CSNS 中国散裂中子源 China Spallation Neutron Source

Operating status and recent upgrades of SANS diffractometer at CSNS

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ICANS-2023

Dongguan, Nov.,1

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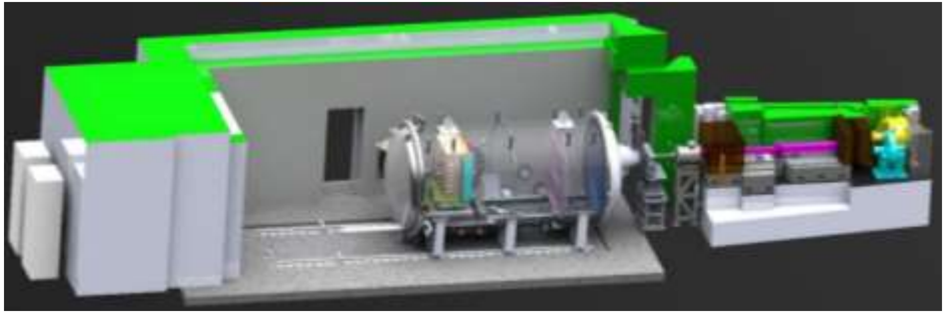
Chinese Academy of Sciences

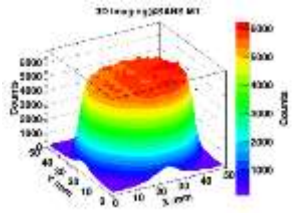
Outline

1. Operating status of SANS@CSNS
2. In-situ capability and kinetic study
3. Recent Upgrades
4. Conclusion

Instrument Specifications of SANS@CSNS



1st neutrons Nov,1,2017



1st user experiment Oct., 2018

- **1st SANS @ pulsed source in China** focusing on **availability** and **reliability**
- **Classical pin-hole geometry** with moveable detector (2~4 m)
- **Short straight beamline (16 m)** enabling **wide Q-range** and **high intensity**

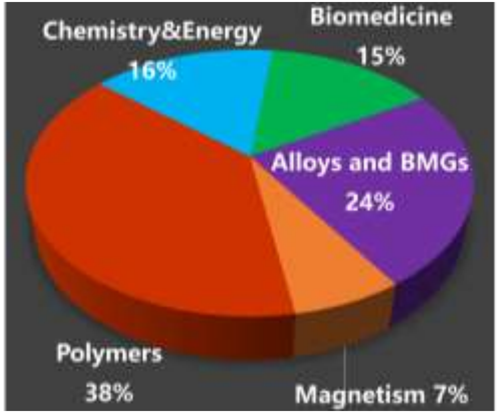
Wavelength-range	**1~12 Å**
Q-range	**0.005~0.70Å^{-1}（S-D: 4m） 0.008~1.40Å^{-1}（S-D: 2m）**
Q resolution	**~8%@0.1 Å^{-1}**
Neutron flux @ Sample（100kW）	**~6*10^{6} n/cm^{2}/s**
detector resolution	**8mm (^{3}He LPSD)**
Sample size	**> 8 mm**

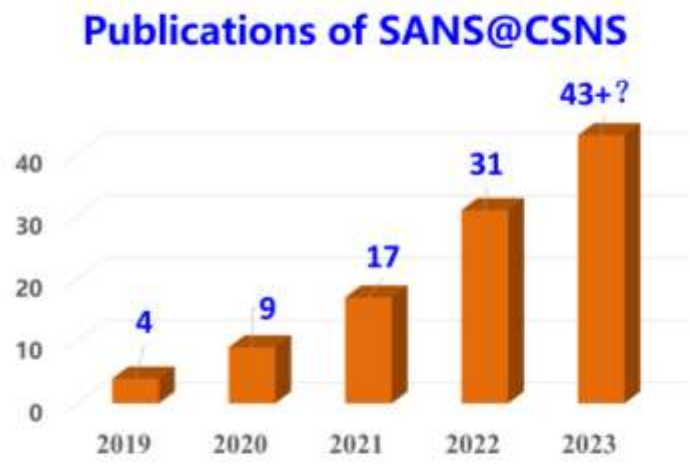
Yubin Ke, etal, (2018), Neutron News, 29:2,14*

Users 'program and outcome

Users' beam time： ~4000h/year

Users' proposals of SANS@CSNS(2 cycles)





Scientific application in soft matters

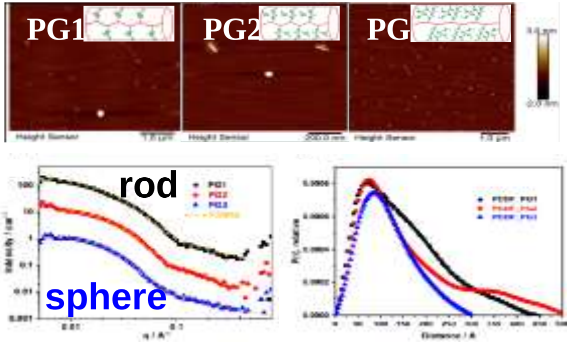
Molecular structure, **phase separation ,**
assembly and aggregation structure

