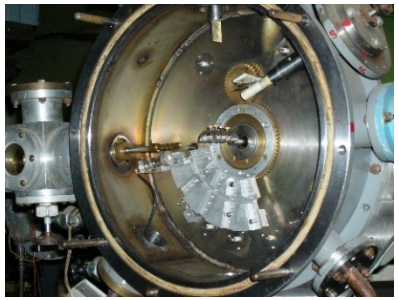
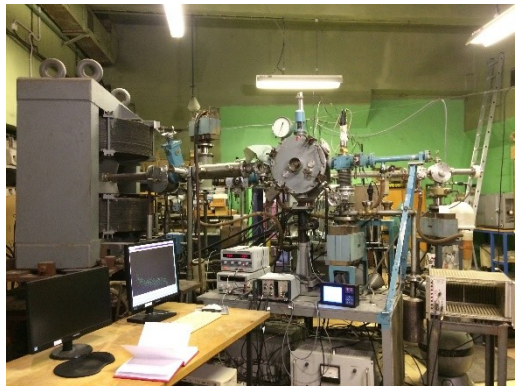
JOINT INSTITUTE FOR NUCLEAR RESEARCH
FRANK LABORATORY OF NEUTRON PHYSICS

USING RUTHERFORD BACKSCATTERING SPECTROSCOPY TO INVESTIGATES ErF_3 DOPED CaF_2 CRYSTAL





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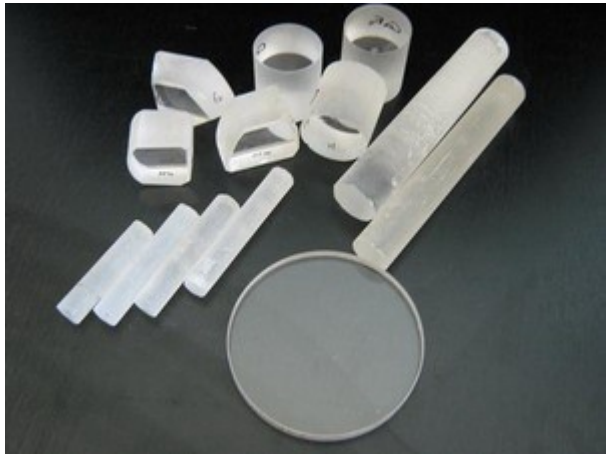
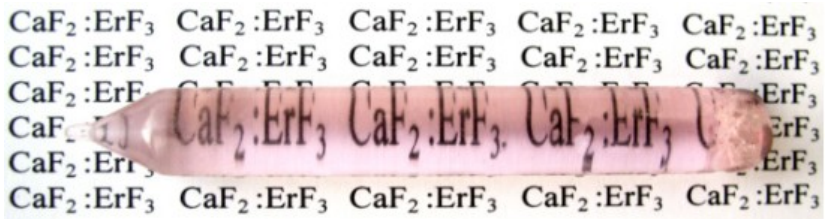
CONTENT

1. INTRODUCTION

ErF_3 doped CaF_2 crystal

- CaF_2 is a kind of typical alkaline-earth fluorides.
- The CaF_2 crystals have been used in many optical components due to its exceptional transparency in the UV as well as in the IR spectral domain
- ErF_3 doped CaF_2 is a type of rare earth-doped fluoride crystal.
- ErF_3 doped CaF_2 crystals possess unique optical and thermal properties, rendering them highly specialized materials suitable for applications in laser amplifiers, fiber-optic communication systems, and infrared imaging.
- ErF_3 doped CaF_2 has demonstrated promising results for use as a scintillator in medical imaging and radiation detection.

