Research and Development for Innovative Partitioning System in COE

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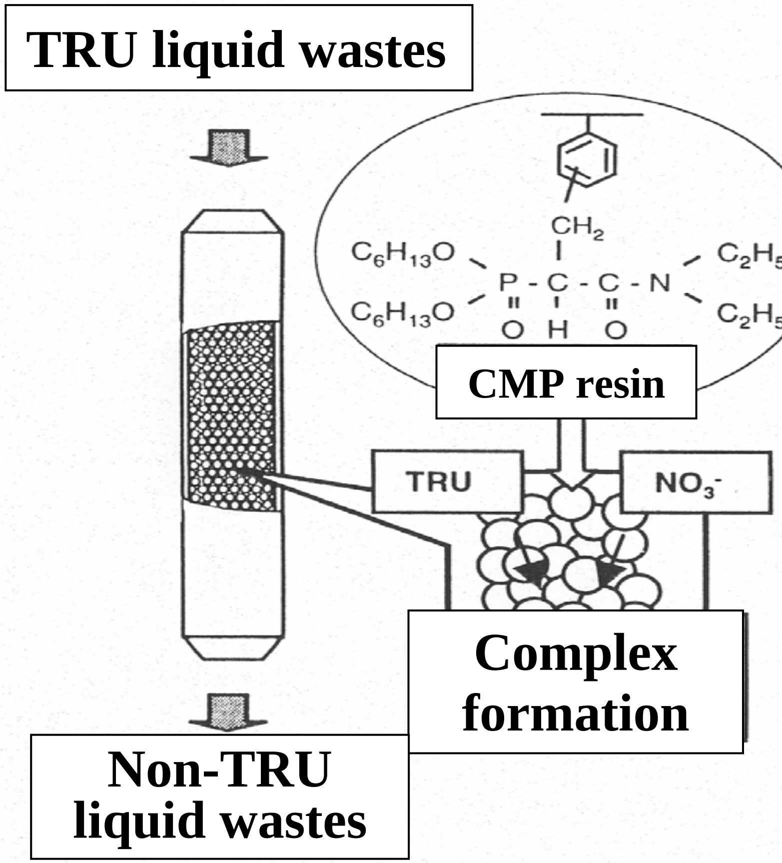
Background

In the concept of Innovative Nuclear Energy Systems for Sustainable Development of the World(COE-INES), we aim at the minimum-release of radioactive wastes from the nuclear energy park.

In order to achieve our aim, we need to do the following matters;

- **rational classification of nuclides**
- **development of techniques for their partitioning**
- **development of appropriate methods for management and disposal of radioactive wastes containing such nuclides.**

Objective



Chelate resin column method

Usual partitioning methods:

Macroscopic separation methods by controlling phenomena in the bulk phases

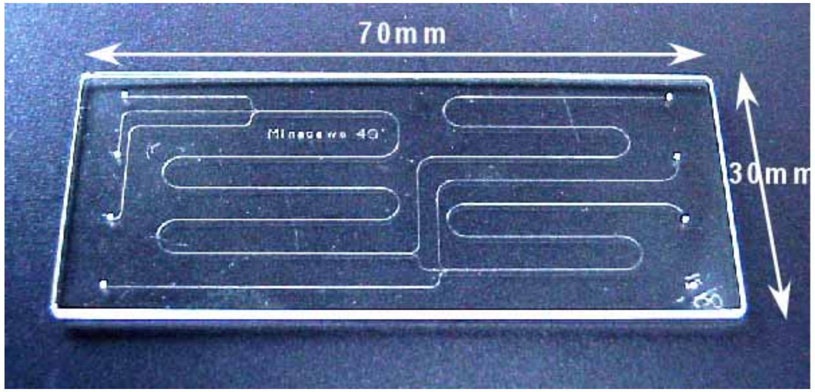
- **Liquid-liquid extraction**
- **Extraction chromatographic method**
- **Chelate resin method**

Innovative methods using phenomena in micro- and nano-levels.