- ✓ Polymers;
- ✓ Micelles ;
- ✓ Sol-gels;
- ✓ Peptides, RNA(medicine), Proteins

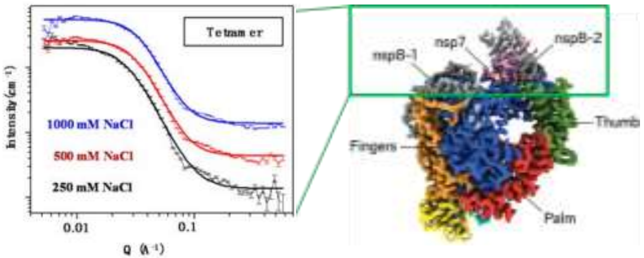

nature communications

Article

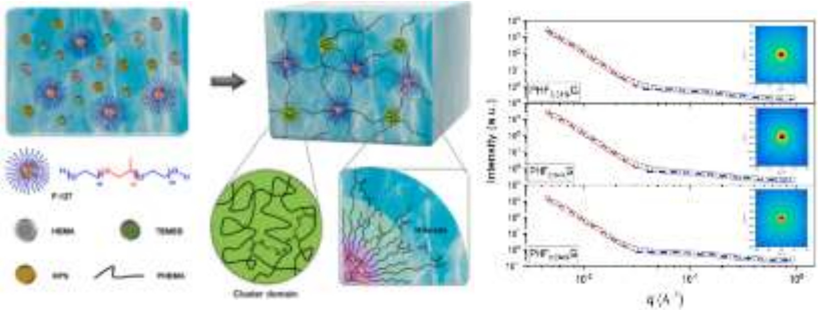
Stimuli-responsive rotaxane-branched dendronized polymers with tunable thermal and rheological properties



SARS-CoV-2 nsp8: stability of protein in salts



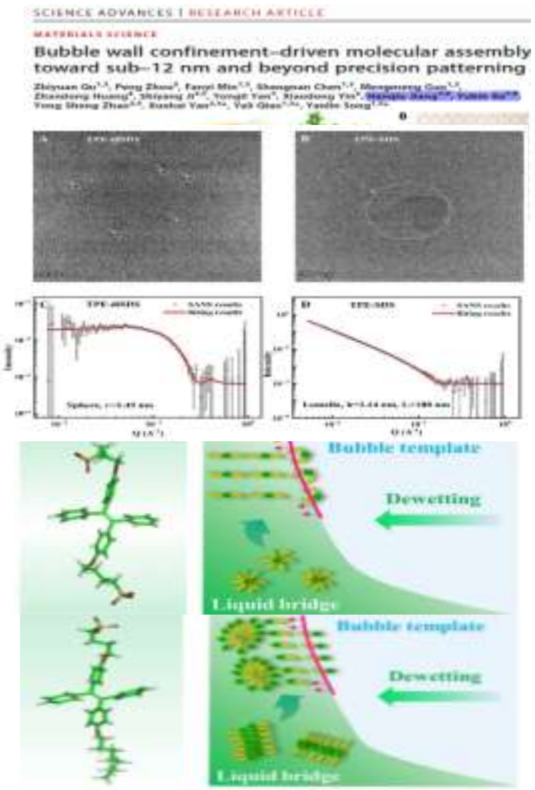
Communication Biology 2022, 925， 5



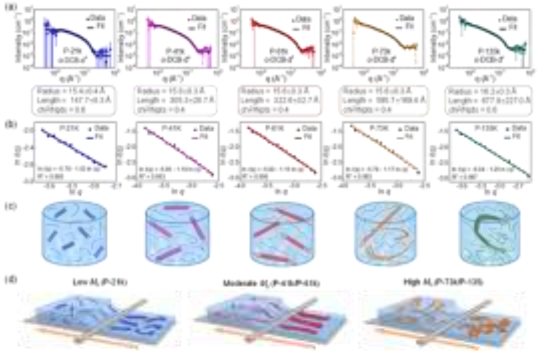
Chemical Engineering Journal 450 (2022) 138346

Morphology of molecular assembly and aggregations

different **molecular symmetry**

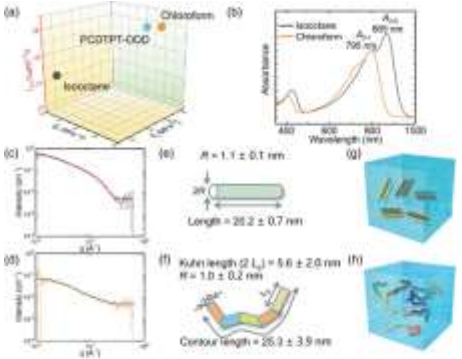


different **molecular weights**



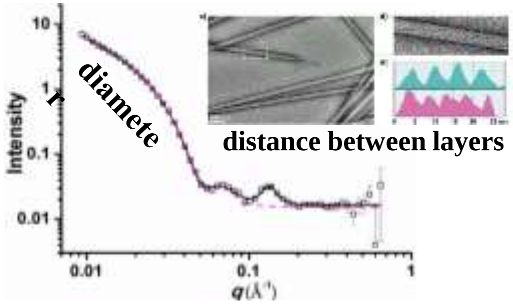
Adv. Mater. 2022, 34, 2108255

different **solvents**

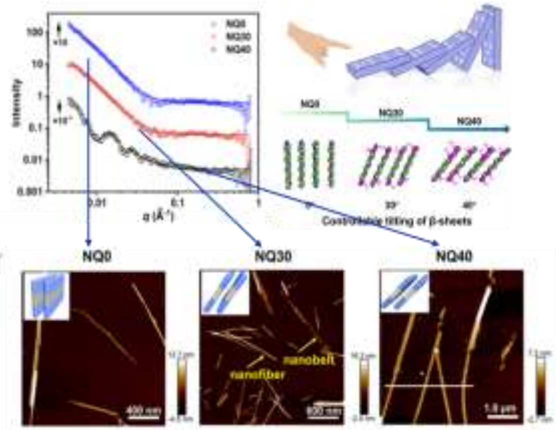


Macromol. Rapid Commun. 2022,43, 2200084

multi-layered nanotube



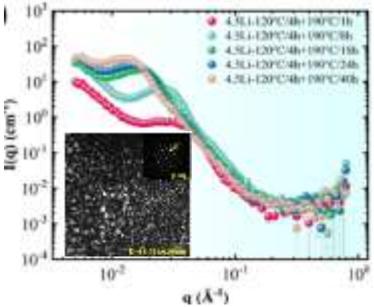
Domino-like structure



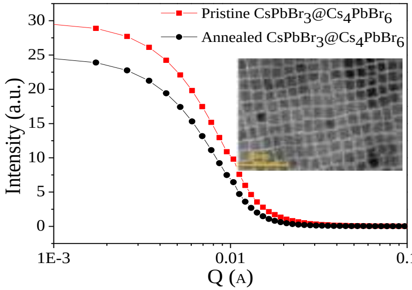
[1] *Nano Lett.* 2021, 21, 24, 10199–10207
[2] *Angew. Chem.Int. Ed.* 2022, 61, e2022125

