Graphite development for Thorium Molten Salt Reactor

Derek Tsang

Center for Thorium Molten Salt Reactor System, CAS

Shanghai Institute of Applied Physics, CAS



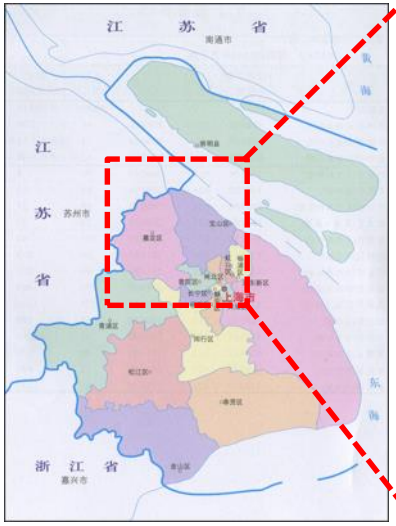
钍基熔盐核能系统

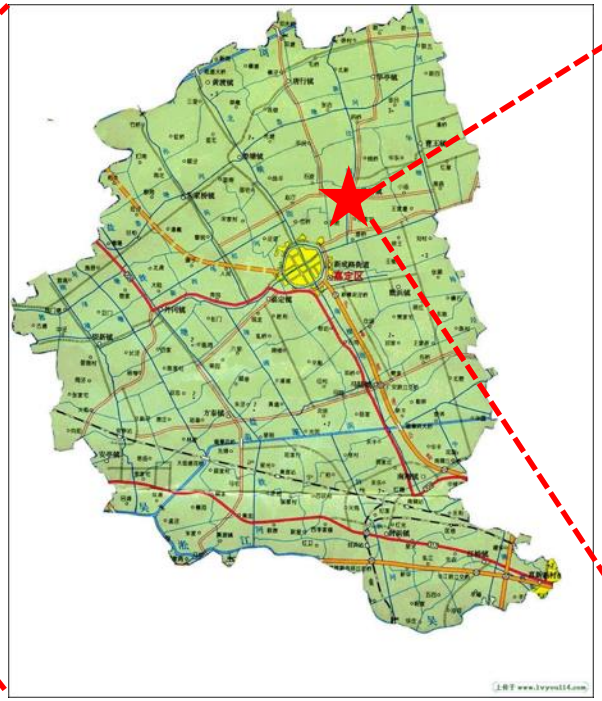
中国科学院上海应用物理研究所

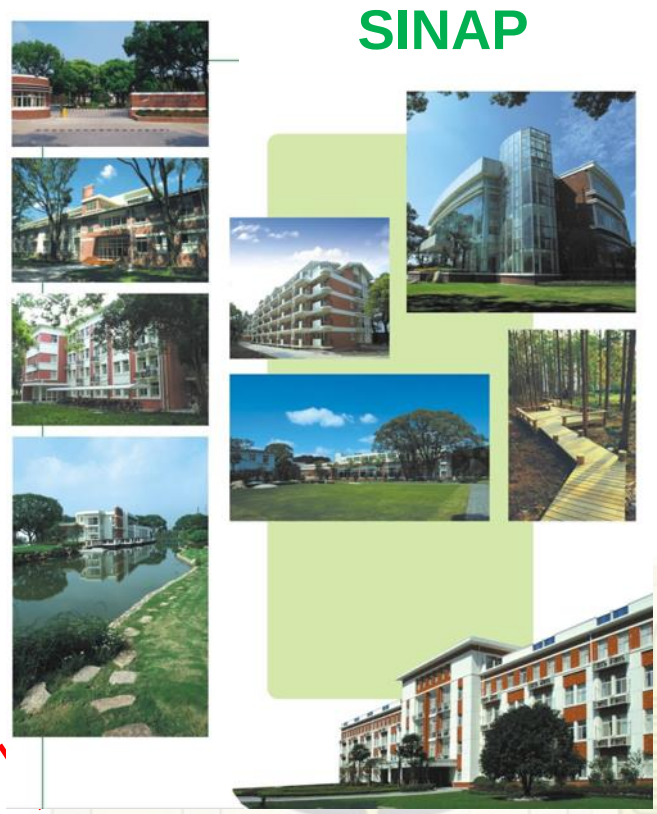
SINAP

Shanghai Institute of Applied Physics, Chinese Academy of Sciences

SINAP: Shanghai Institute of Applied Physics



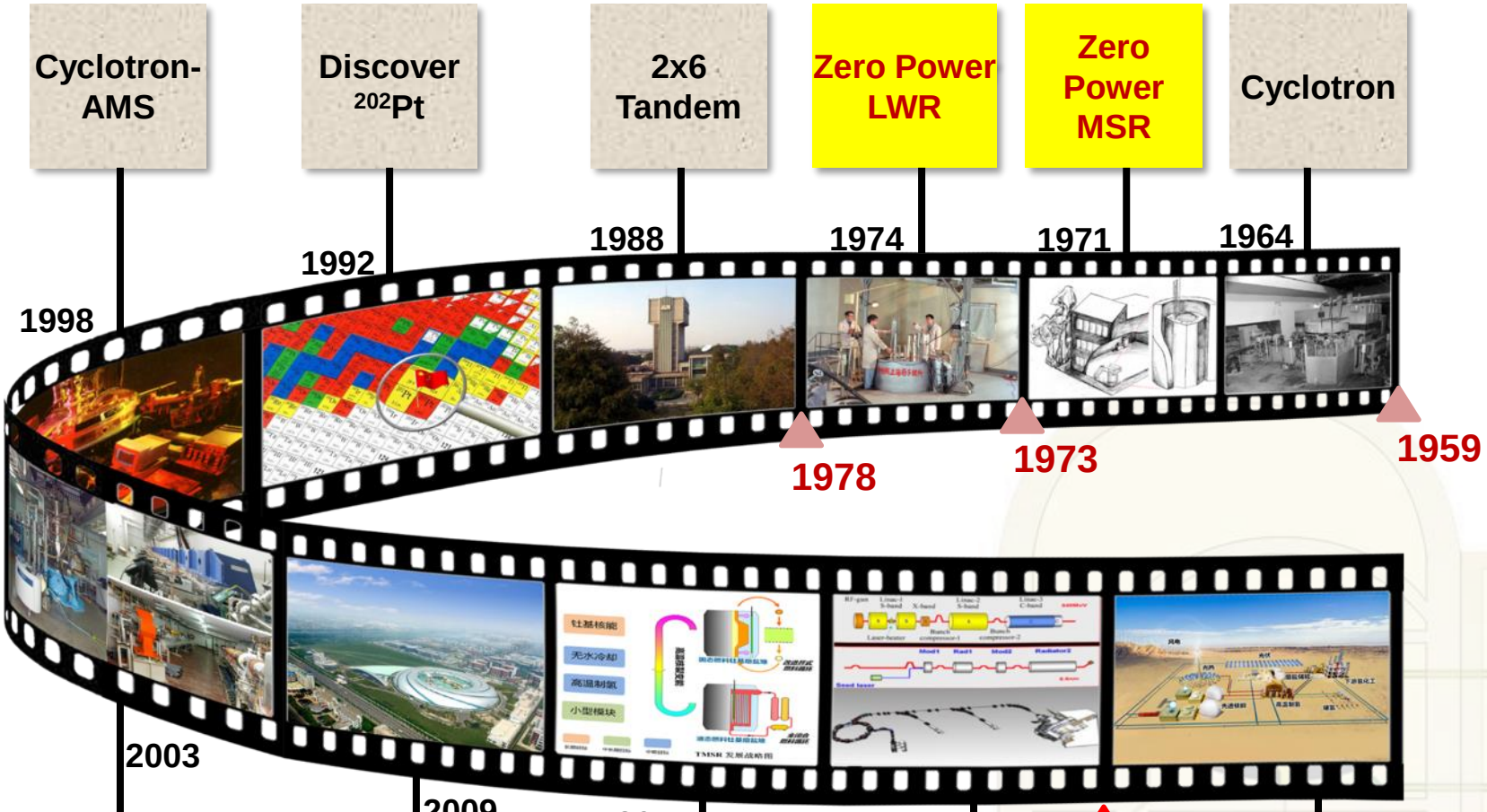




Staffs: about 750

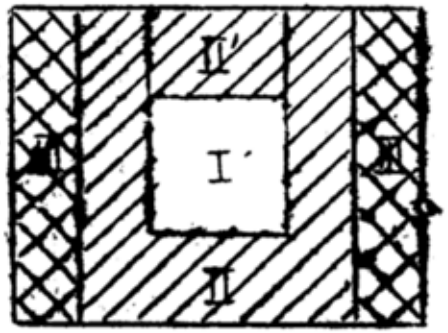
Students: about 250

