Geopolymer material high-added-value application: coating, membrane and microsphere

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Reporter: Xuesen Lyu

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Guangxi University

Guangxi University was established in 1928, locates in Nanning city(E 108°22′, N 22°48), capital of Guangxi Province in China, 9200 KM to Paris, 2040 KM to Peking

Specialized Major:

1.Chemical Engineering (Materials)

2.Civil Engineering

Library

University Gate

Biyun Lake

Auditorium

Group introduction

Lab head:

Dr. Xuemin Cui

Welcome to join in our group:
Postdoctor, Phd. and postgraduate students
Email:Cui-xm@tsinghua.edu.cn

Lab members:

Dr. Leping Liu

Dr. Yan He

Dr. Yuanyuan Ge

Dr. Yaocong Han

Dr. Kaituo Wang

Research interests:

1.Preparation, molecular structure characterization, polymerization mechanism and physical/chemical properties of geopolymer materials.
2.Development of microporous and mesoporous materials, new inorganic membrane materials and water treatment technology
3.Development and application of engineering protective materials, inorganic coatings, building energy conservating and decorating materials
4.Comprehensive utilization of solid waste and development of green building materials.

Research content

1.Exploitation of alkali activated geopolymer materials of different raw material systems
2.Study on depolymerization and condensation polymerization process and influencing factors in activated period: reaction kinetics and thermodynamics
3.Study on the relationship of alkali-activated materials' macroscopic properties with gel (quantity, composition, structure).
4.Development of high-value-added alkali-activated materials

Exploration of alkali - activated geopolymer materials: Different raw material systems

1.Precursor: kaolin (mekakaolin), slag, fly ash, red mud, volcanic ash, meteorite, electrolytic manganese slag, etc.

2.Activators: sodium hydroxide solution, sodium silicate solution, dry powder sodium silicate, potassium hydroxide solution, potassium silicate solution, dry powder potassium silicate, quick lime etc.

3.Fillers: steel slag, calcium carbonate, quartz sand, etc

Contents of group research works

metakaoline+sodium silicate solution system
metakaoline+NaOH solution system
→ Exploration of geopolymerization mechanism
→ Preparation of zeolite molecular sieve

slag+sodium silicate solution system
slag+NaOH solution system
→ Exploration of polymerization reaction mechanism

slag+fly ash+sodium silicate powder → Powder type alkali-activated cement

slag+red mud+sodium silicate solution system
metakaolin+manganese slag+sodium silicate system
slag+manganese slag+sodium silicate system
→ Immobilization and utilization of waste residue

meteorite +alkaline activators
volcanic ash+alkaline activators
→ Near 0-water demand geopolymer cement

slag(metakaolin)+volcanic ash+sodium silicate solution → Composites materials, 3D printing

slag+steel slag+sodium silicate+foamer → Thermal insulation material

Slag(metakaolin)+sodium silicate solution → Filtration and adsorption porous materials

slag(metakaolin)+sodium silicate powder → Geopolymer coatings

slag: ground granulated blast furnace slag

Application 1: geopolymer coating

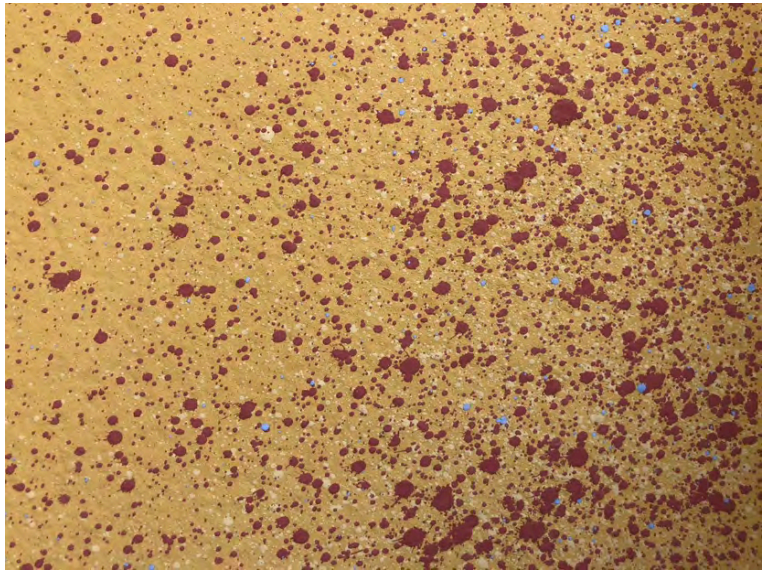
Geopolymer coating manufacture line

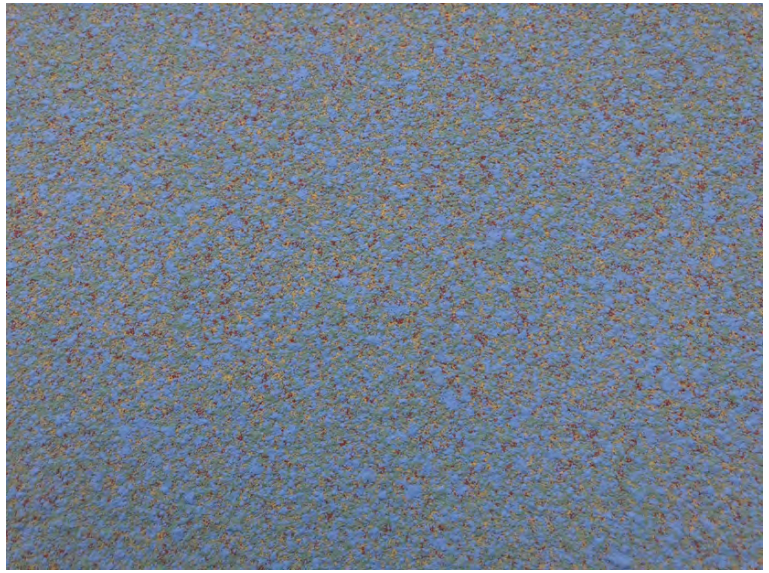
Application of geopolymer coating in engineering
Nanning city, China, 2018

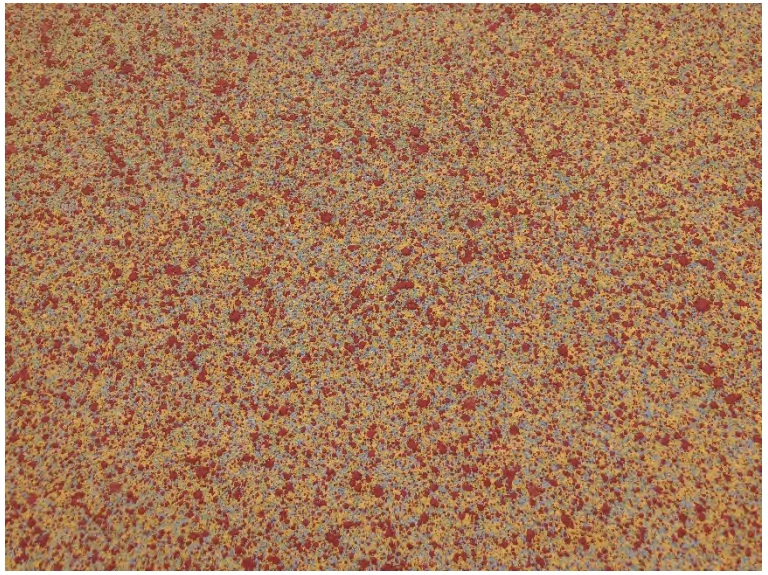
We established a geopolymer coating factory in 2017,
production of 3000t/year each line
the manufactured coating has been used in engineering

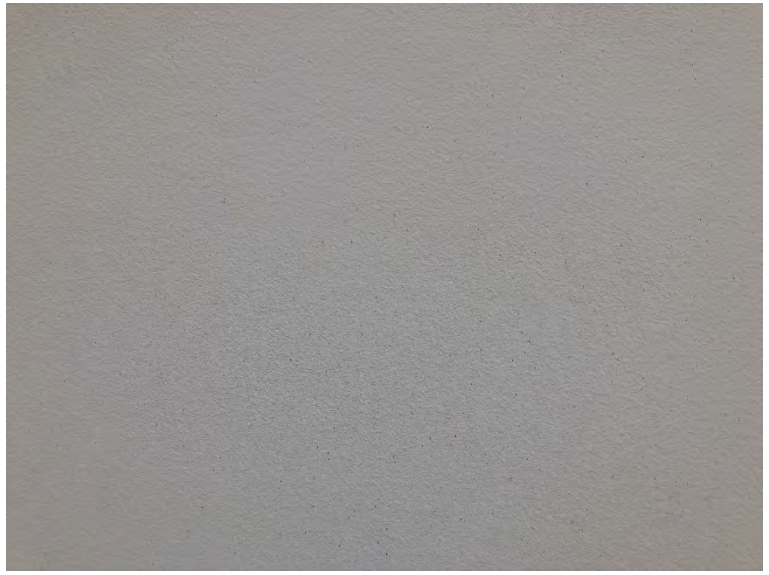
Geopolymer coating used in emergency repair engineering
Nanning city, China, 2019