Scientific applications in hard matters

- Morphology of nano-scale **cluster, precipitate, crystal, and domain**
- **Concentration fluctuation/wave**
- **Nano-porous structure**

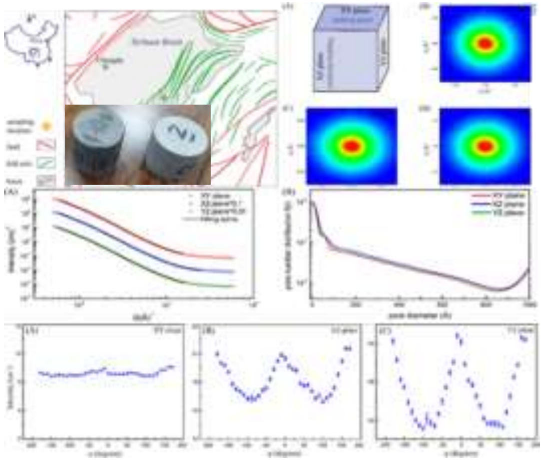


JMST,2023,145:125-135



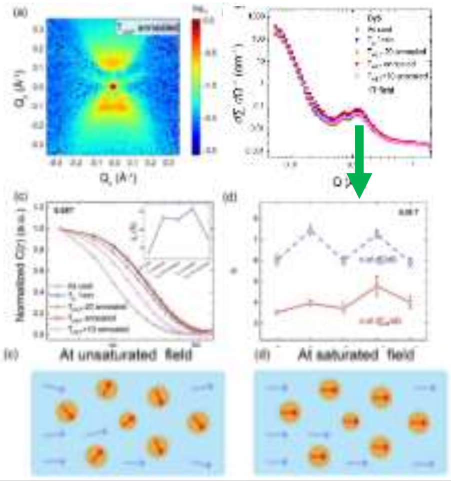
ACS Nano 2020, 14, 5, 5183–5193

Morphology and orientation of nanoscale pores in shales

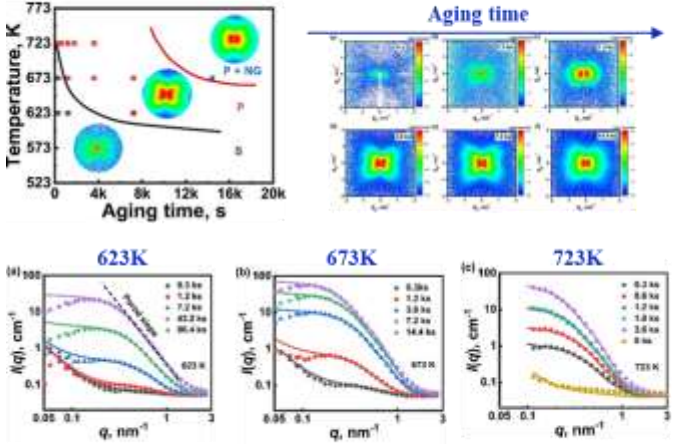


Energy & Fuels,34(2020): 7974

Topological magnetic domains in LLPT soft-magnetic BMGs



JMST,2024,176:224-235



Acta Materialia 233 (2022) 117969

Outline

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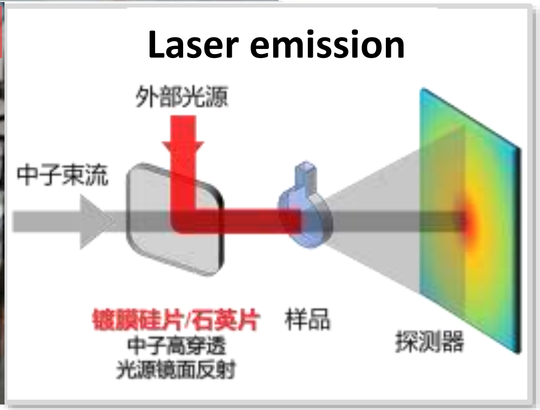
2. In-situ capability and kinetic study
3. Recent Upgrades
4. Conclusion

In-situ sample environment

Water-bath	Stress-temp	Magnetic devices

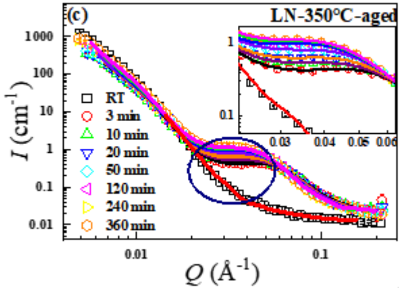


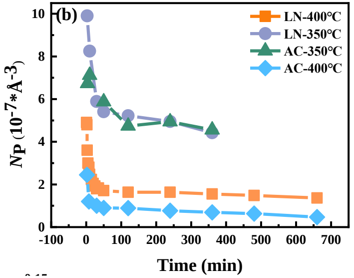
In-situ kinetic study: Time-resovled SANS technique

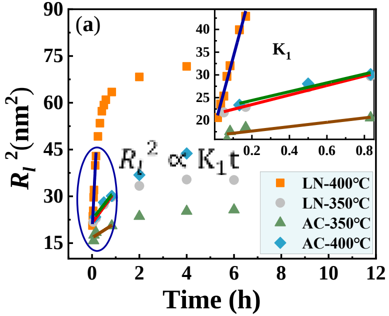
Kinetic evolution: $\lambda^{\frac{1}{n}} - \lambda_0^{\frac{1}{n}} = k * t$

