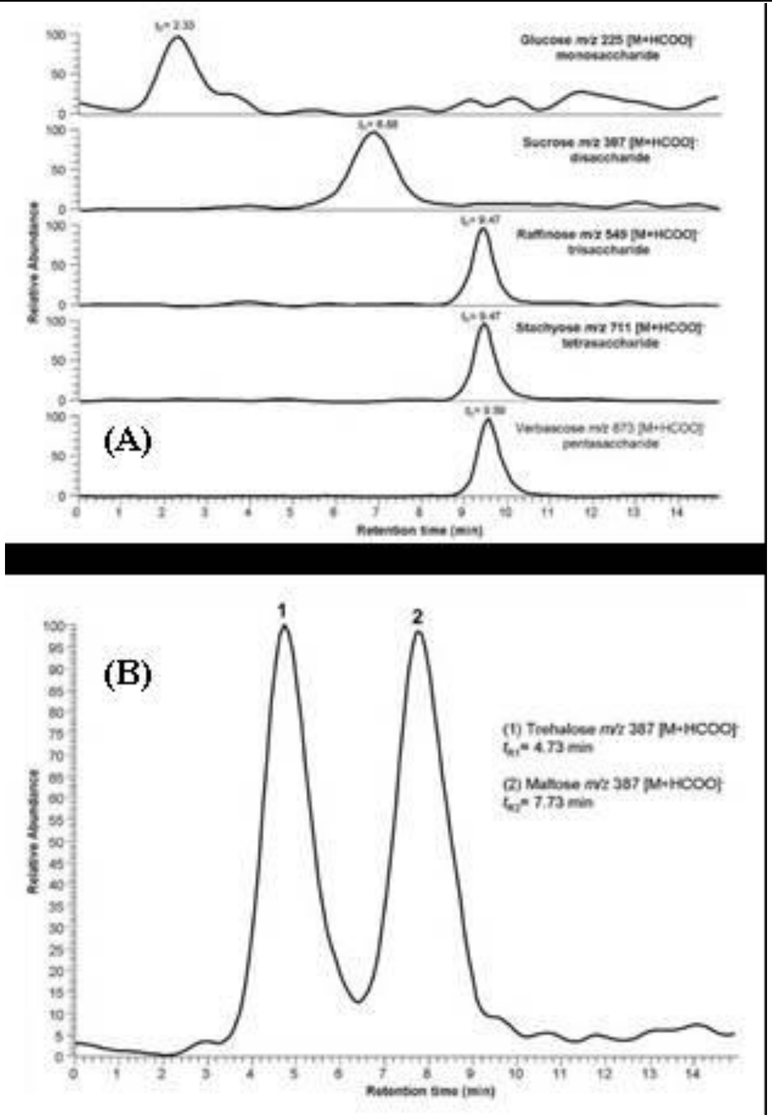




- ✓ **Each acid is catalysed by Starbon prepared at specific temperature for that acid.**

Chem.Eur.J., 2007, **13,** 6914

Starbon ® application: Chromatography.