Application 1: geopolymer coating

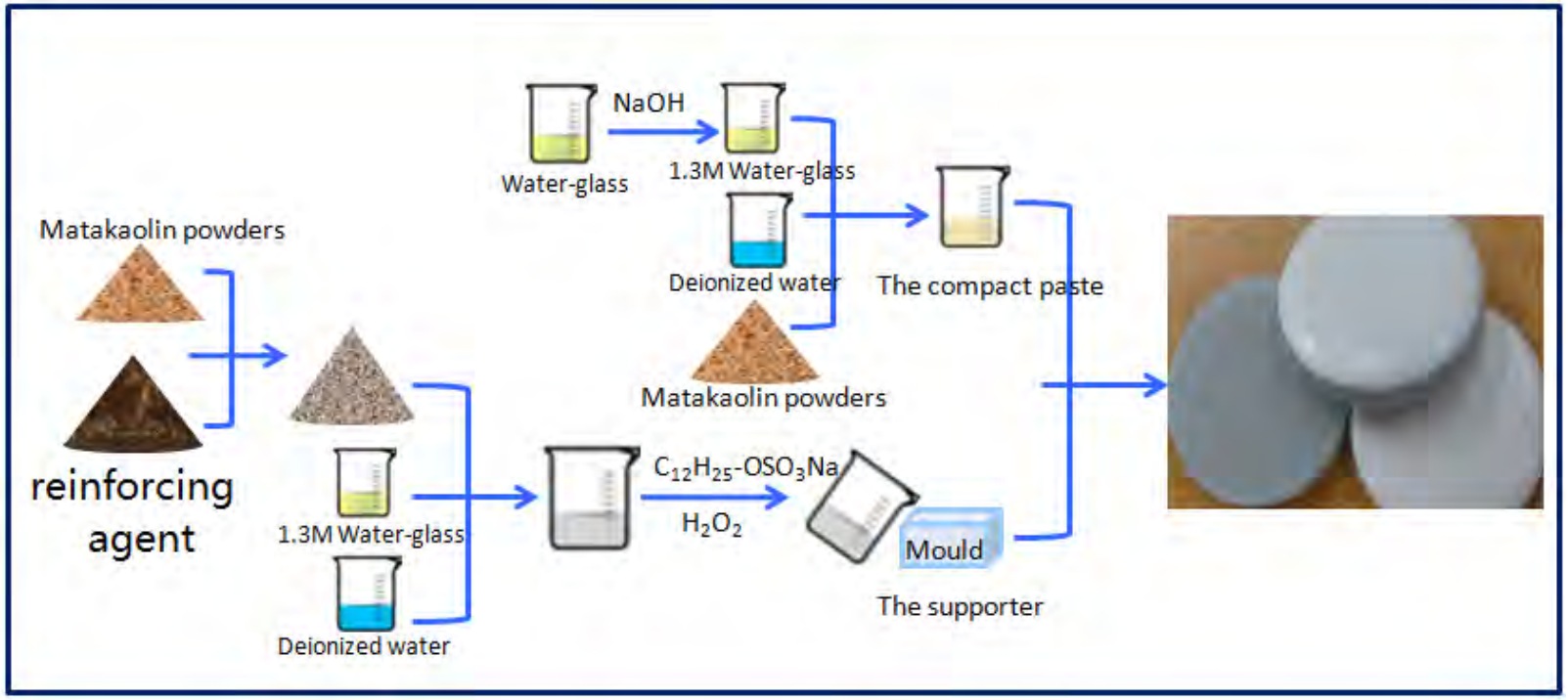


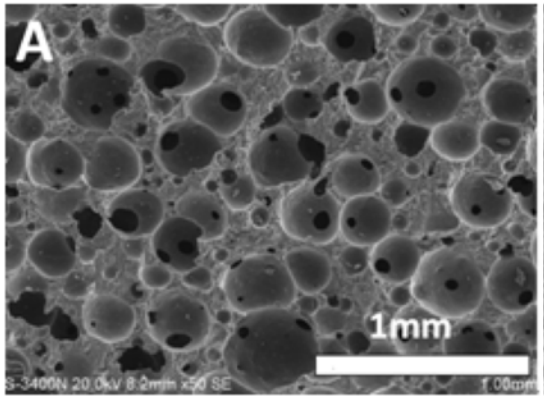


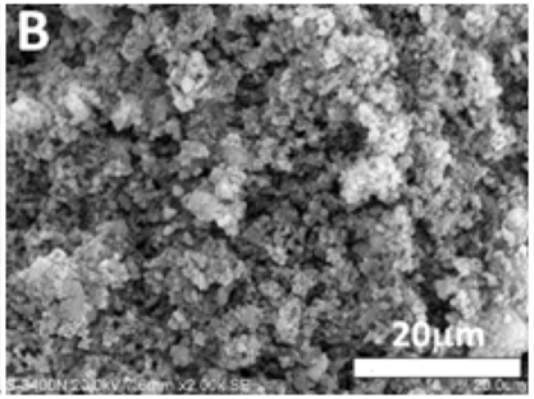


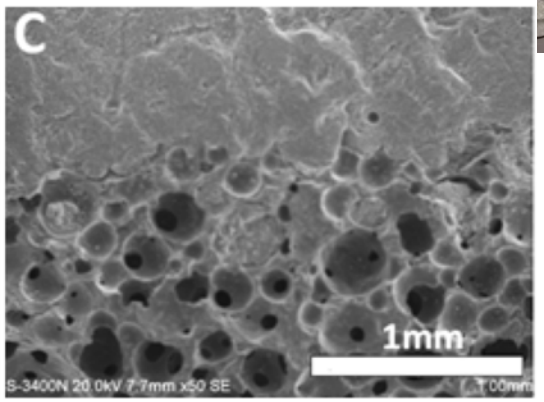


Application 2. geopolymer membrane for water treatment

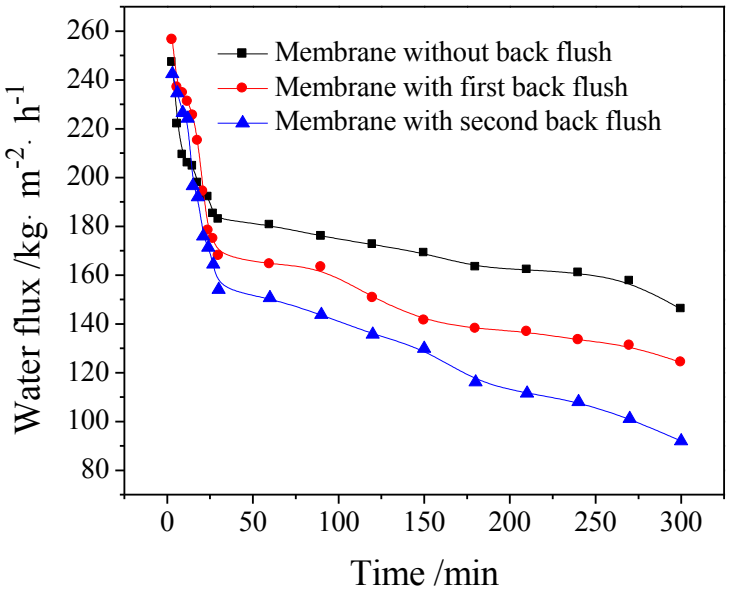


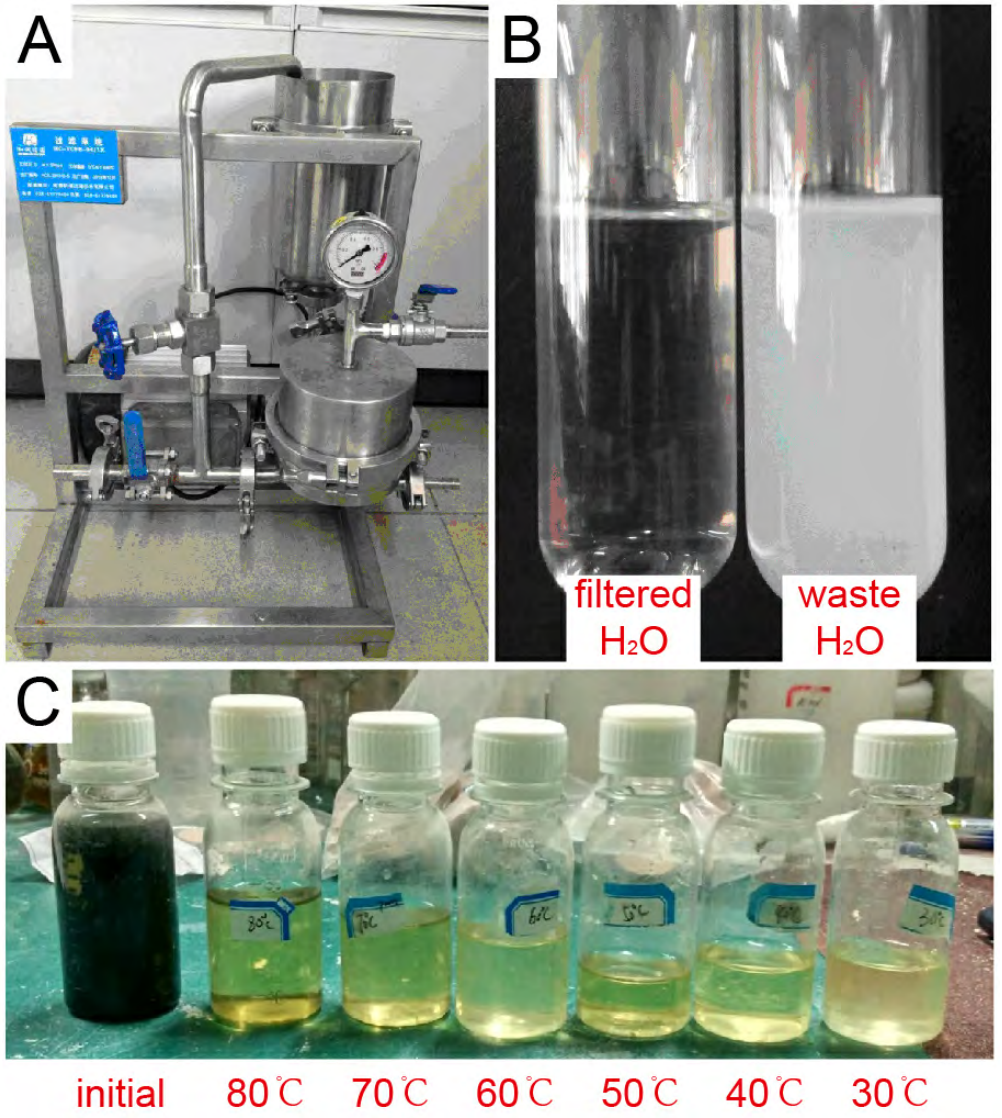