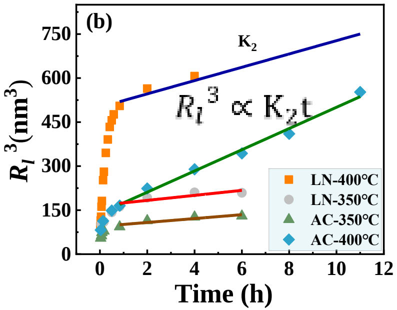
In-situ heating/cooling

Nucleation-growth



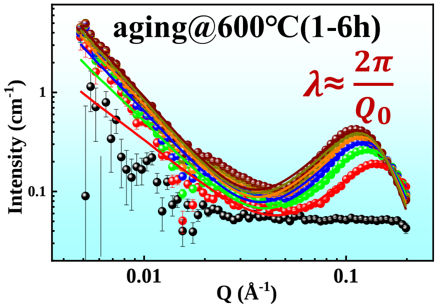


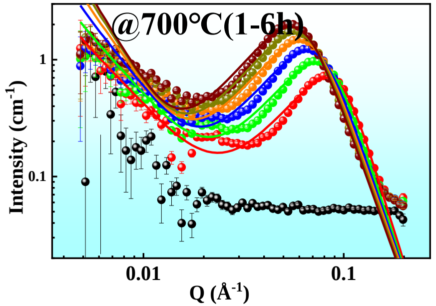




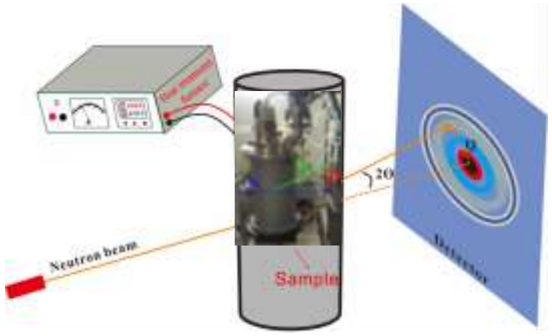
X.T.Zhao, **Y.B.Ke***,et al, (under reveiw)

Spinodal decomposition

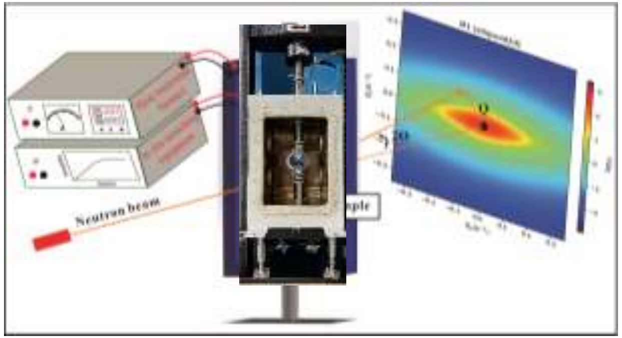




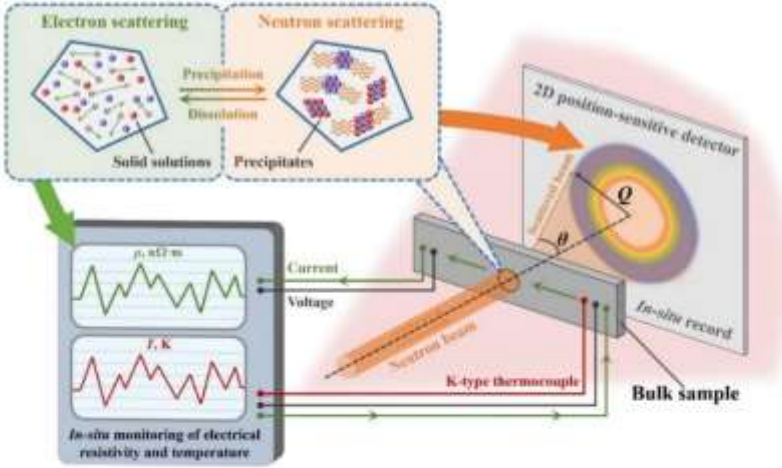
S. F. Xie, **Y. B. Ke***, et al,
（**in preparation**）



In-situ coupled **Stress**-**temp** loading



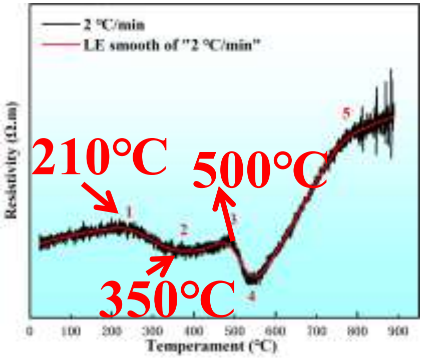
SANS Methodology: Simultaneous Electro-resistivity