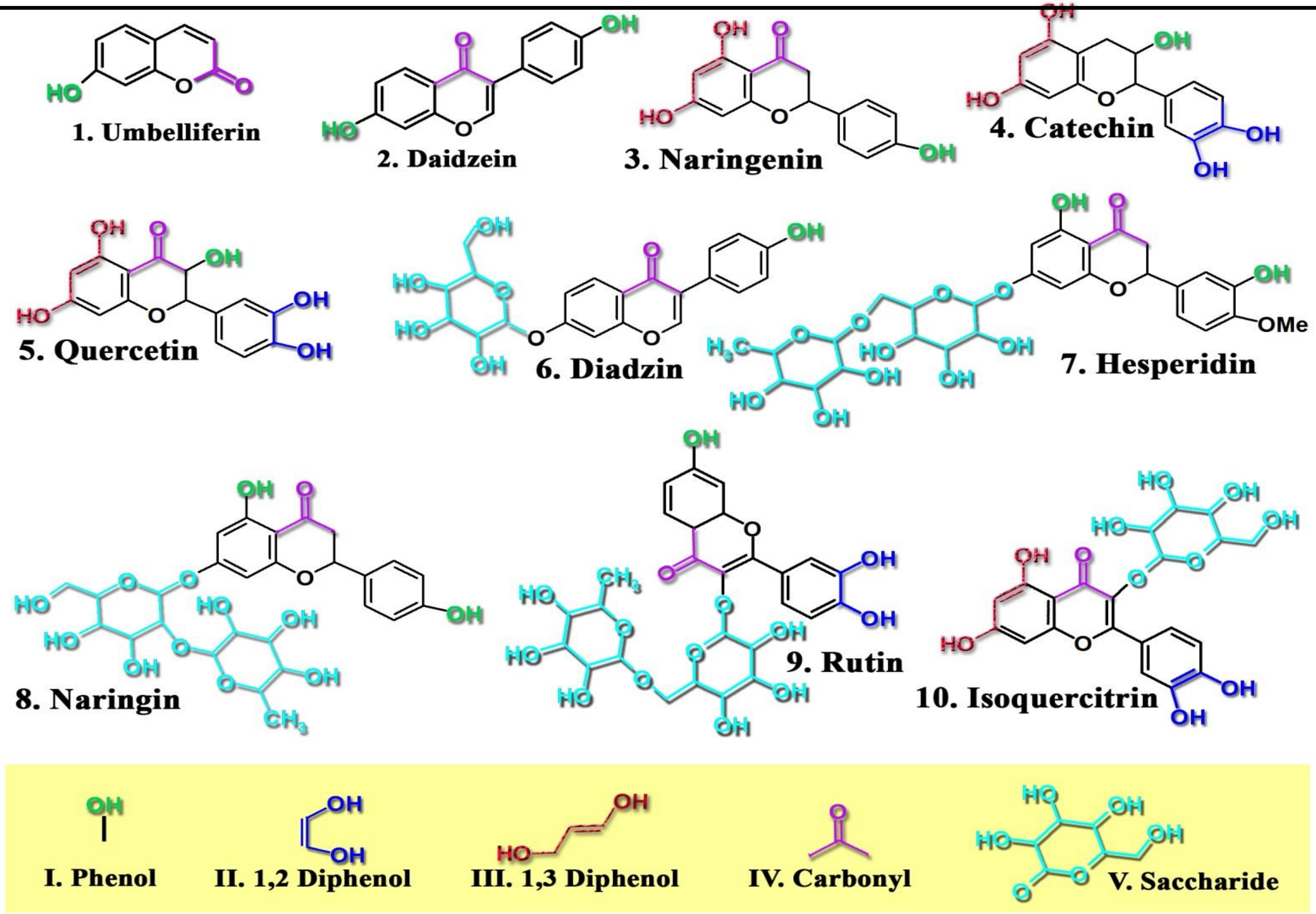
A) Separation of 50 µM standard solution of a mixture of

- **glucose,**
- **sucrose,**
- **raffinose,**
- **stachyose and**
- **verbascose**

B) separation of 50 µM standard solution of a mixture of **the disaccharide isomers : trehalose and maltose**