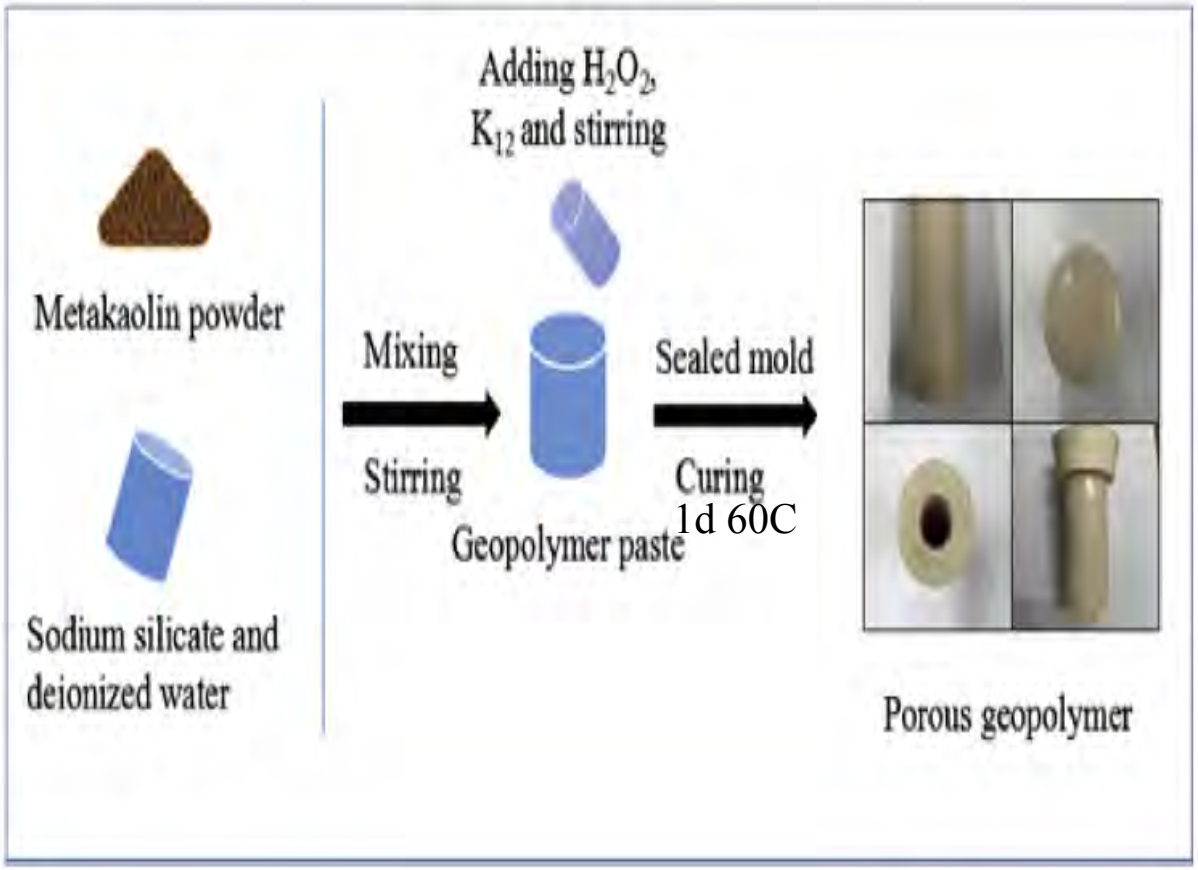


Application 2. geopolymer membrane for water treatment

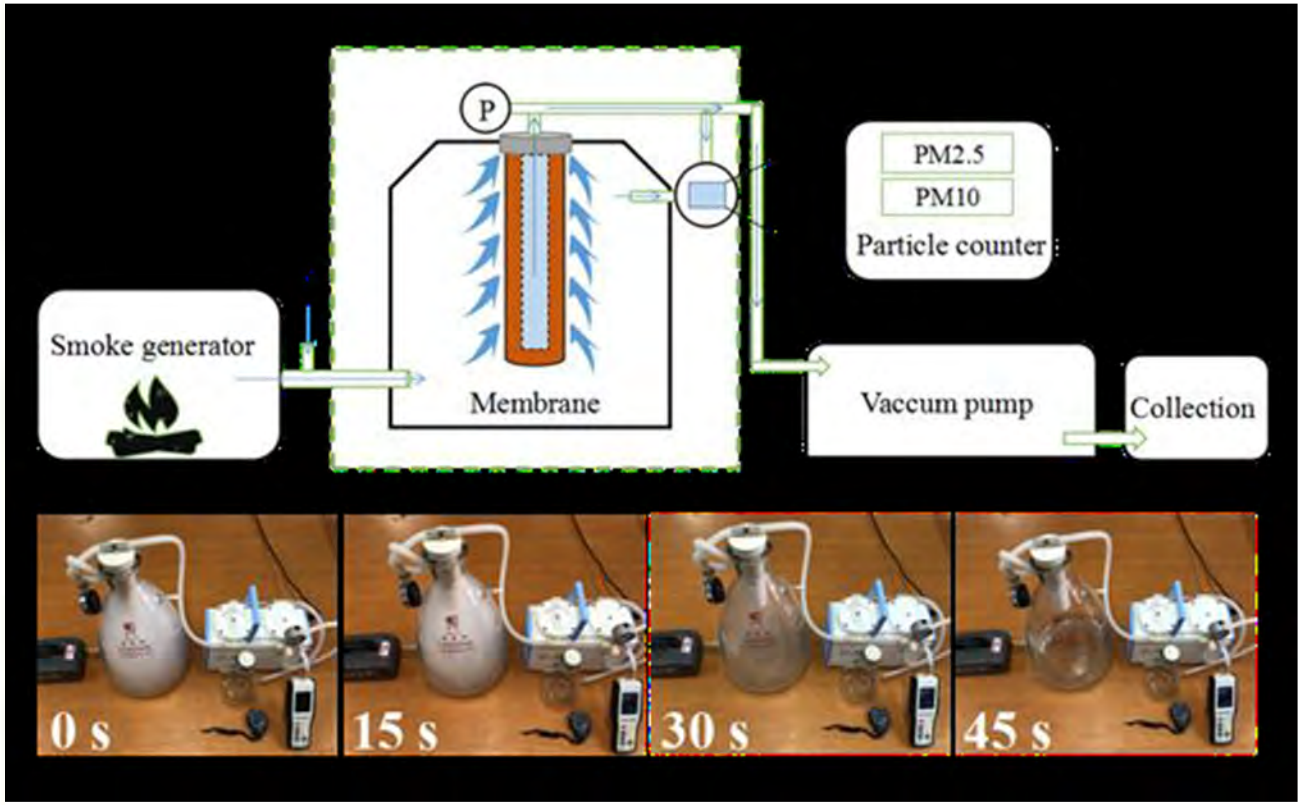




Application 2. geopolymer membrane for gas treatment

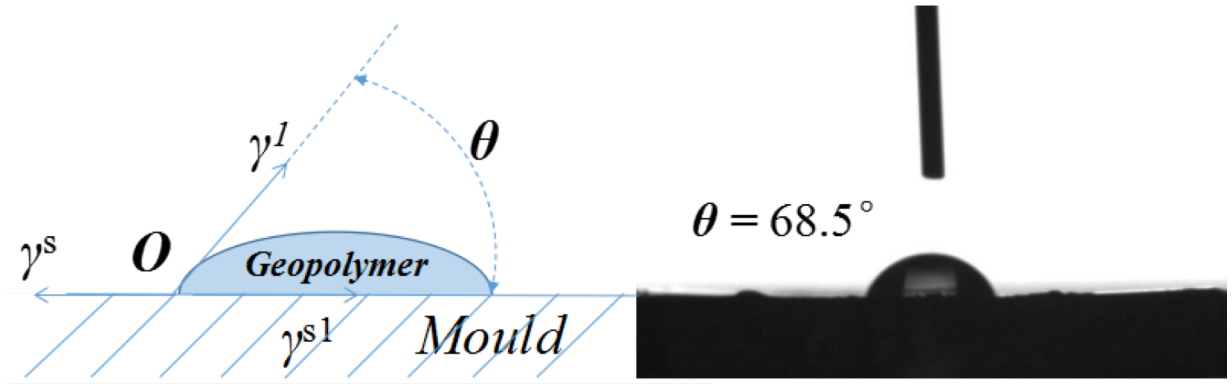


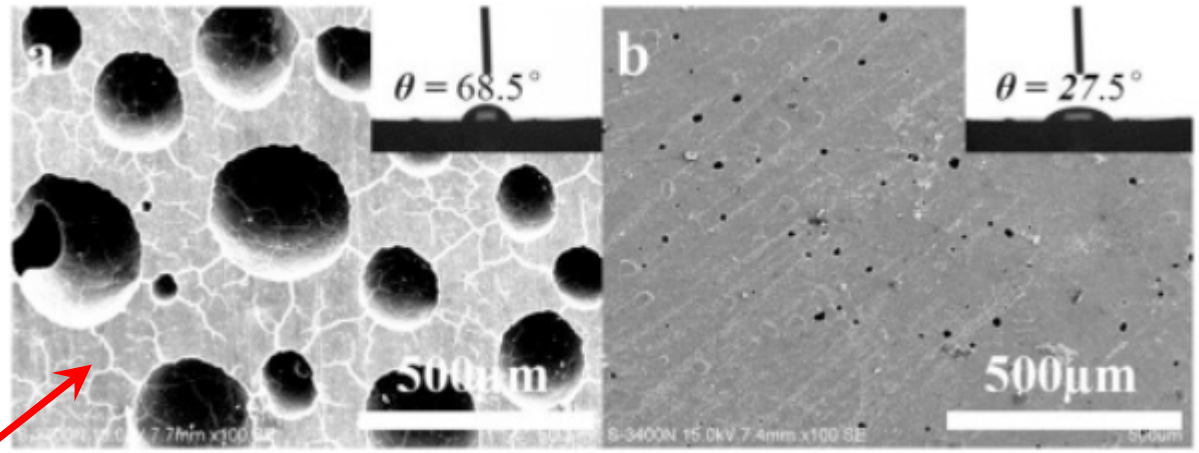
Fabrication process of micro porous geopolymer-based membrane.