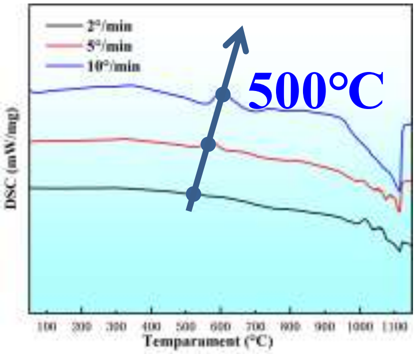


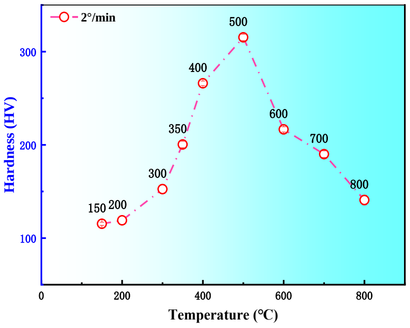
Electro-resistivity measurement

Patent：柯于斌等，原位监控金属材料热处理过程的测试平台、方法及应用，202310283751.8

Phase transition of Al alloys during ageing

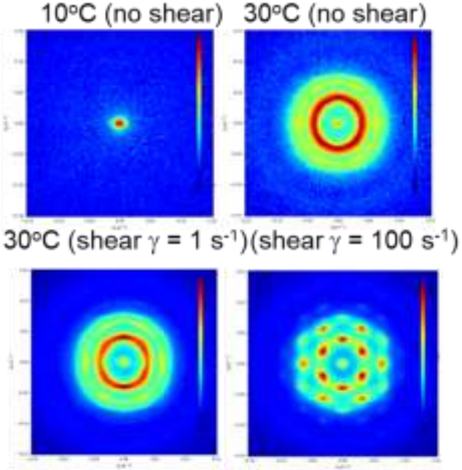




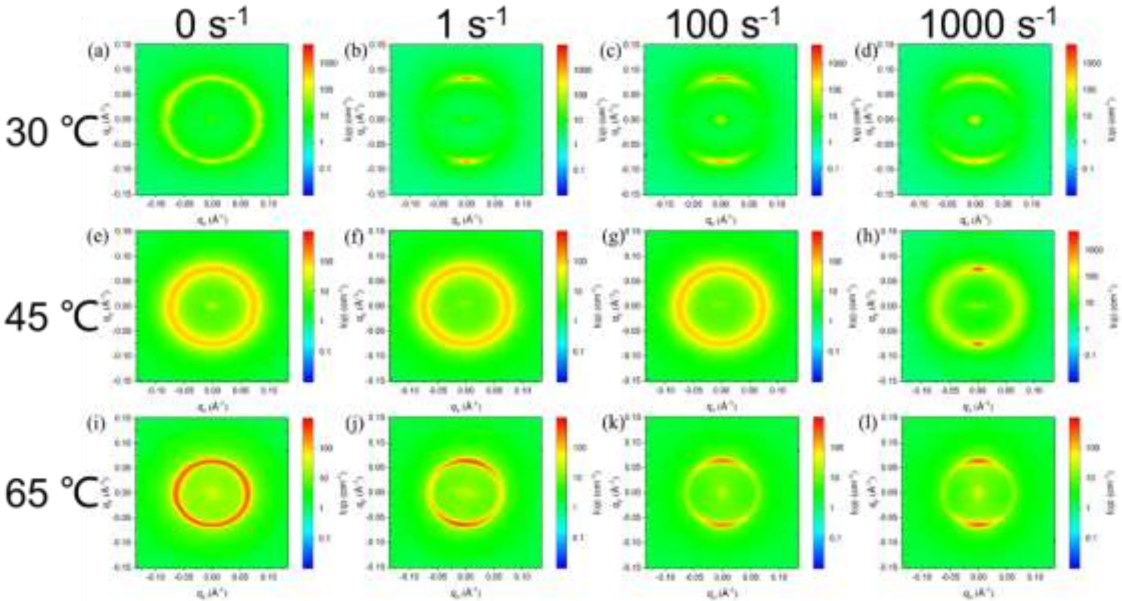


Rheo-SANS technique

Pluronic F127 (in D_2O)

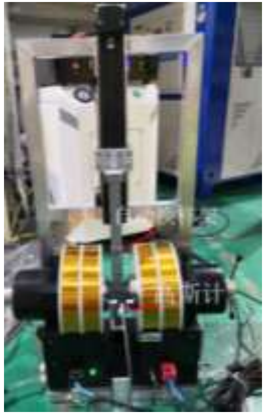


➢ **Heating/shearing-induced phase transition and ordering process**



Jun Wang, et al. Study the Phase Behavior of Pluronic and Diblock-polypeptoid by the Rheo-SANS at China Spallation Neutron Source (in preparation)

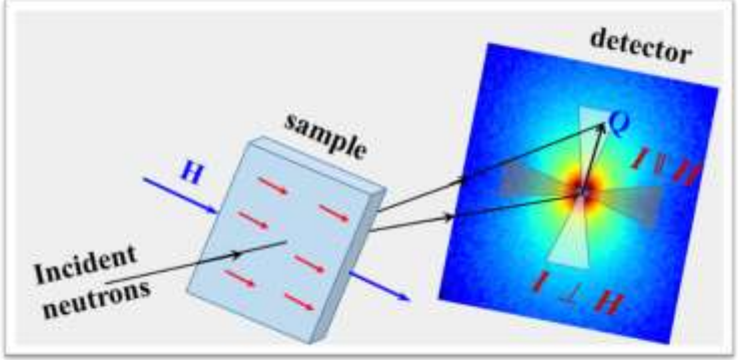
In-situ Magnetic SANS technique

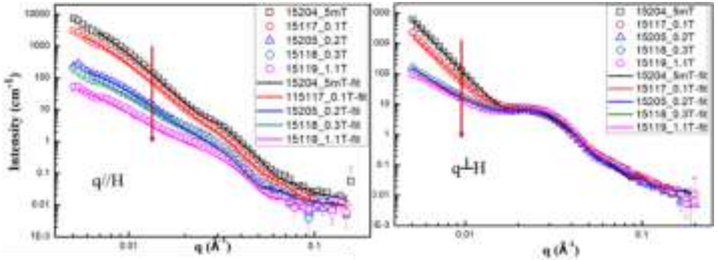


- **Separation the Magnetic-Nuclear scattering**

$$I_{nuc} = I_{\parallel}(\vec{H})$$

$$I_{mag} = I_{\perp}(\vec{H}) - I_{\parallel}(\vec{H}) = \frac{8\pi^3}{V}|\vec{N}|^2$$