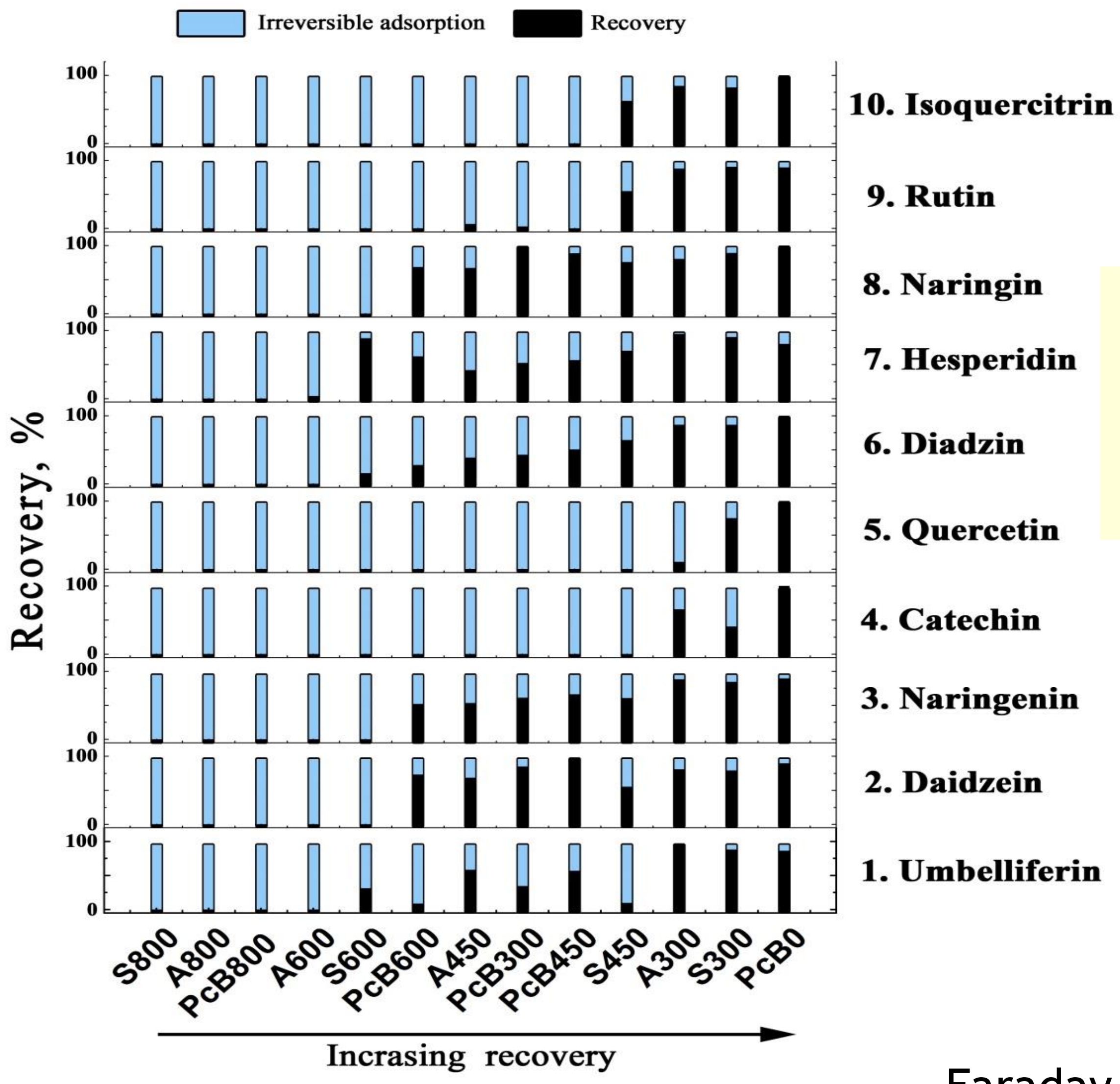
Advanced functional materials , 2010, p.1834-1841