Filtration process of PM2.5/10 simulate realistic filtration process.

Application 2. geopolymer membrane for gas treatment





Young equation:

$$y^s = y^{s1} + y^l \cos\theta$$

1.If θ is too high: bubbles diffuse from inside up only

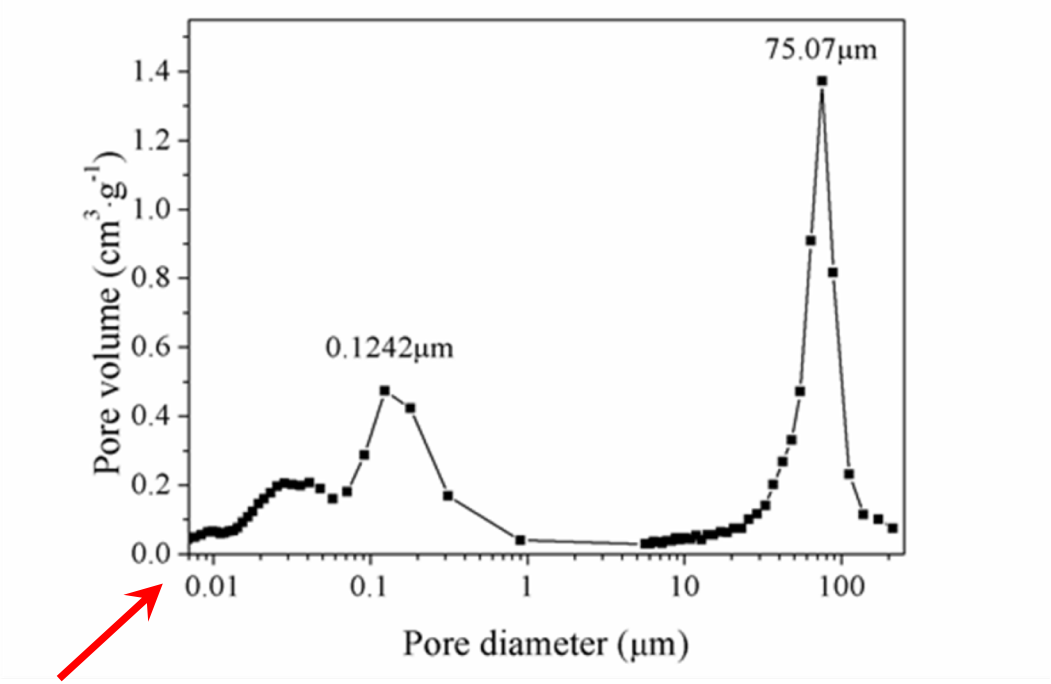
2.If θ is too low: mold surface will be stuck by the paste and lost the compact layer with small pores.

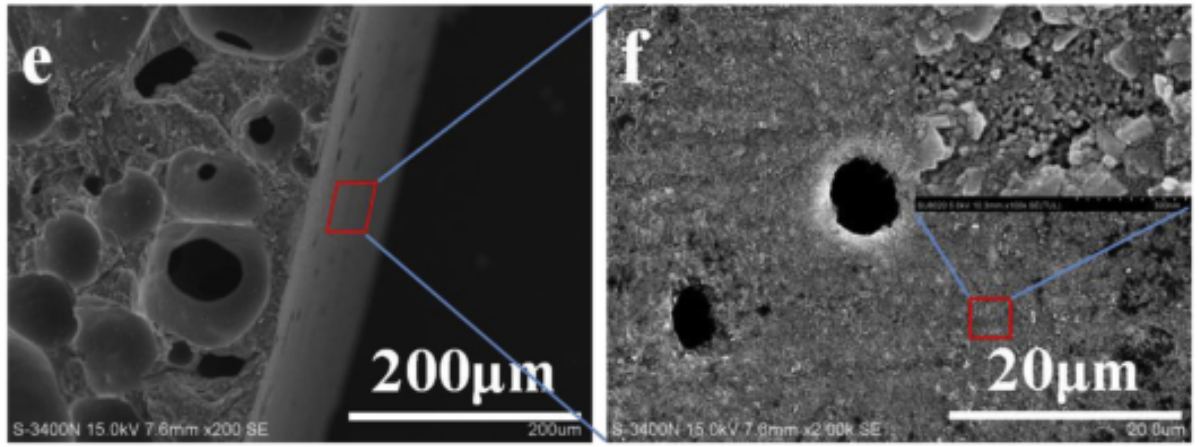
θ =68.5°, membrane with large open cells

θ = 27.5°, compact layer with small pores

Surfactant K12 was used to adjusted the θ, thus the geopolymer paste can maintain complete contact with the surface of the mold, a porous gradient structure was fabricated.

Application 2. geopolymer membrane for gas treatment

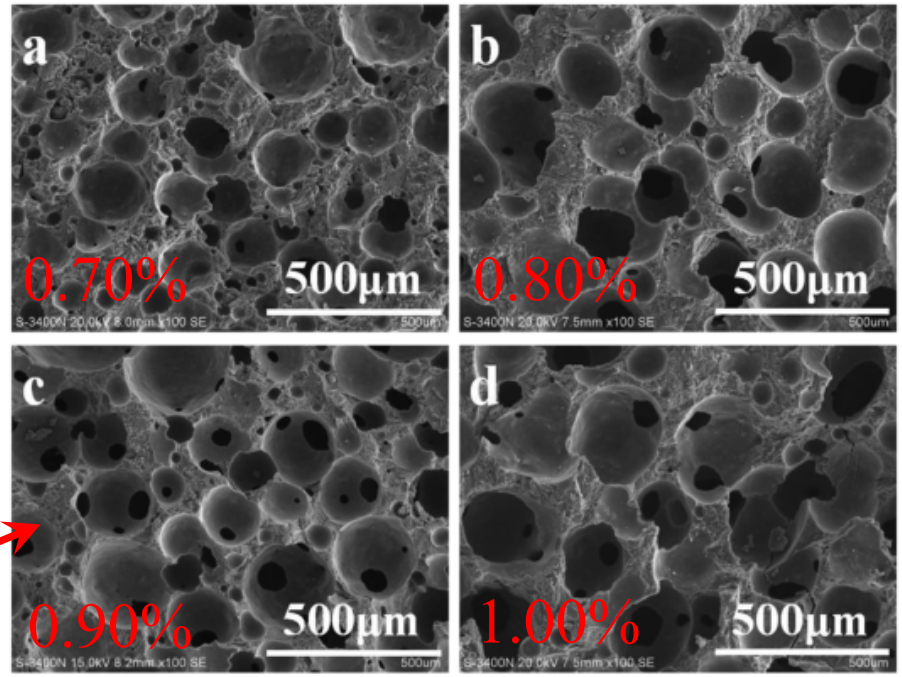




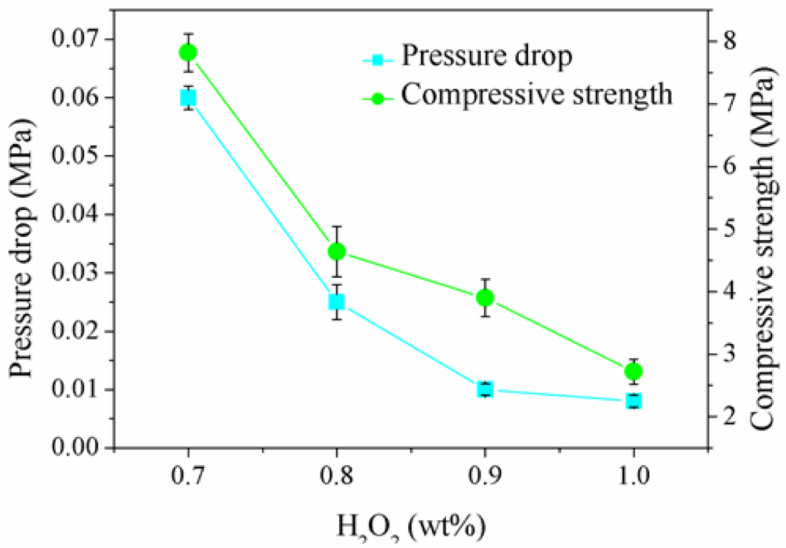
Porous body of cross-section combined with compact surface

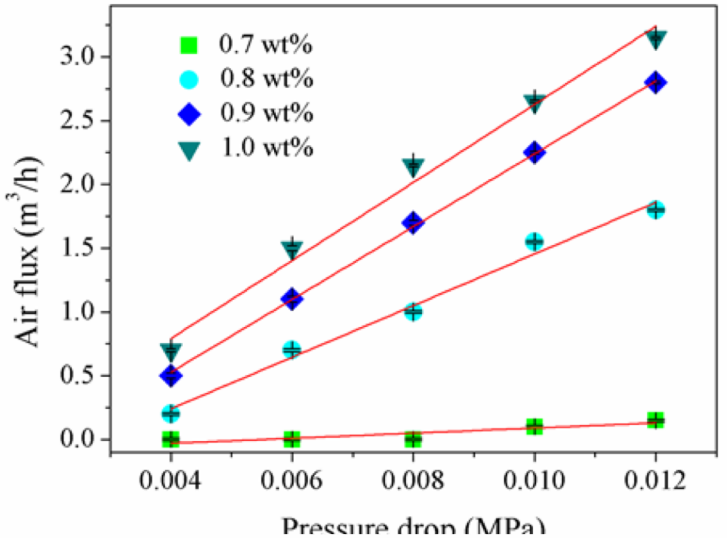
0.12 μm pore of compact surface results from water evaporation and 10 -100 μm pore of internal structure
Nano porous structure of the surface ensured the interception of particles, and the near millimeter-sized porous structure of the membrane body ensured high permeability.