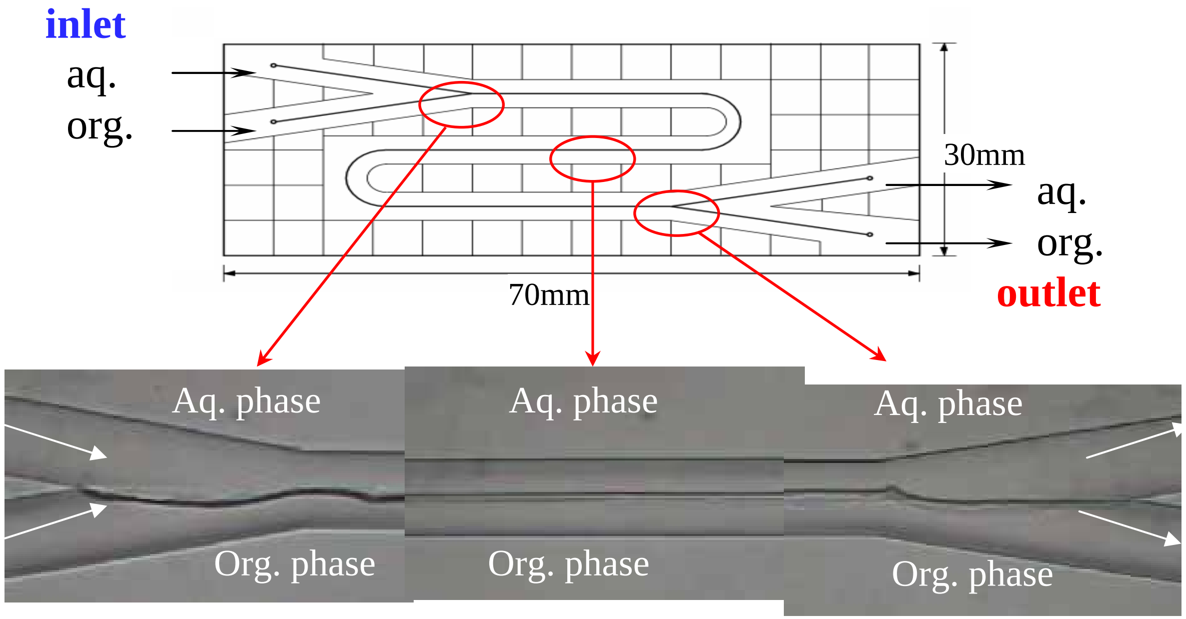
To investigate the innovative partitioning system consisting of

- **the nuclide separation using microchannel chips**
- **the laser isotope separation by near-field optics**
- **high sensitive nano-level analytical methods**

Extraction separation of nuclides using microchannel chip

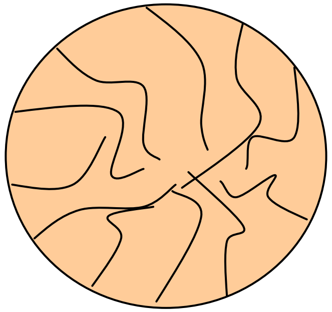


Typical microchannel chip (Channel size: 1- 200 μm)