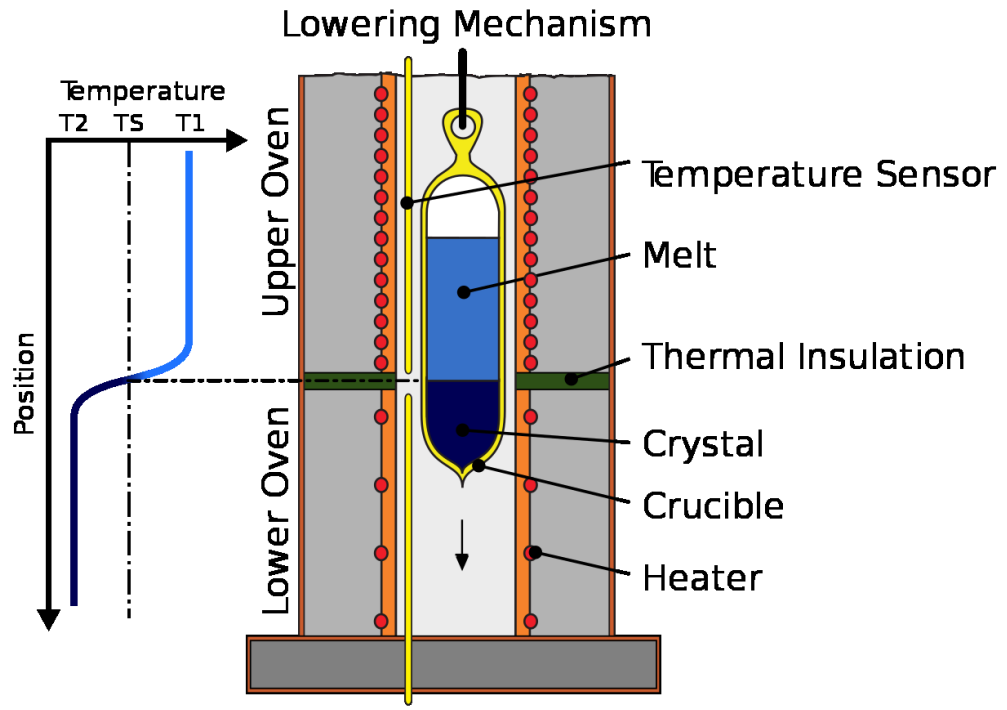




1. INTRODUCTION

The Bridgman- Stockbarger method

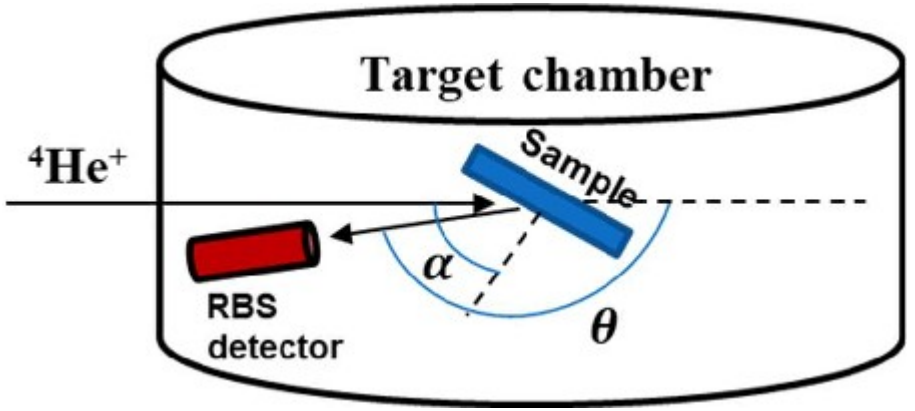
- First used by Bridgman (1925) and improved by Stockbarger (1949).
- This method involves melting the materials together in a high-temperature furnace and then cooling them slowly to form a single crystal. The materials melt congruently without decomposition at the melting point.
- About 40% of production of artificial crystals
- Simple technology
- Does not require complicated control systems.



1. INTRODUCTION

Rutherford backscattering spectroscopy - RBS

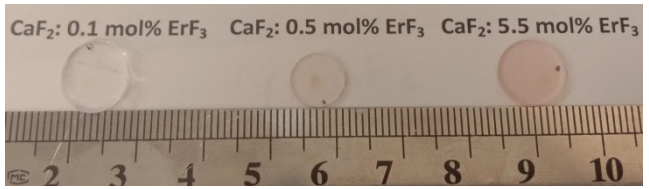
- A beam of high-energy ions is directed at a sample, and the backscattered ions are detected and analyzed to determine the elemental composition and depth profile of the sample.
- The energy of the backscattered ions is related to the mass and energy of the sample atoms, allowing for the determination of elemental composition.
- The angle of the backscattered ions is related to the depth of the atoms in the sample, allowing for depth profiling.