Randomly distributed millimeter-sized open pore giving the high permeability. Pores size increased with the H_2O_2 addition

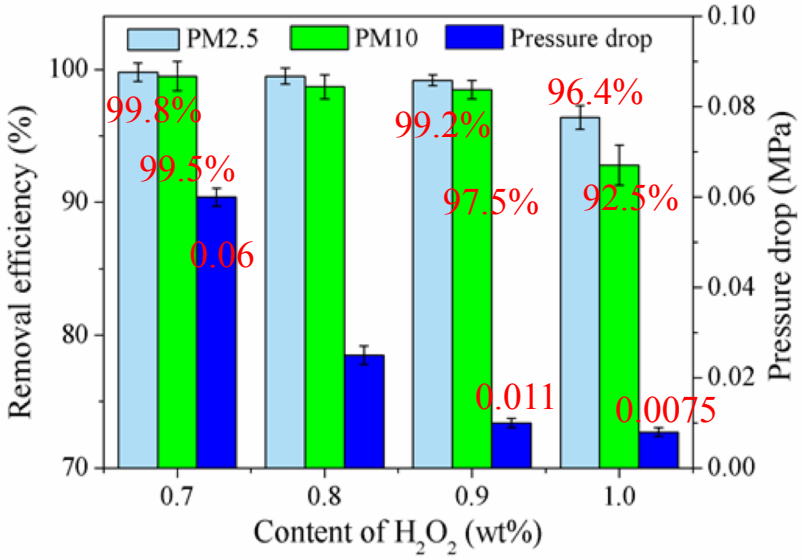


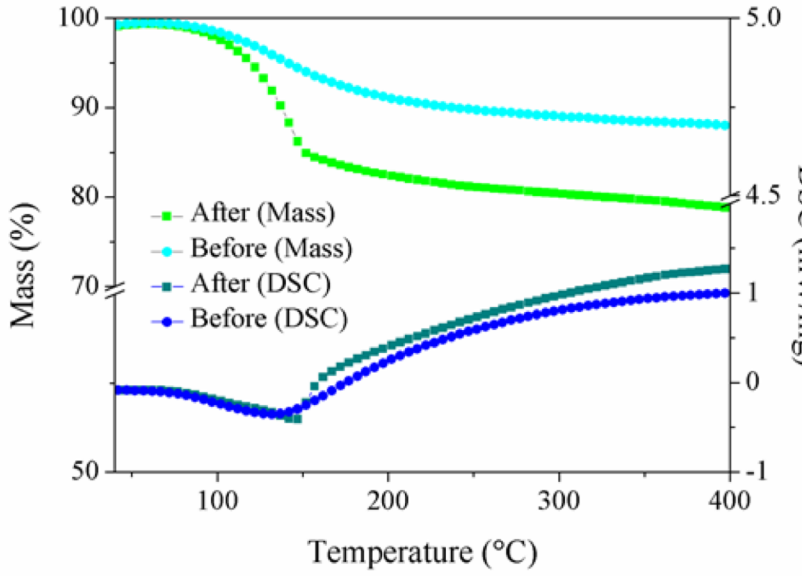
Application 2. geopolymer membrane for gas treatment





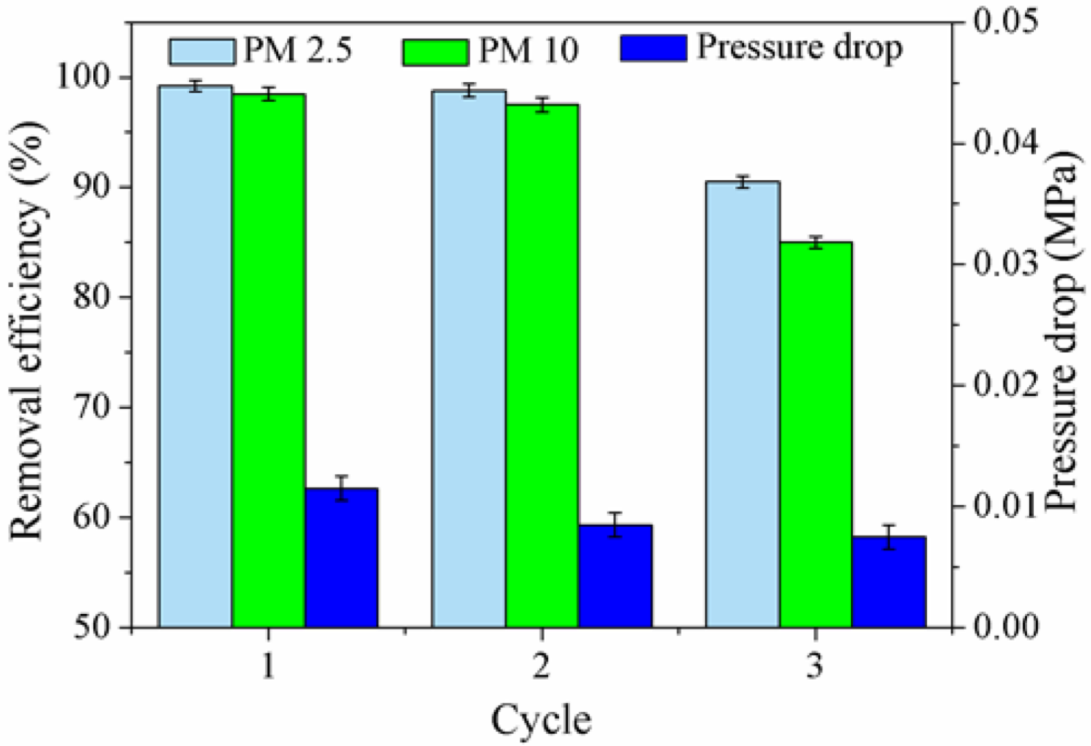
1.Pressure drop and compressive strength decrease with the increase of foaming agent.
2. Air flux improve with the increase of Pressure.
3. Permeability can be controlled by foam agent.

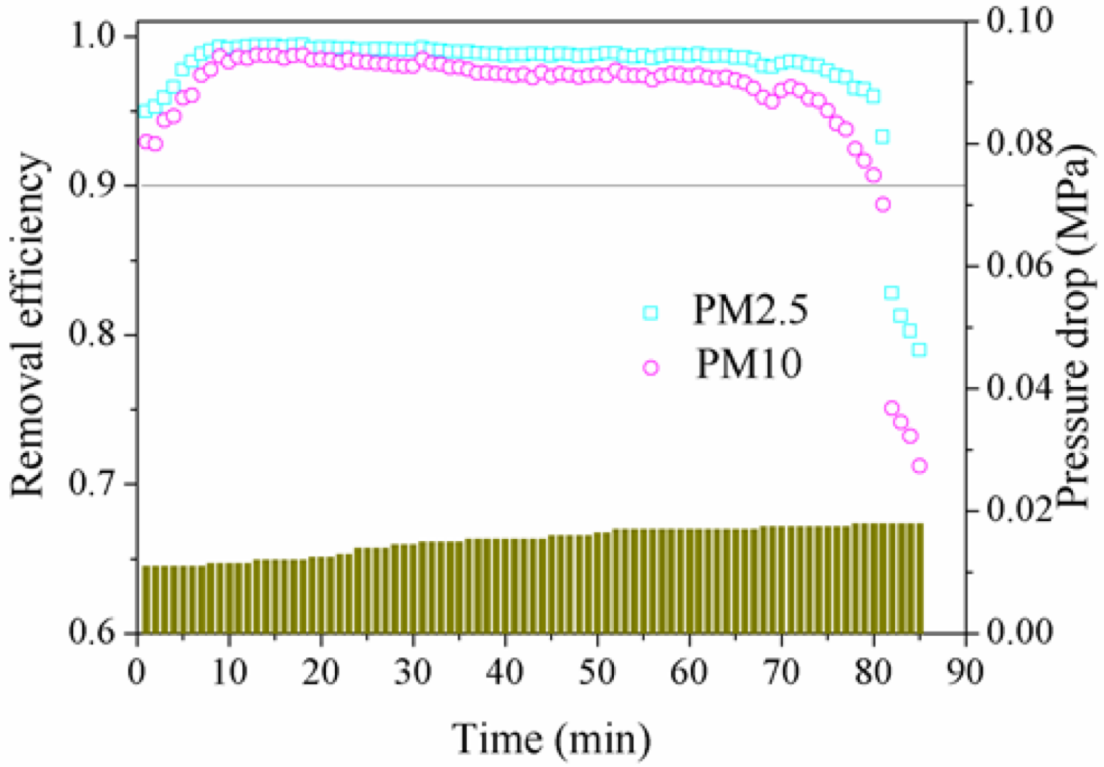




1.Membrane with 0.9% foam agent shows PM10 and PM5 removal efficiency of 99.2% and 97.5%.
2.After 90 min filtration, about 9 wt% PM matter was filter in membrane.