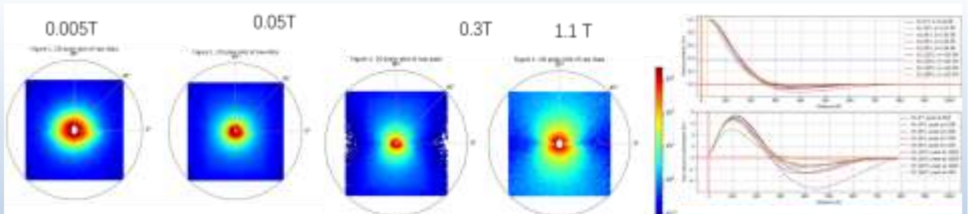


- **Extraction of Spin-misalignment**

$$\frac{d\Sigma_M}{d\Omega}(q) = \frac{8\pi^3}{V} b_H^2 [|\widetilde{M}_y^2| \cos\theta^2 - (\widetilde{M}_y \widetilde{M}_z^* + \widetilde{M}_y^* \widetilde{M}_z) \sin\theta \cos\theta]$$

$$C(r) = \frac{1}{8\pi^3} \int_{q=0}^{\infty} q \frac{d\Sigma_M}{d\Omega}(q) \exp(iqr) d^3q$$

PDDF and correlation length



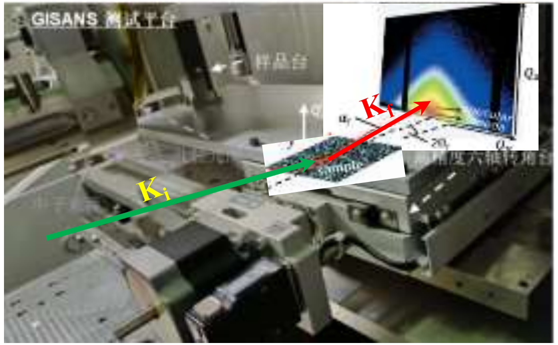
Field (T)	P(r)_0° (nm)	P(r)_90° (nm)	L_c_0° (nm)	L_c_90° (nm)
0.005	9.5	11.5	11	13.4
0.05	12.5	16	15.3	19.7
0.1	13.5	17.5	16.6	22.1
0.3	16	25	18.7	29.2
1.1	12.5	12	14.1	13.9

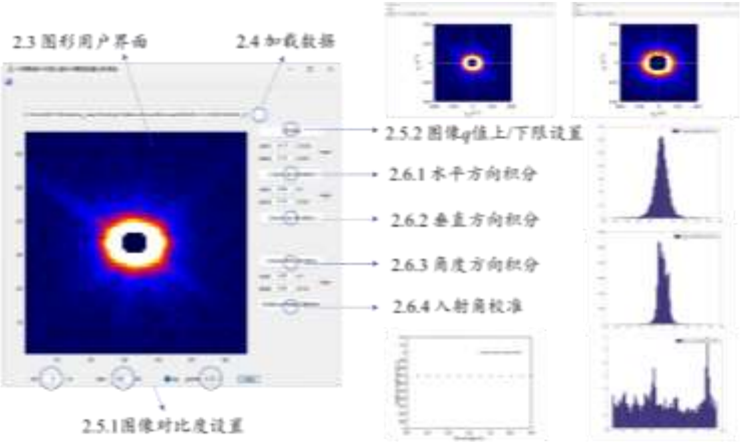
GISANS technique

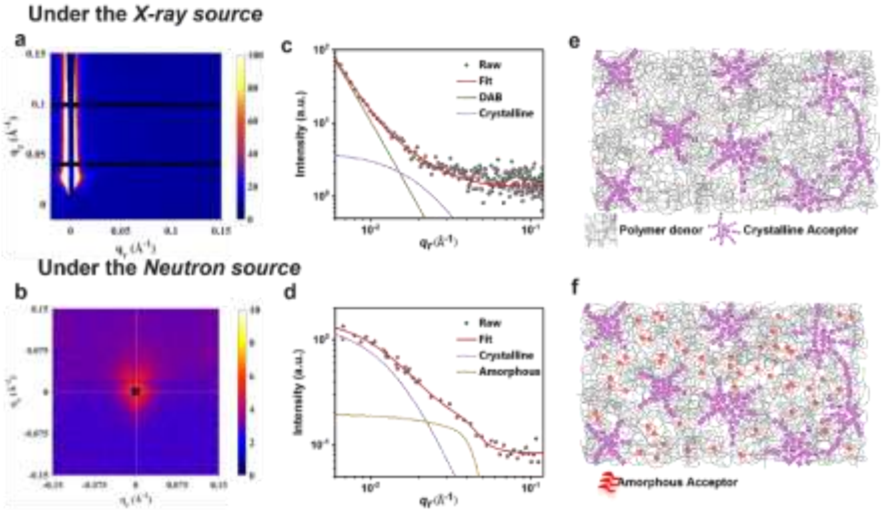
CUHK Xinhui Lu

Nanostructure probe in thin film and interface

- **Deuteration obviously increase the contrast between D/A**
- ***Amorphous acceptor was firstly discovered by GISANS, which is invisible in GISAXS result***







GL Cai, Yuhao Li， et al,. *Revealing the 3D Morphology of Organic Solar Cells via Advanced Neutron Scattering Techniques,* **Nature Comm.** *(under review)*

Outline

1. Operating status of SANS@CSNS
2. In-situ capability and kinetic study
3. Progress of recent upgrades
4. Conclusion

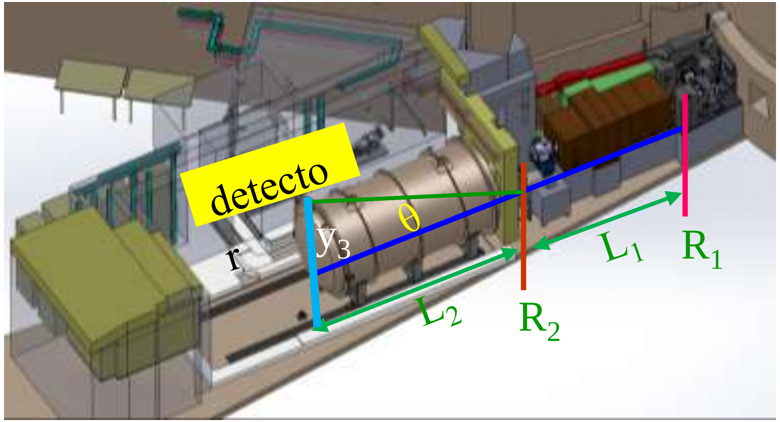
SANS upgrade objectives

Upgrade objectives	Before upgrade	After upgrade
Broaden Q-range	0.006~1.4 Å^{-1}	0.004~1.5 Å^{-1}
Increase spatial resolution	10 mm	8 mm
Enhance counting-rate	20MHz	200MHz
enlarge sample space	1.2 m*0.5 m	3 m*1m
Load capacity of sample stage	300Kg	2000Kg

key parameter: Q_{min}

$$Q_{min} = \left(\frac{2\pi}{\lambda L_2}\right)\left(\frac{L_2}{L_1}R_1 + \frac{L_1+L_2}{L_1}R_2 + \frac{\Delta y_3}{2} + 2A\lambda^2\left(\frac{\Delta\lambda}{\lambda}\right)\right)$$