Starbon ® application: SPE cartridges Flavonoids separation



Faraday discussions. , 2017, Vol.202, p.451-464

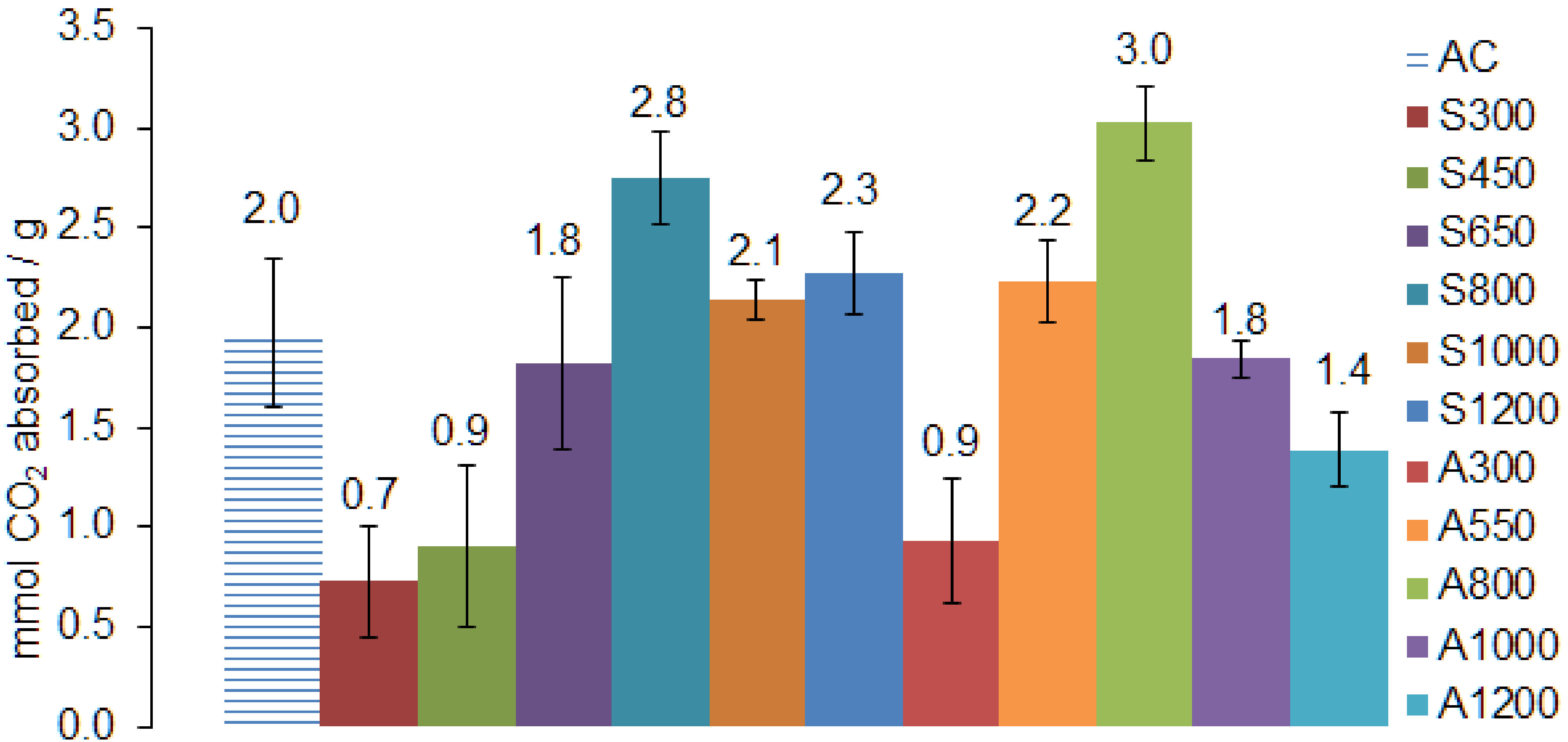
Starbon ® application: SPE cartridges Flavonoids separation



Recoveries results of polyphenols (10 μg mL^{-1}) obtained using the 13 Starbon® SPE (0.1 g cartridges) and 10 mL of Methanol as eluent.