Application 2. geopolymer membrane for gas treatment

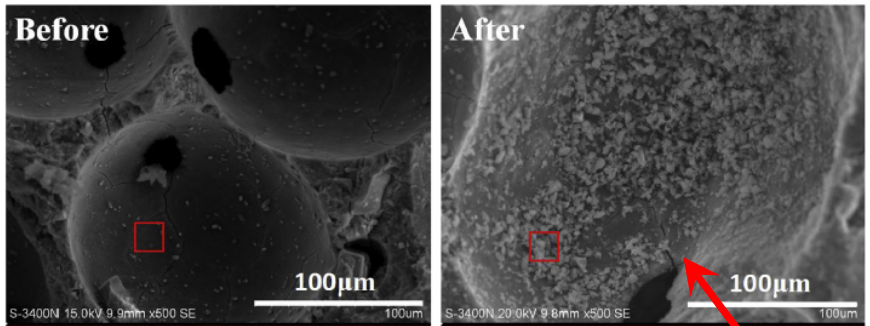




After 90 min filtration, PM2.5 and PM10 removal efficiencies of 98.5% and 99.3%, pressure drop from 0.011 to 0.018 Mpa.
After recycling, PM2.5/10 removal efficiency of still as high as 90%/85%.

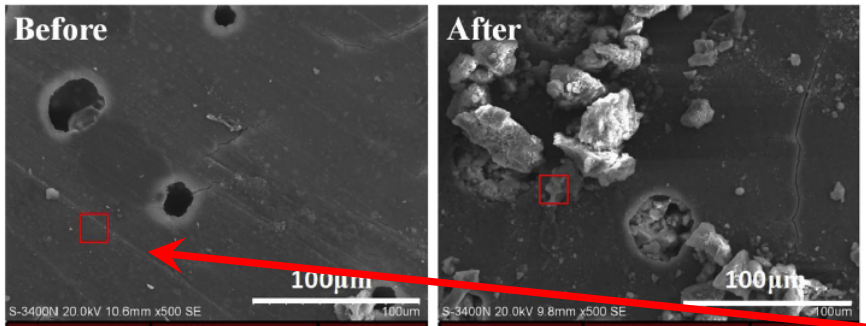
3 stages of filtration:
1st, removal efficiency increase, forming cake layer
2nd, keeping stable removal efficiency
3rd, removal efficiency decrease, adsorption saturation.

Application 2. geopolymer membrane for gas treatment



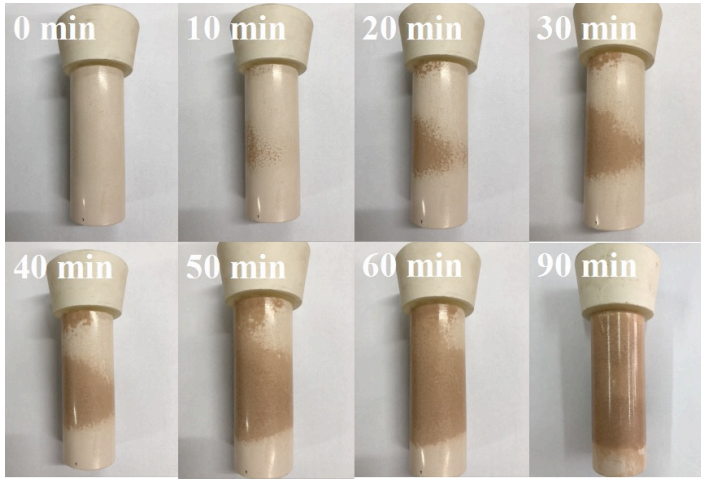
Element	Wt%	At%
CK	02.94	04.66
OK	59.40	70.55
NaK	04.62	03.82
AlK	08.87	06.25
SiK	16.18	10.95
CaK	07.99	03.79
Matrix	Correction	ZAF

Element	Wt%	At%
CK	08.85	13.52
OK	54.88	62.90
NaK	06.55	05.22
AlK	08.29	05.63
SiK	14.95	09.76
CaK	06.49	02.97
Matrix	Correction	ZAF

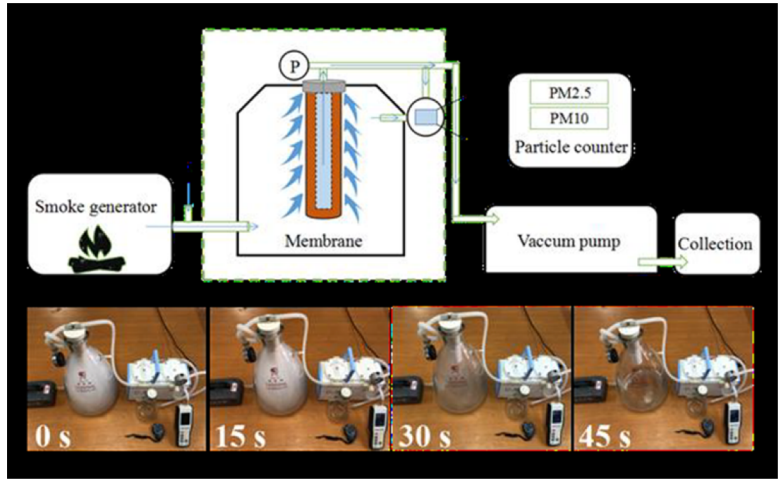


Element	Wt%	At%
CK	02.86	04.90
OK	46.59	59.99
NaK	04.01	03.59
AlK	10.69	08.16
SiK	22.48	16.49
CaK	13.37	06.87
Matrix	Correction	ZAF

Element	Wt%	At%
CK	11.22	18.12
OK	44.32	53.76
NaK	03.92	03.31
AlK	07.30	05.25
SiK	16.71	11.55
CaK	16.52	08.00
Matrix	Correction	ZAF



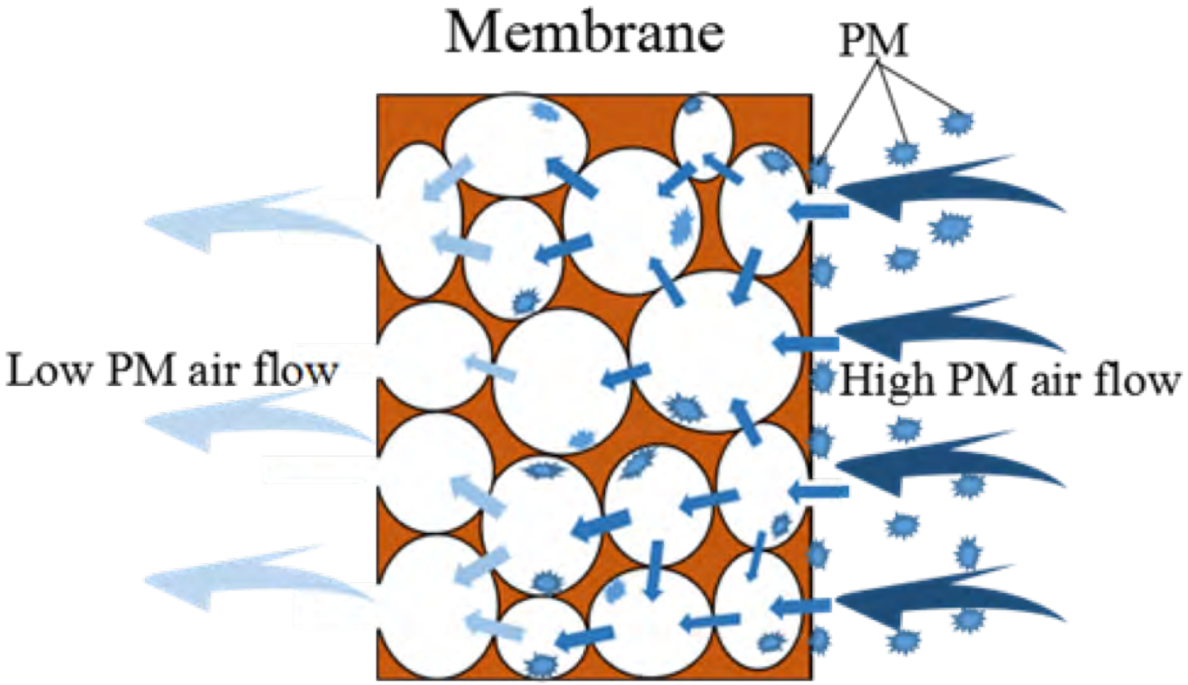
After 90 min, membrane completed the filtration



large PM was rejected on the surface

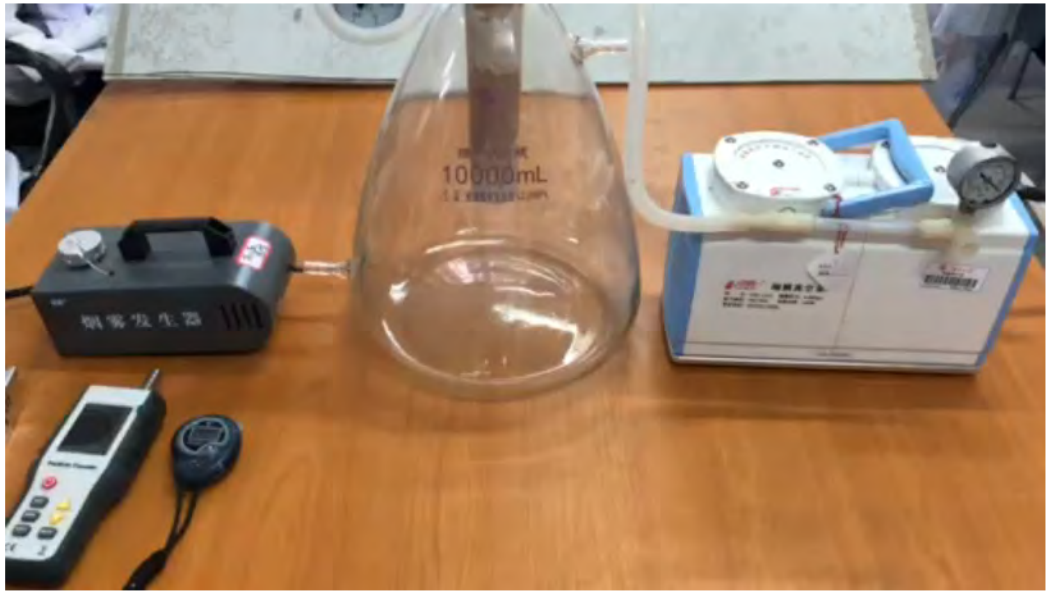
surface compact layer intercepted extremely small particulate matter.