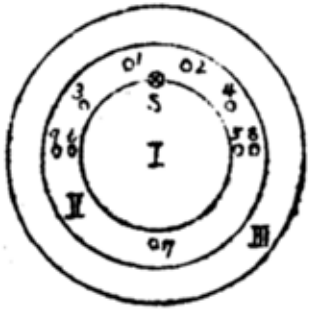
History of SINAP



Early Research on Nuclear Energy at SINAP

1970 – 1971, SINR a zero-power (cold) MSR.





Ⅰ - core
Ⅱ - reflector
Ⅱ'- reflector cover
Ⅲ - protection wall
S- neutron source (100mCi Ra-Be)

1-2- safety rod
3- regulating rod
4- shim rod
5-6- backup safety rod
7-8-9- BF_3 neutron counter

1972 - 1973, SINR a zero-power LWR.



SINAP Campus 1: Jiading, Shanghai







SINAP Campus 2: Site of the TMSR-LF1



- The site of experimental reactor is located in Wuwei (武威），Gansu Province, about 2000 km from Shanghai

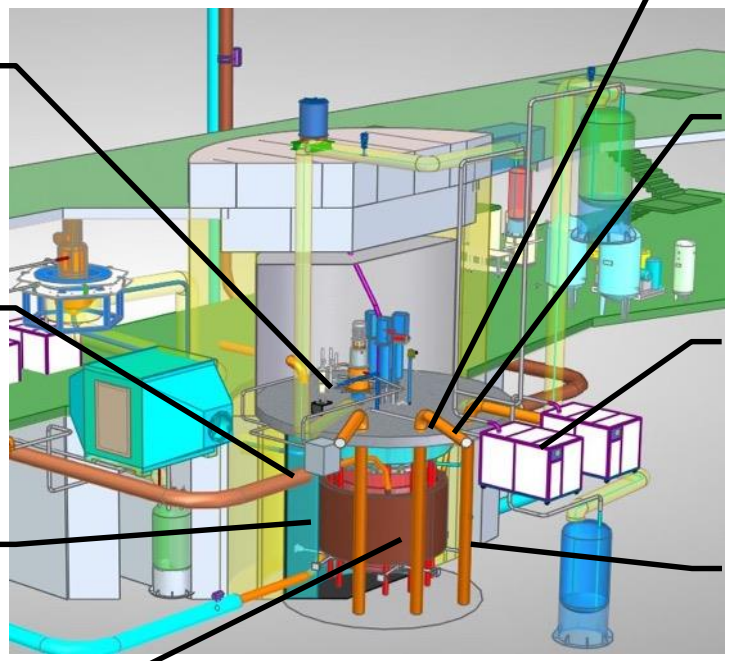
Materials selection for TMSR-LF1

Control Rod/Assembly
Materials：GH3535
Function：Separate materials from molten salt
Temperature：600~650 ˚C
EOL Fluence：1.0E20 n/cm^2
Contact with MS：Yes

Core Container
Material：GH3535
Temperature：<600 ˚C
EOL Fluence：3.5E18 n/cm^2
Contact with MS：Yes

Reflector
Material：Graphite
Temperature：<650 ˚C
EOL Fluence：1.0E20 n/cm^2
Contact with MS：Yes

Nuclear Fuel
Material: FLiBeZrU/ FLiBeZrUTh
Temperature：600~650 ˚C



Head of Container
Materials: SS
Temperature：<500 ˚C
EOL Fluence：1.0E19 n/cm^2
Contact with MS：No