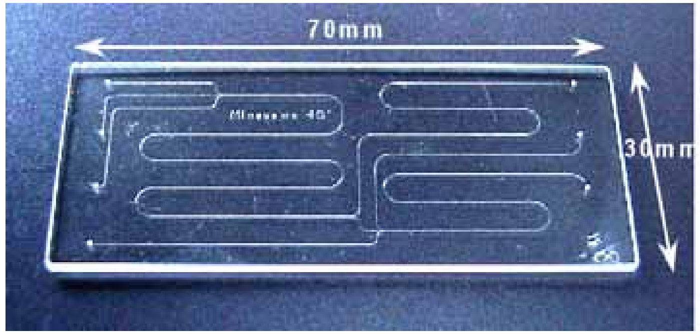
Stable laminar flow

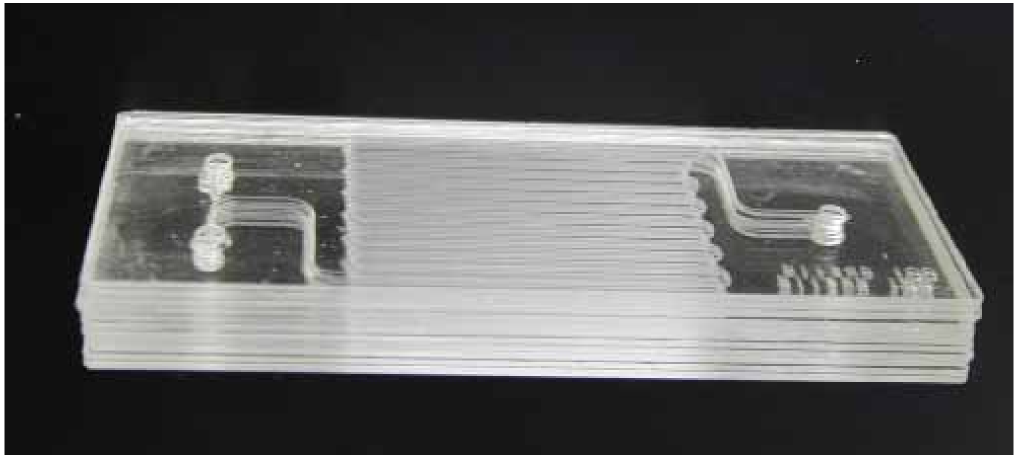
Multilayer microchannel chip



Ion exchange or chelate resin

Chip with microchannel similar to pores in ion exchange and chelate resins

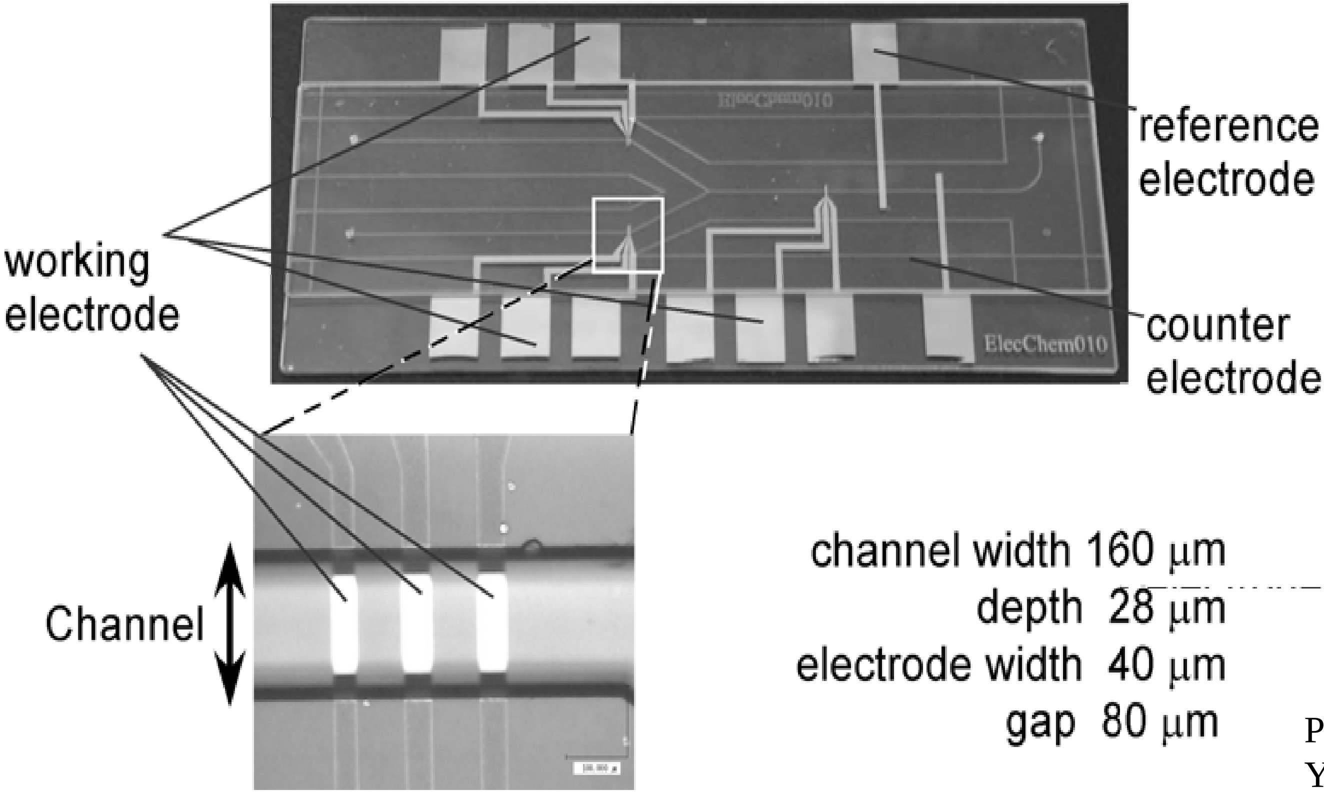




Photograph: provided by Dr. M. Tokeshi, Prof. T. Kitamori

In each chip, the selective adsorbents for specific nuclide are self-assembled onto the surfaces of microchannels.