Faraday discussions. , 2017, Vol.202, p.451-464

Pressure swing CO2 adsorption

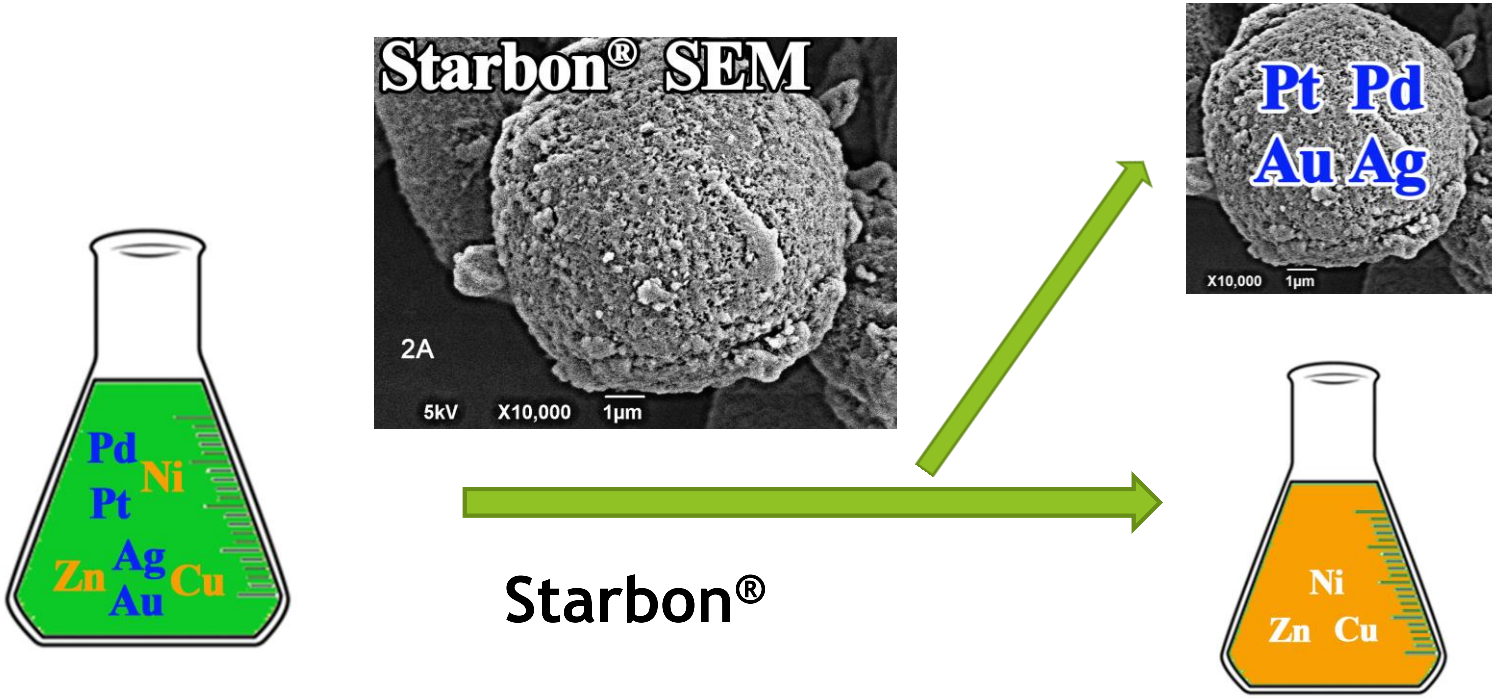


Samples exposed to 5 bar CO_2 for 30 minutes at RT, weighed, then exposed to vacuum at RT and weighed again to get the % mass change. This was repeated 5 times to give the error bars.

ANGEWANDTE , 2016, 9173-9177

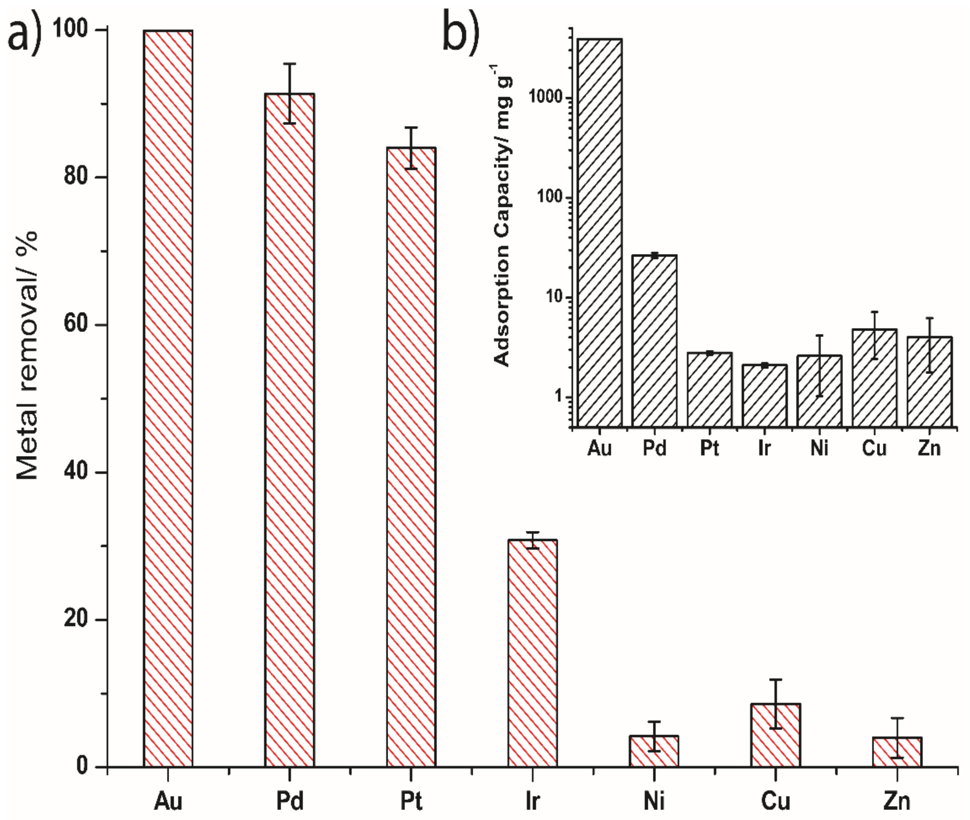
Starbon® for separation of precious and earth metals

- Starbon® has been used to adsorb precious metals (Au, Pt and Pd) from a complex mixture also containing similar concentrations of earth abundant metals (Ni,Cu and Zn).
- The experiments were also carried out to simulate 'more realistic' situations where the non-precious elements were more concentrated than the precious metals.