Pump
Temperature：600~650 ˚C
EOL Fluence：1.0E19 n/cm^2
Contact with MS：Yes

Heat Exchanger
Material: GH3535
Temperature：600~650 ˚C
EOL Fluence：1.0E19 n/cm^2
Contact with MS：Yes

Moderator
Materials：Graphite
Temperature：600~650 ˚C
EOL Fluence：1.0E20 n/cm^2
Contact with MS：Yes

Structural Materials

Functional Materials

Nuclear Fuels

Other Materials

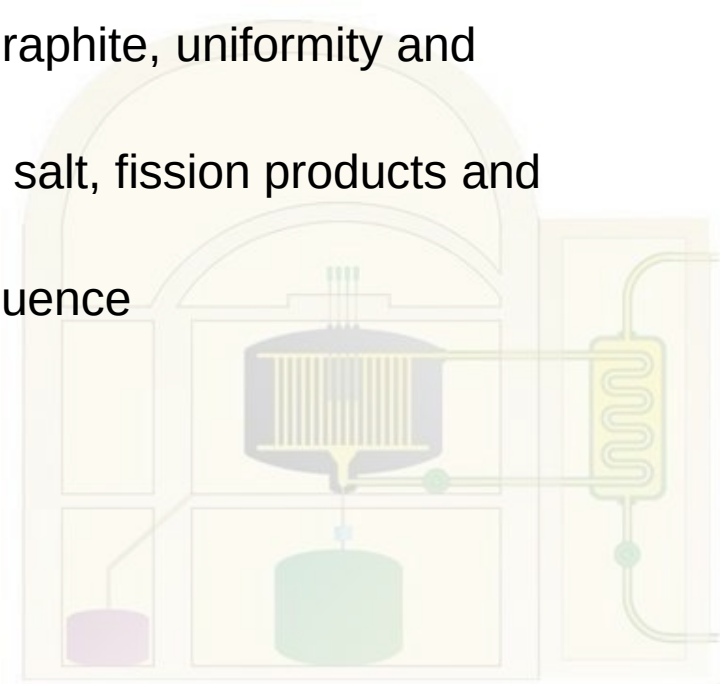
Challenges of Materials for TMSR

Service Conditions

- High temperature (above 700 ˚C)
- Molten salt corrosion
- High flux neutron irradiation

Graphite

- **Manufacture:** large block of ultrafine grain graphite, uniformity and reproductivity
- **Compatibility:** Infiltration/diffusion of molten salt, fission products and tritium absorption
- **Data base:** Irradiation behavior under high fluence

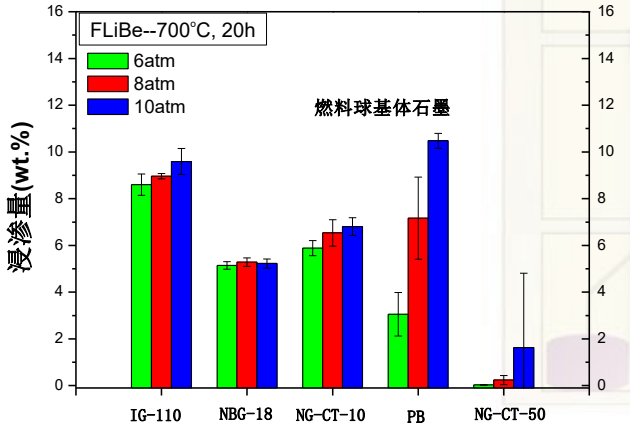


Production of Nuclear Grade Graphite

- Development of the ultrafine grain nuclear graphite for MSR, involved in the establishment of ASME and ASTM codes for MSR nuclear graphite

- ☐ Two candidates: NG-CT-50 and T220
- ☐ Manufacture capability – size up to 1400 x 600 x 350 mm
- ☐ Smaller pore size compared to common commercial graphite
- ☐ FLiBe infiltration – zero impregnation for molten salt under reactor pressure