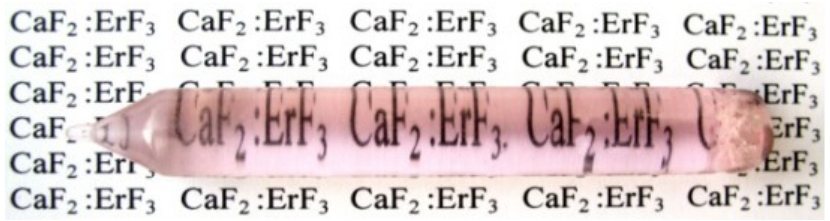


2. EXPERIMENTS

ErF_3 doped CaF_2 crystal

- The crystals were grown using the Bridgman- Stockbarger method
- Supra-pure grade CaF_2 and ErF_3 were used as raw materials.
- ErF_3 added to the starting mixture: 0.1, 0.5 and 5.5 mol %
- Vacuum about 10^{-1} Pa
- The pulling rate was 4 mm/h.
- The crystals of about 10 mm diameter and over 6–7 cm length
- Thickness of the crystal slices: 2.5 mm

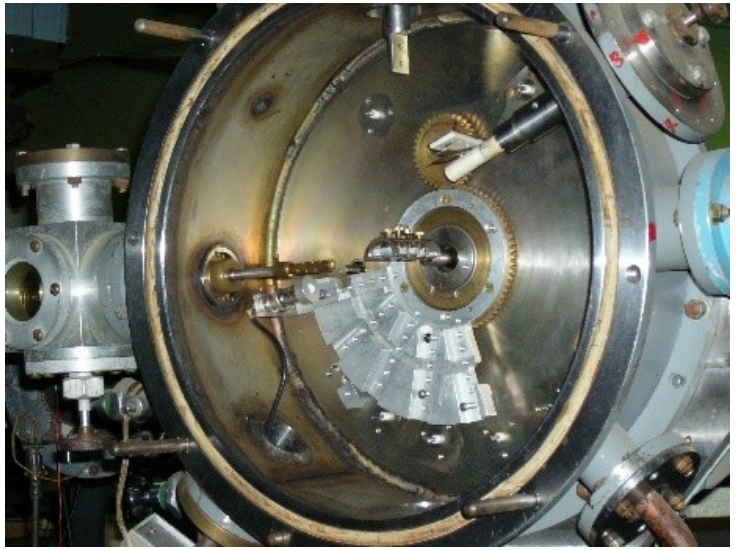




2. EXPERIMENTS

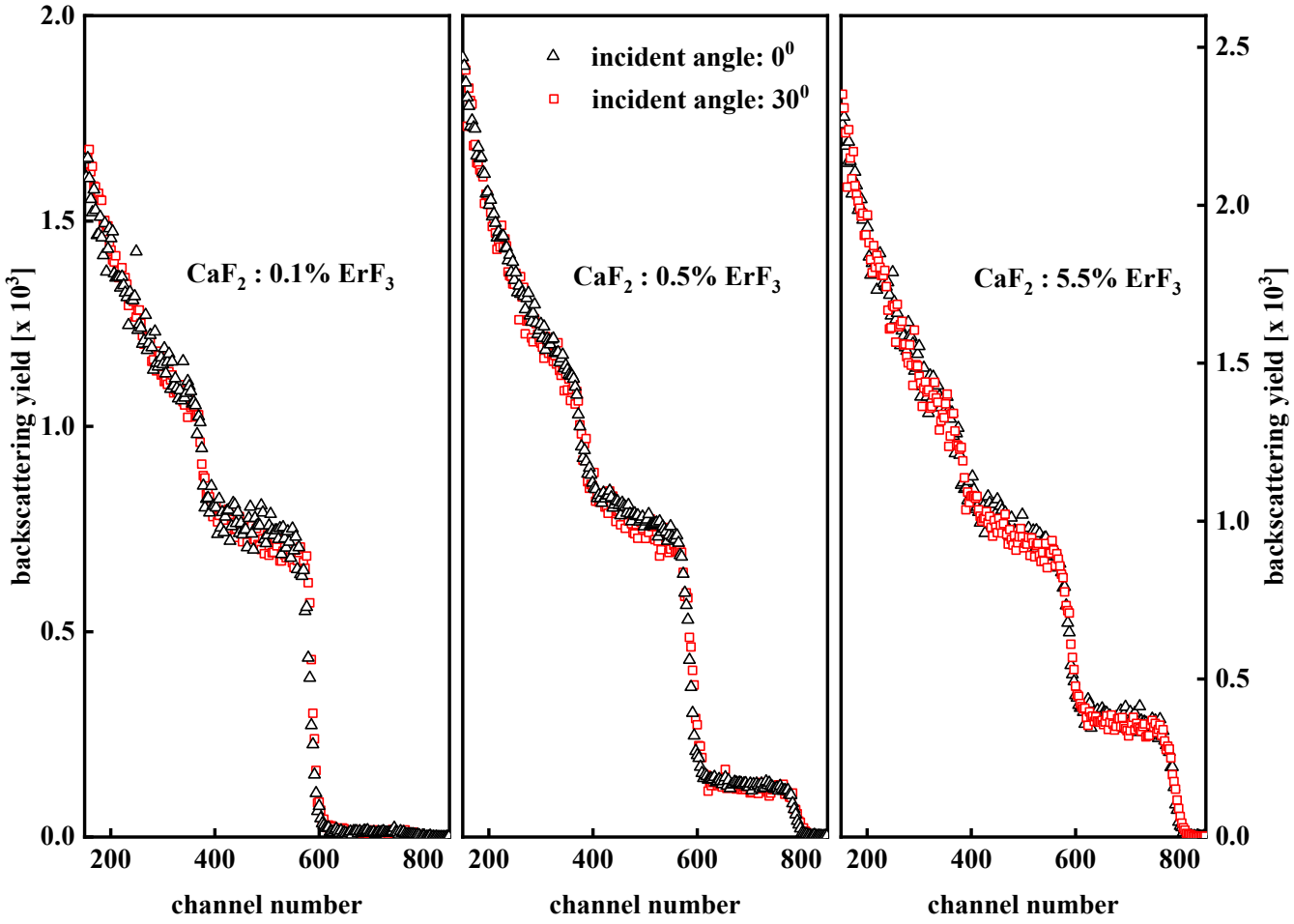
The RBS experiments

- Vacuum chamber less than 10^{-4} Pa
- The incident angles: 0^0 and 30^0
- The scattering angle: 170^0
- Energy of α-beam: 2 MeV
- Detector resolution: 15 ÷ 25 keV