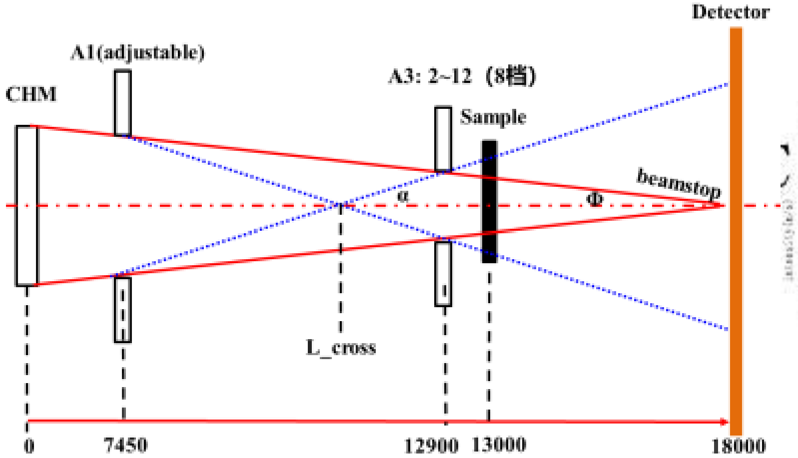
- **Long wavelength: λ (overlap)**
- **Large SD distance: L_2**
- **High spatial resolution: Δy_3**

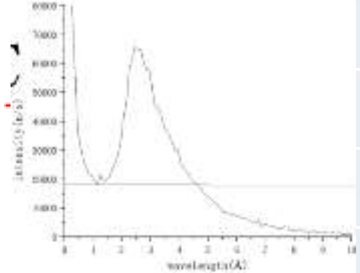


L_1: 4.55m → 5.55m; L_2: 4m → 5m

Simulation and Calculation

New geometry: sample@13m; detector@18m



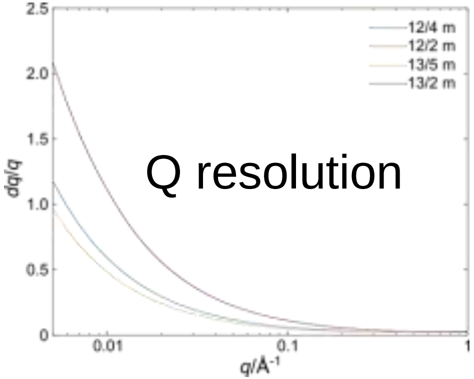


Neutron flux @ sample (1~10Å)

Detector area	Aperture size (mm)	(A3@11.897) 12m ($n*s^{-1}cm^{-2}$)	(A3@12.897) 13m ($n*s^{-1}cm^{-2}$)
8mmx8mm	**A3=Ø8, S1=16x16**	**8.31E+06**	**5.59E+06**
6mmx6mm	**A3=Ø6, S1=14x14**	**6.39E+06**	**4.31E+06**
6mmx6mm	A3=Ø6, S1=16x16	8.36E+06	5.64E+06
8mmx8mm	A3=Ø6, S1=14x14	3.59E+06	2.45E+06

Q-range calculation

Qmin	Qmax	λmax	λmin	L1	sample posi	R1	L2	Detector posi
0.0077	1.450346	10.5	1.1	4550	12000	7	2165	14000
0.0044	0.753902	9.5	1.1	4550	12000	7	4165	16000
0.0033	0.362308	10.6	2	5550	13000	3	5200	18000
0.0084	1.557025	10.5	1.1	5550	13000	3	2200	15000