Valence adjustment using microchannel chip equipped with thin-layer electrodes



channel width 160 μm
depth 28 μm
electrode width 40 μm
gap 80 μm

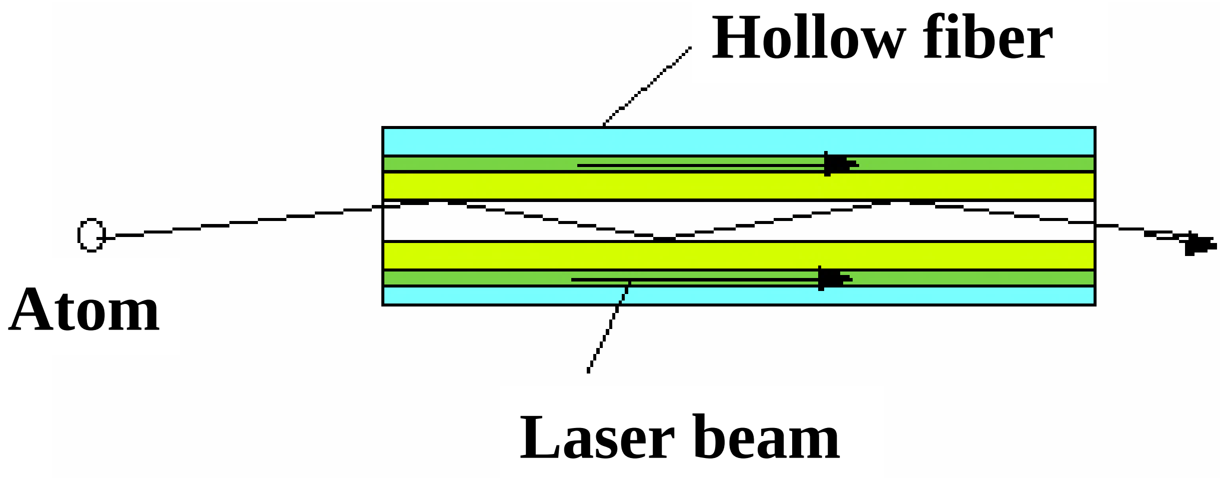
Photograph: provided by Dr. Y. Kim, Prof. T. Kitamori

The valences of nuclides can be adjusted by the electrodes in microchannels. This should lead to fine separation of nuclides.

Laser isotope separation by near-field optics

(by Prof. Akatsuka)

This method should be applicable to the nuclides, which need isotope separation for transmutation.