3. RESULTS AND DICUSSIONS

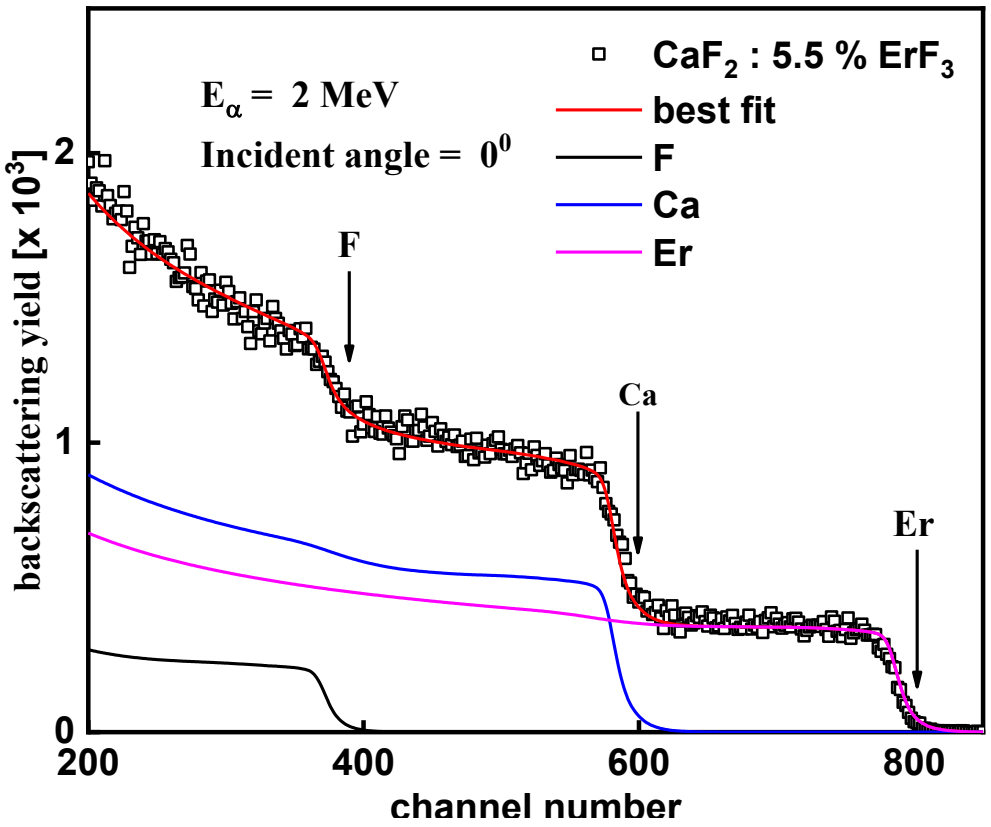
The homogeneity of crystals from RBS spectra



- The shape of the spectra did not change significantly.
- The signals from the backscattered particles were superimposed to form a "substrate" spectrum
- The atomic concentrations of the elements were relatively uniform at all depths in the samples