Application 2. geopolymer membrane for gas treatment

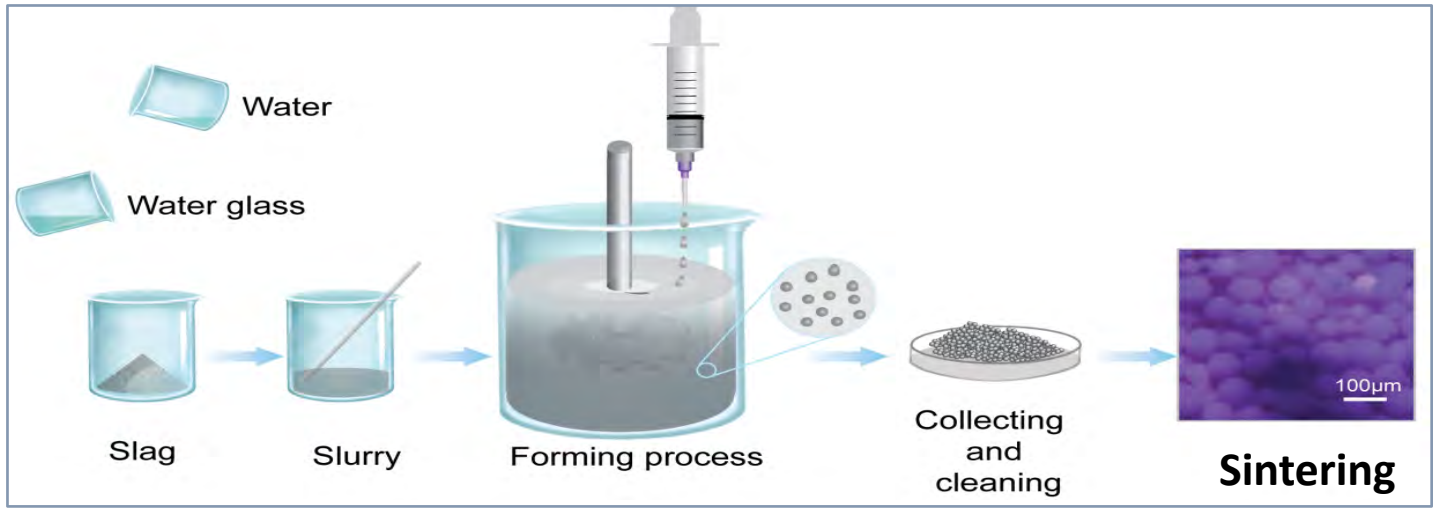


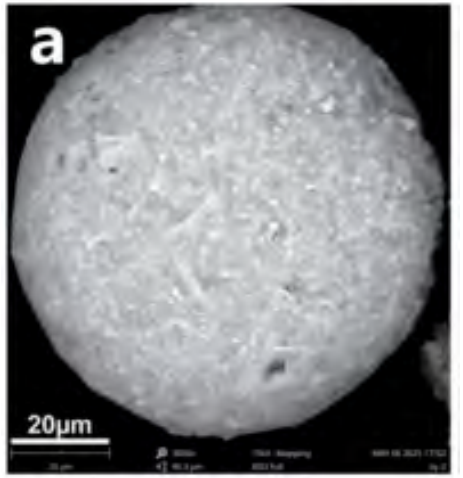
Filtration mechanism of membrane for PM:

Majority of PM were absorbed and removed by the large surface area of the membrane body. Nano-size PM were filtered by near-nanoporous surface of the membrane,

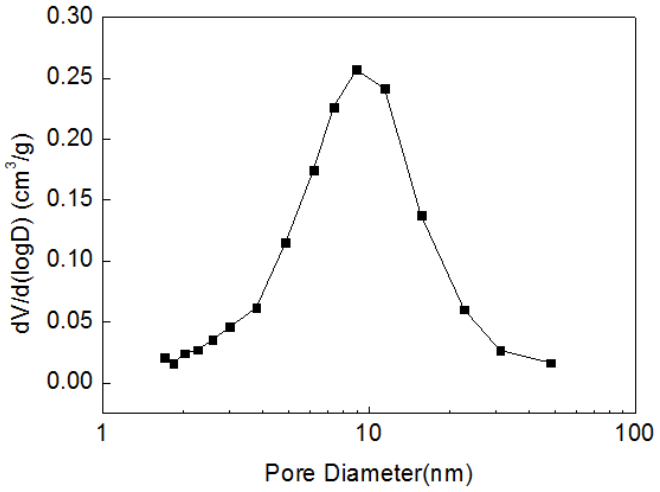


Application 3. geopolymer microsphere for heavy metal ions removal

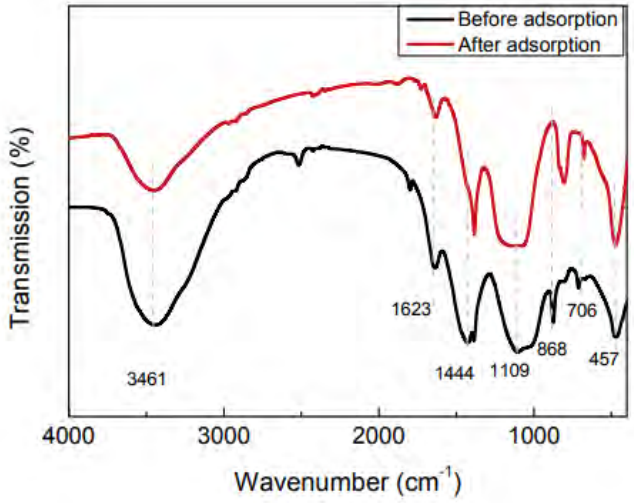




Geopolymer microsphere

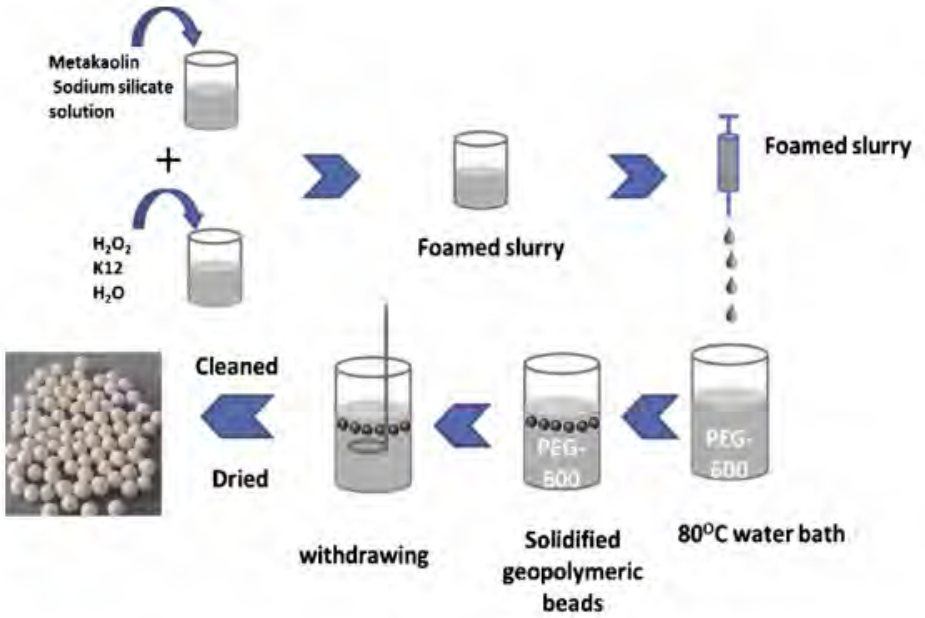


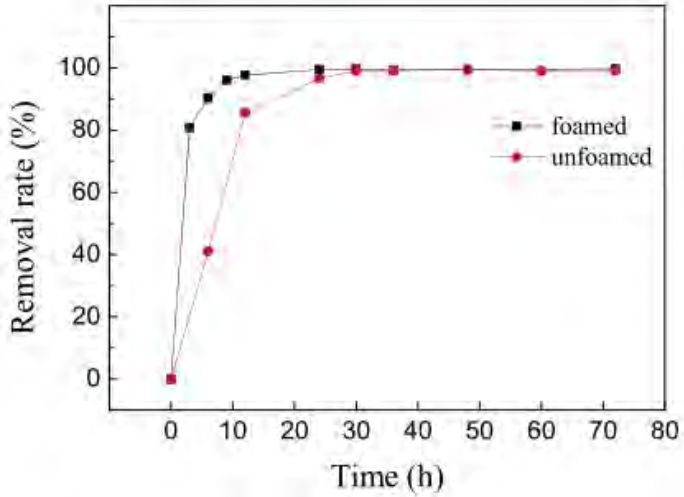
Specific surface 79.80 m^2 /g
Mean pore 7 nm