Parameters	NG-CT-50	T220
Pore size (um)	0.86	0.95
Tensile Strength (MPa)	25.9	33.2
Bending Strength(MPa)	36.3	35.5
K_{IC}(MPa/$m^{1/2}$)	0.71	0.85
Thermal Conductivity (W/mK)	90.6	83.4
Infiltration Pressure(atm)	6.5	6.5



FLiBe salt infiltration

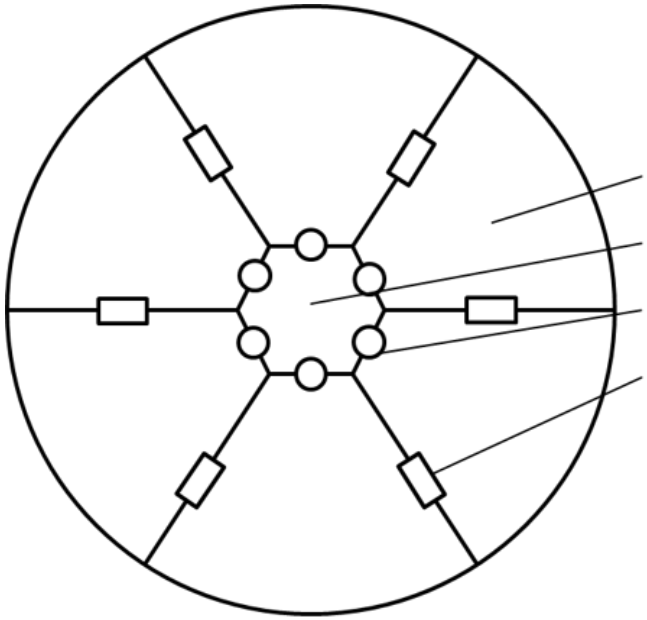


Ultrafine grain nuclear graphite

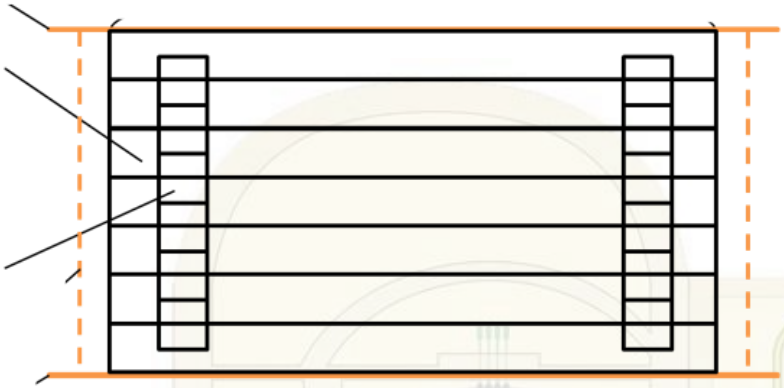
Irradiation Test

Materials	Temperature	Flux (n.cm-2.s-1)	Fluence (n.cm-2)	Condition	PIE
Hastelloy N	650°C	1.8E13	2.5E19 (E>0.1MeV)	Ar+He	Tensile, elastic modulus, Poisson's ratio, Charpy impact, hardness, size and density, metallographic and SEM
GH3535	RT	-	2.5E19, 1E20 (E>0.1MeV)		Tensile, Density
NG-CT-10 NG-CT-50 IG110	650°C	-	5E20 (E>0.1MeV)	Ar+He	Thermal expansion, splitting, compression, bending, shearing
NG-CT-10 NG-CT-50 IG110 TFX-10	700°C	1.1E14	4E20 (E>0.1MeV)	FLiBe	Density, size, XRD, Raman, SEM, TEM, thermal conductivity
C/C	650°C	-	5E20 (E>0.1MeV)	Ar+He	Thermal expansion, splitting, compression, bending, shearing, molten salt infiltration
	700°C	1.1E14	4E20 (E>0.1MeV)	FLiBe	Density, size, microstructure analysis (XRD, Raman, SEM, TEM), thermal conductivity

Graphite core



石墨砖（扇形）
石墨砖（六边形）
石墨销键
石墨方键







Thanks for your attention!