3. RESULTS AND DICUSSIONS

Build the model to fitting RBS spectra

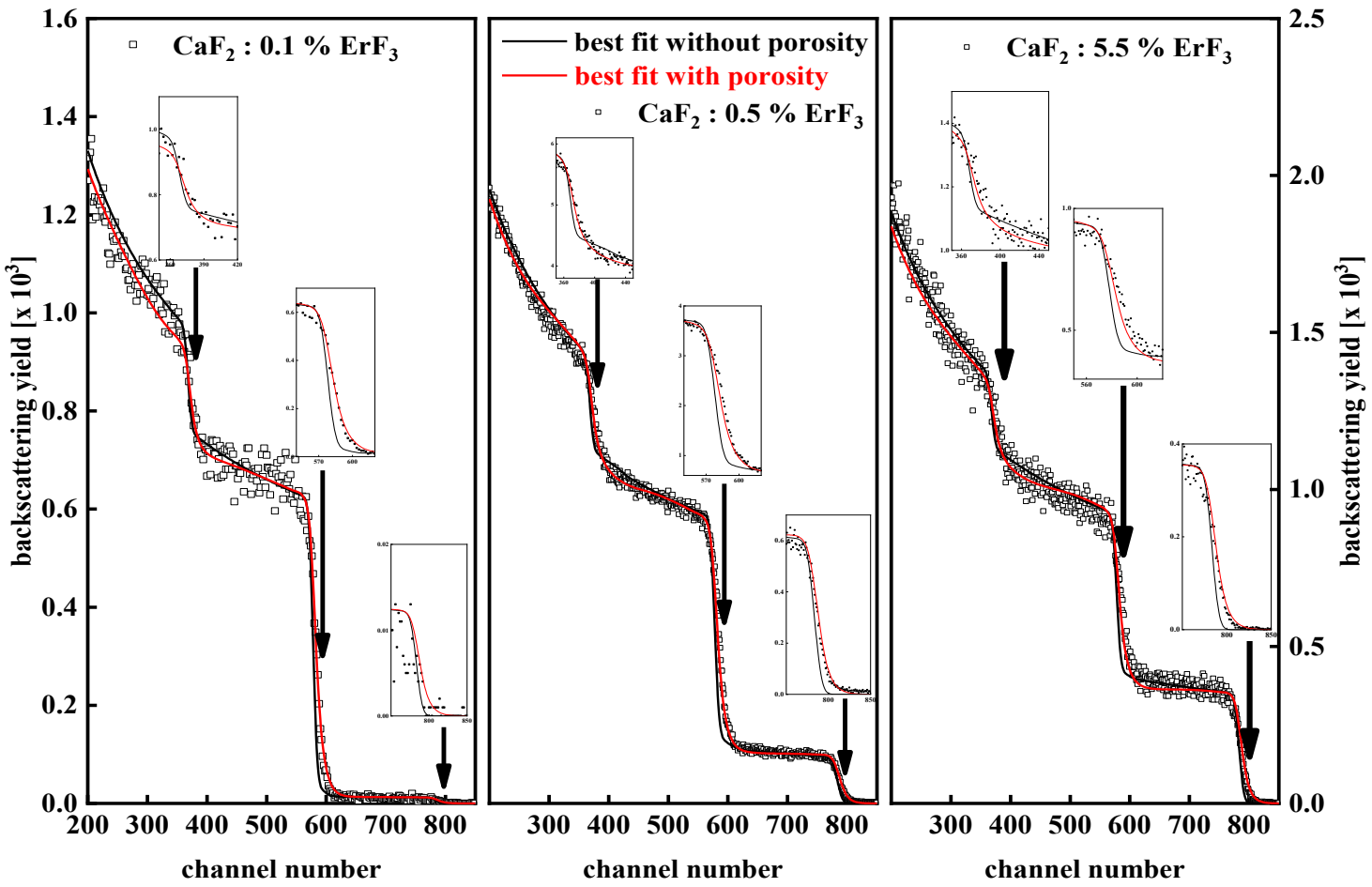


The models	Layers	Thickness (10^{15} atoms/cm^2)	atomic concentration (%)			χ^2	
			F	Ca	Er	0^0	30^0
CaF_2:5.5% ErF_3	1	4000	66.50	31.50	2.00	1361.3	1355.4
	2	5000	66.30	31.70	2.00		
	3	4000	66.29	31.71	2.00		
	4	6000	66.30	31.70	2.00		
CaF_2:0.5% ErF_3	1	4000	65.50	33.82	0.68	1302.2	1308.1
	2	6000	65.00	34.30	0.70		
	3	3000	65.02	34.28	0.70		
	4	5000	64.99	34.31	0.70		
CaF_2:0.1% ErF_3	1	6000	61.93	38.00	0.07	1138.4	1134.2
	2	5000	62.00	37.93	0.07		
	3	6000	62.03	37.90	0.07		
	4	7000	62.01	37.92	0.07		

- The SIMNRA software is used to explore the depth profile of the samples.
- The SIMNRA can simulate the RBS spectrum of a sample model specified by the user.
- The model contains all experimental characteristics.

3. RESULTS AND DICUSSIONS

Possible porosity in the crystals



The models		χ^2
CaF_2:0.1% ErF_3	with porosity	1134.2
	without porosity	2903.4
CaF_2:0.5% ErF_3	with porosity	1308.1
	without porosity	3570.2
CaF_2:5.5% ErF_3	with porosity	1355.4
	without porosity	3841.1

- The simulated spectra match the experimental better when the presence of pores inside the investigated samples.
- χ^2 for simulated spectra without porosity are consistently three times larger than those with porosity.
- The pores may exist in the CaF_2:ErF_3 crystal generated by the Bridgman method

4. Conclusion and …

- The RBS spectra of these samples show the crystal samples is homogeneous.
- The atomic concentration of elements in the samples were measured and analyzed using the SIMNRA software. The results shown that the same atomic concentrations in four-layer model.
- In additions, we suggest that there might exist pores inside investigated samples.
- This emphasizes the need for additional cross-verification using techniques such as scanning electron microscopy (SEM) and tomography to directly quantify porosity. These supplementary methods can assist RBS describe the porosity of the sample in greater detail and confirm that RBS's models are accurate.

THANK YOU FOR YOUR ATTENTION!