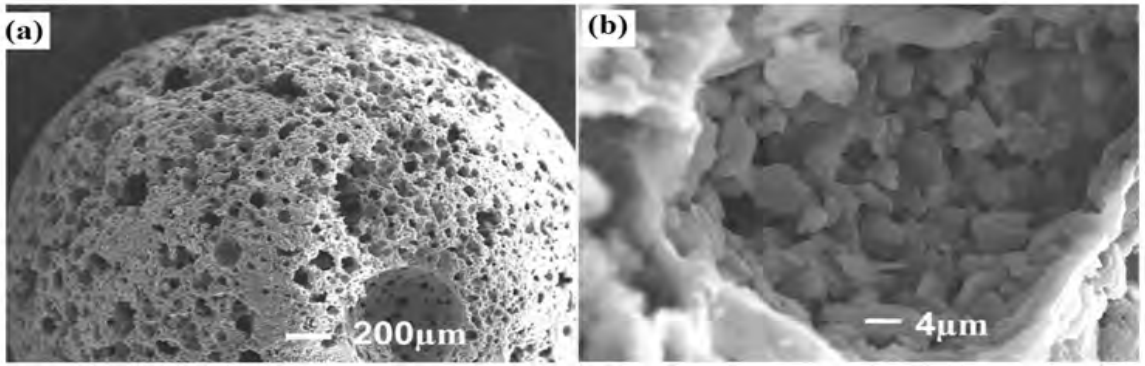
Si-O-Si shift to lower number
Pb^{2+} adsorb in geopolymer

Application 3. geopolymer porous microsphere



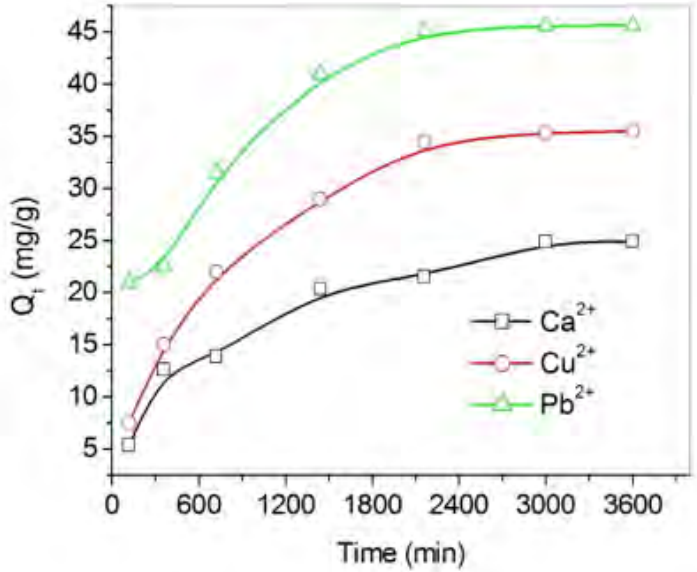


Active sites and surface area increase, after foaming



Surface of microsphere

Cross-section of microsphere



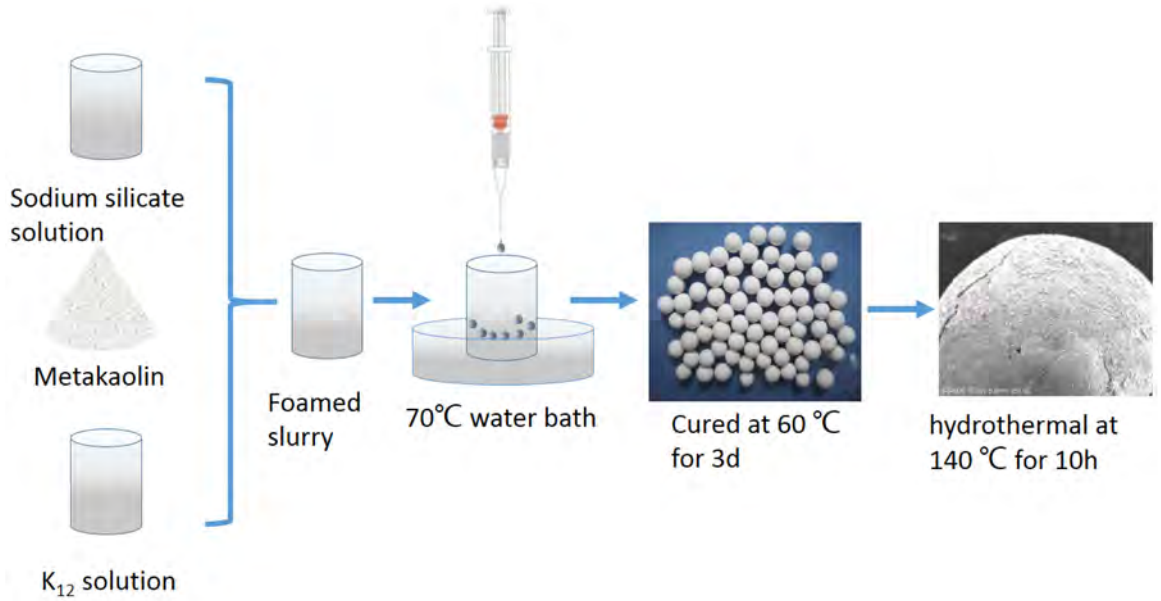
Adsorption capacity of metal ions: Pb>Cu>Ca

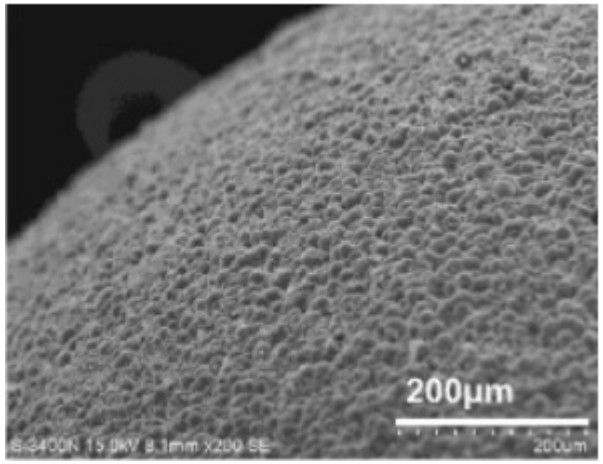
Application 3. geopolymer microsphere for heavy metal ions removal

Number	Adsorbent	Type	BET surface (m^2/g)	Heavy metal	pH	Temperature (° C)	Qm (mg/g)
1	Fly ash-based geopolymer	Powder	/	Pb^{2+}	5	25	134.95
2		Powder	/	Cu^{2+}	6	25	96.80
3	Metakaolin-based geopolymer	Particle	65.7	Pb^{2+}, Cu^{2+} Cr^{3+}, Cd^{2+}	4	25	100.00 54.54 10.15 75.74
4		Membrane	39.66	Ni^{2+}	5	25	43.36
5		Powder	9.65	Cu^{2+}	5	25	43.48

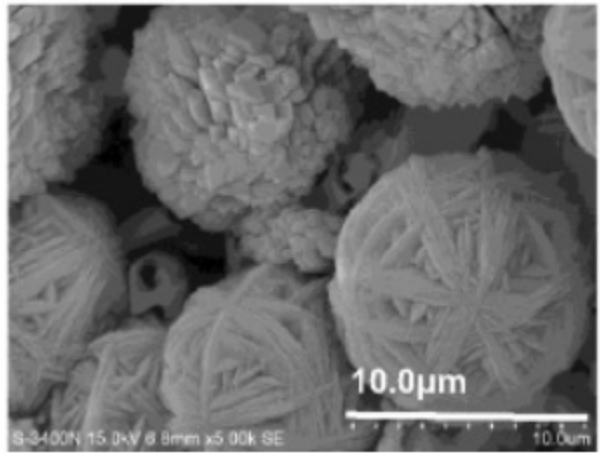
Porous geopolymer microspheres present an adsorption capacity 4–5 times larger than similar geopolymer materials

Application 3. geopolymer P-type zeolite microsphere

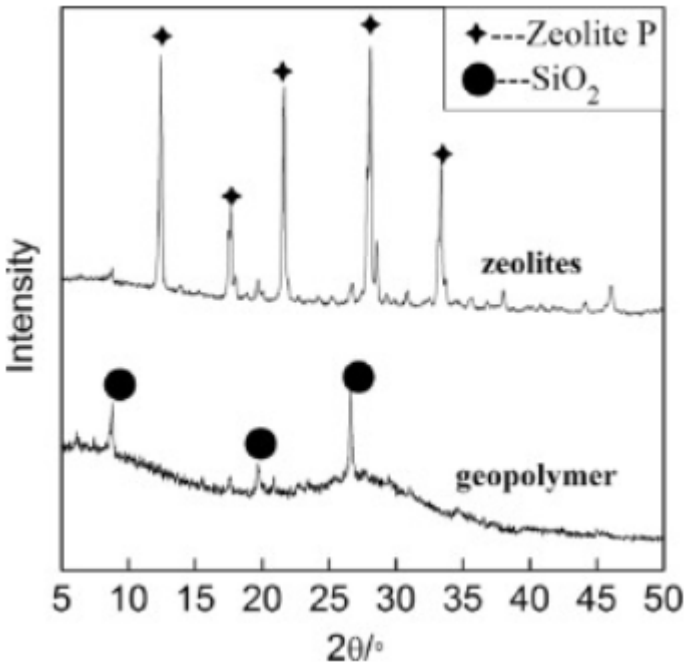




Surface of zeolite sphere



Cross-section of zeolite sphere



Zeolite P ($Na_{3.6}Al_{3.6}Si_{12.4}O_{32}\cdot 14H_2O$ transition

That’s all of my presentation,
thanks for listening!