Green chemistry, 2015, Vol.17(4), p.2146-2149

Starbon® for the adsorption of precious metals



a) Metal removed from 30 ml of an HCl solution when 50 mg of adsorbent were added (%) and b) adsorption capacity for each metal ($mg{\cdot}g^{-1}$)

- Good adsorption of precious metals and minimum adsorption of Ni, Cu and Zn.
- The selectivity remained when the precious metal were present at much lower concentration compared to the other metals (1:100).
- The adsorption capacity of gold was as high as 3800 $mg{\cdot}g^{-1}$.

Green chemistry, 2015, Vol.17(4), p.2146-2149

Industrial waste as a source of critical metals ?

Bottom ash

Metal	Concentration, ppm
La	0.18
Ga	0.04
Sc	0.04
Co	0.03
W	0.02
Be	0.01

Red Mud

Metal	Concentration, ppm
La	0.32
Sc	0.1
Co	0.01
W	0.03

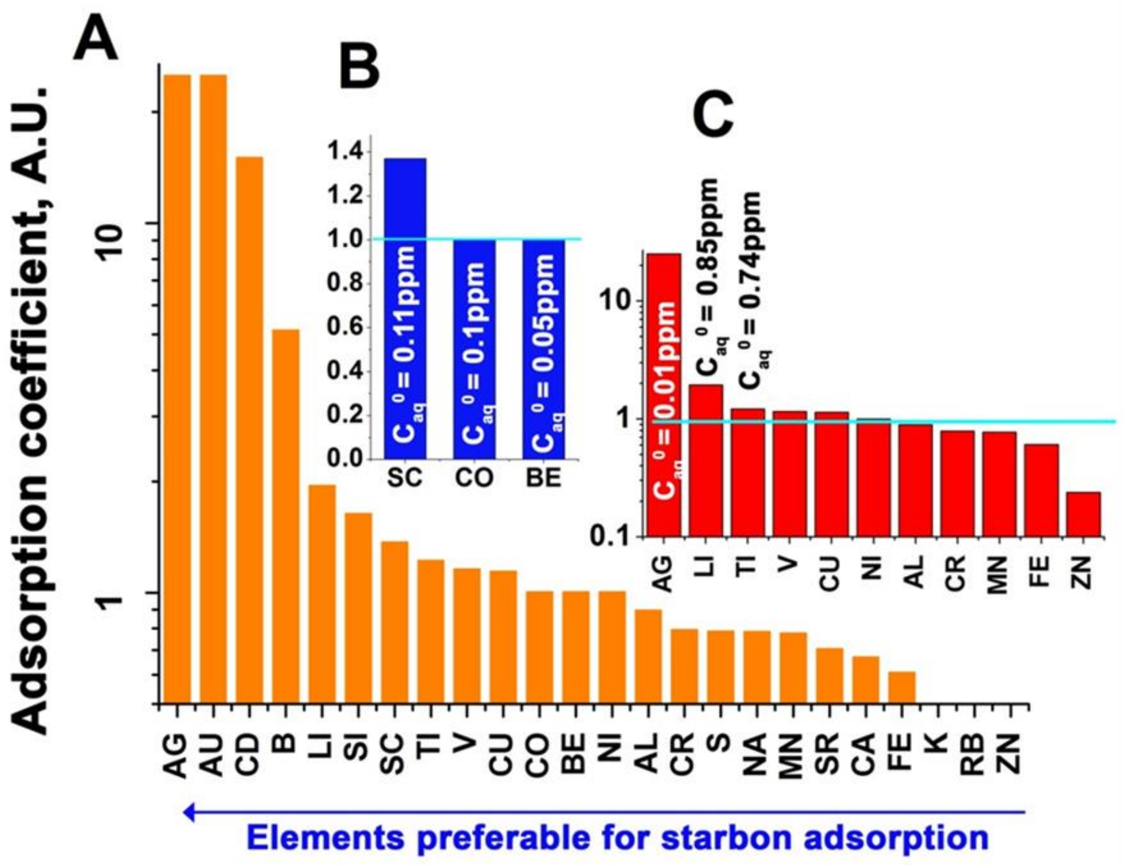
Phosphogypsum

Metal	Concentration, ppm
Co	0.16
Y	0.14
Nb	0.03
W	0.02

Pulverised fuel ash -S800 System