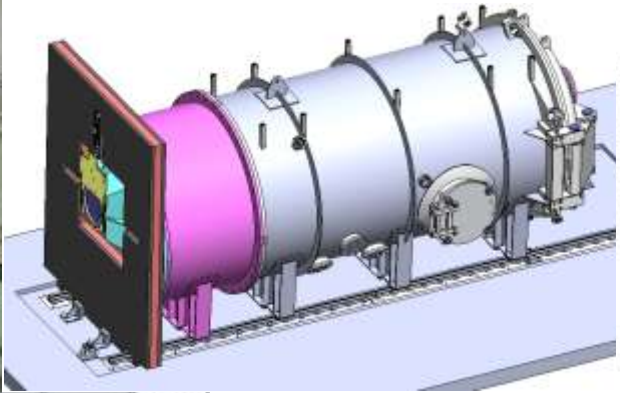


Upgrade Progress: sample space and scattering chamber

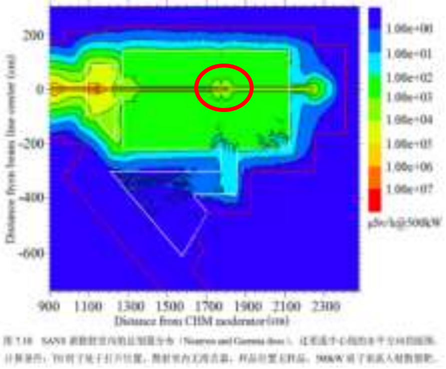
Sample Space and Stage

Top-loading gate

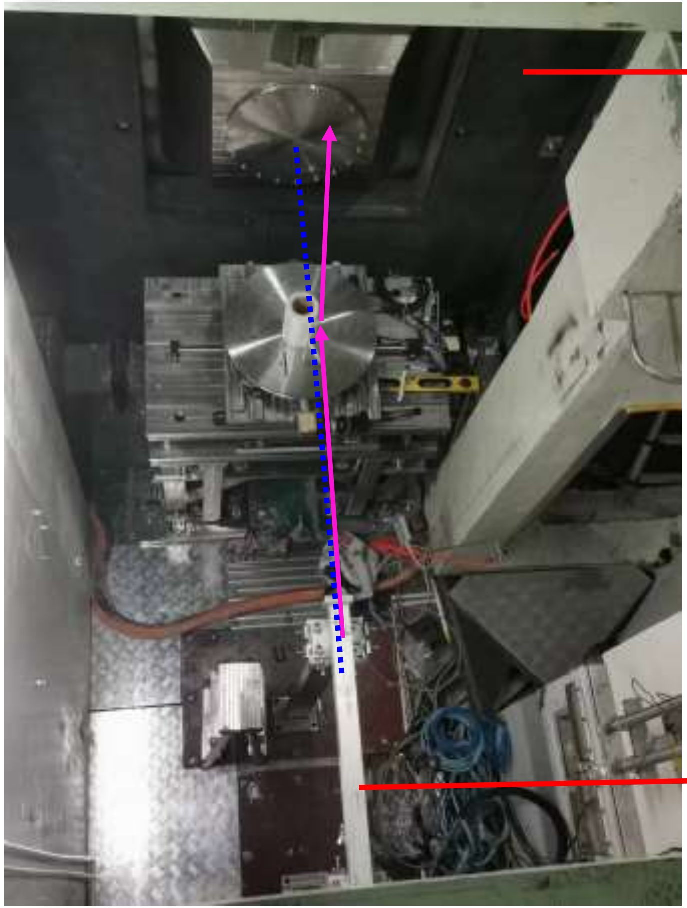
Extension of the scattering chamber



Upgrade the back cover

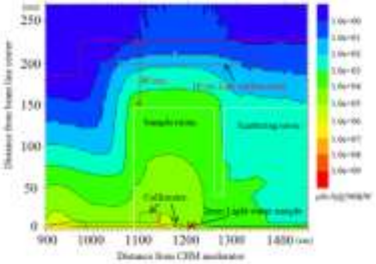


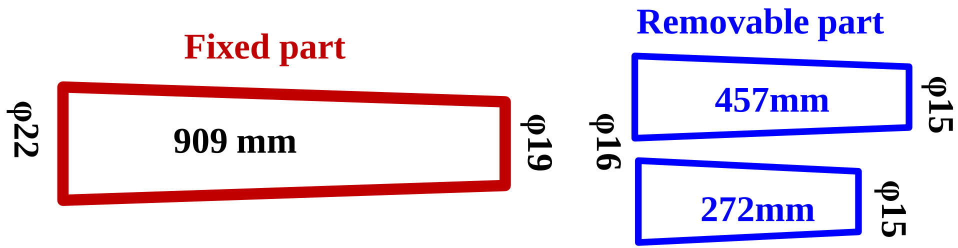
Beamline Collimation upgrade

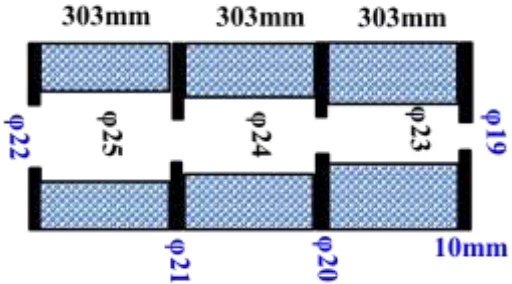


Sandwich structure shielding

50mmB-PE +100mmFe+50mmB-PE







Scraper: sintered B_4C

Spacer :B_4C/Fe composite

Fe shot+B_4C+PTFE

Upgrade the electronics of Main detector

SANS electronic system

谱仪散射室外
散射室
散射罐内真空腔

控制机柜
DAQ机柜
UPS机柜

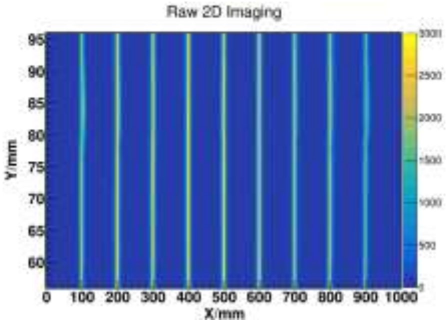
T0扇出板 10ch
高压设备 10ch
电源设备 10ch
光纤交换机 >10ch

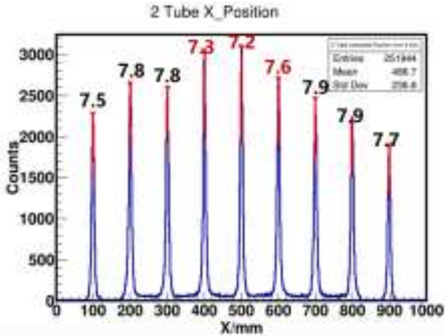
坦克链
坦克链
坦克链

电子学模块 no.1
BANK 1
电子学模块 no.5
电子学模块 no.6
BANK 2
电子学模块 no.10

机柜组
设备组

spatial resolution （< 8mm）





4. Conclusion

- SANS@CSNS has been running five years and applying in a broad research scopes, which has developed wide users community and high-scientific output
- SANS@CSNS has wide-Q range, high intensity and in-situ characterization ability under variant external field. Based on SANS instrument, experimental methodologies have been developed, such as GISANS, Simultaneous Electro-resistivity and DSC measurement.
- An recent upgrade has been conducted which can increase the instrument length and enhance the detector resolution to reach lower Q_{min}.

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