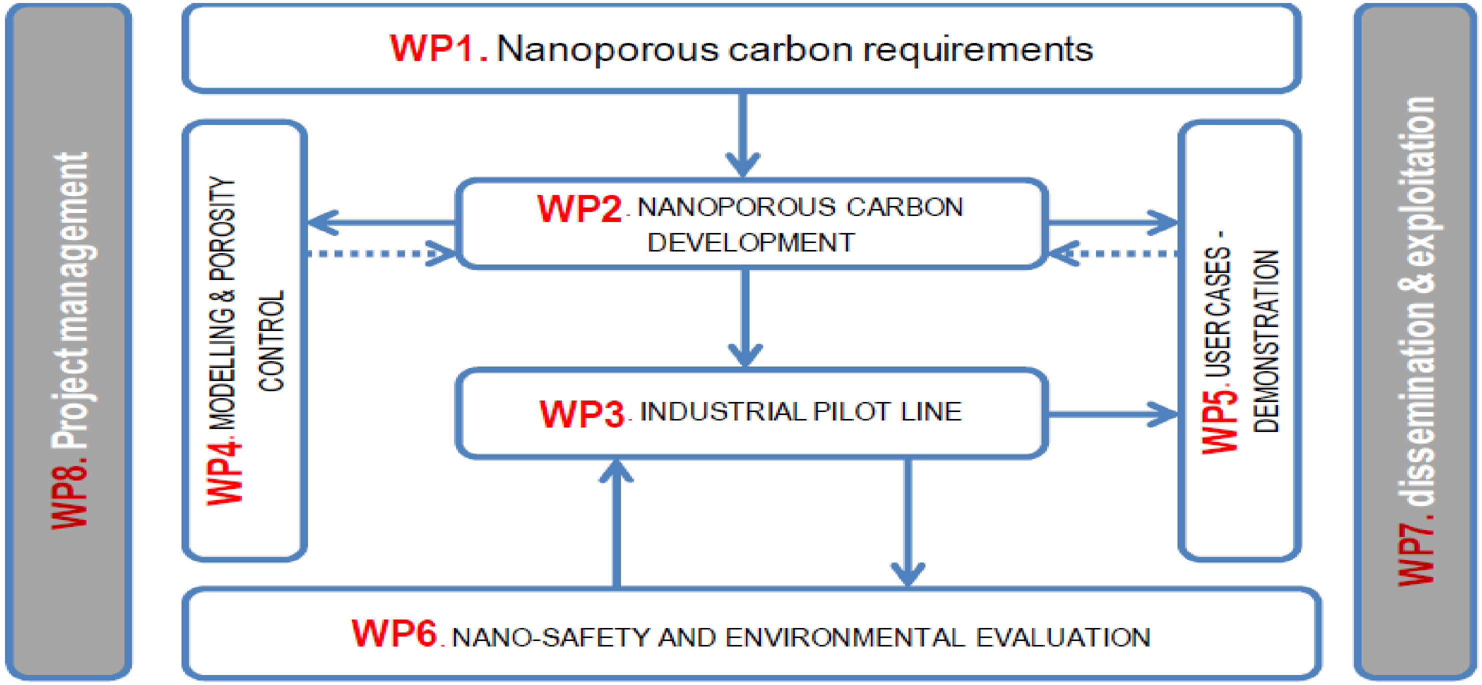
A (Orange bar)- represent all elements
B (Blue bar) – represent elements from Critical EU list
C (Red bar) – valuable elements

Elements with adsorption coefficient higher than 1 preferably adsorbed (concentrated) on the Starbon surface



Concentrated metals	
Critical	Valuable
Sc	Li
	Ti
	V
	Cu

Contribution to POROUS4APP



Interactions with developers

LEITAT – comparison of starbons to IL based systems
CNRS – development of alkoxide based systems
BDC - interaction to transfer knowhow and aid in scale up
LEITAT/EMPA nanosafety
ICIQ/CNRS modelling

Interaction with users
VMI – development and provision of MMO-starbon composite materials
JM (Nigel Powell, Sarah Ball, James Cookson, Fang Liu) – development and provision of starbon-based hydrogenation catalysts and battery components
IBERCAT – development and provision of starbon based decarbonylation catalysts