- **Atoms are passed through hollow fiber.**
- **By selecting laser beam with appropriate wavelength, the dipole force induced by the near-field optics acts on the specific isotope as the repulsive force. Other isotopes are adsorbed on the inner surface of fiber.**
- **Inner diameter: << a few μm, length: a few cm, wavelength of laser: visible.**

R &D of nanomaterials for microchannel processes

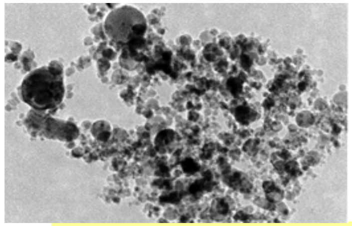
(by Prof. Watanabe)

Atmospheric glow discharge

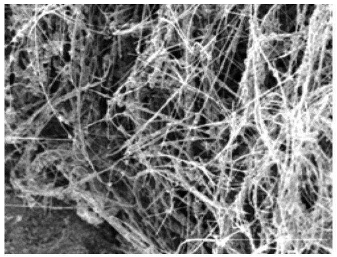
High frequency thermal plasma

Atmospheric plasma

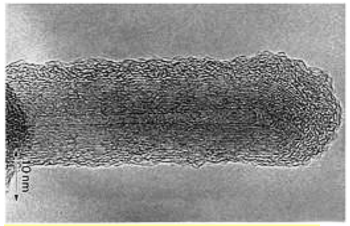
- **Selective separation**
- **Material for microchannel**
- **High speed nanoscale etching**
- **High performance nanomaterial syntheses**



LaB6 nanoparticle



Carbon nanocubes



BCN nanochubes

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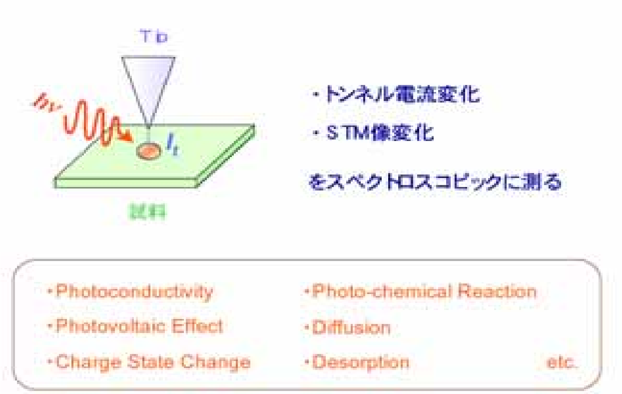
High sensitive nano-level analytical methods (1):

Development of a new apparatus of nano-spectromicroscopy for single-molecule science (by Prof. Onoe)



Spatial resolution：1-2 nm

Energy resolution：10 meV

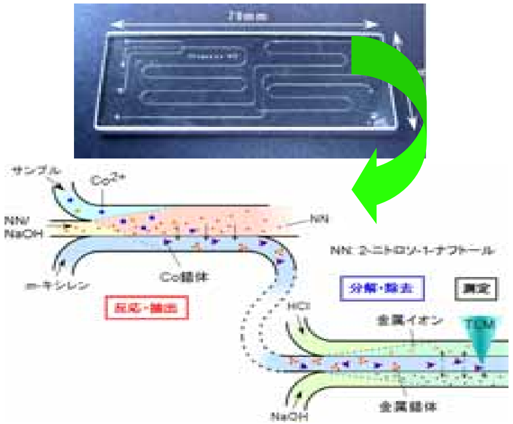
Goal -> Top level of spatial and energy resolution

In situ single molecule observation of a metal complex under solvent free conditions (UHV)

DFT calculations

Effect of solvents on the electronic structure of the metal complex

To reveal a single-molecule behavior



Application to in situ observation in microchannel processes

Molecular-level understanding of extraction processes using nano-spectromicroscopy technique

Quantum design of ligand molecules for an innovative separation process

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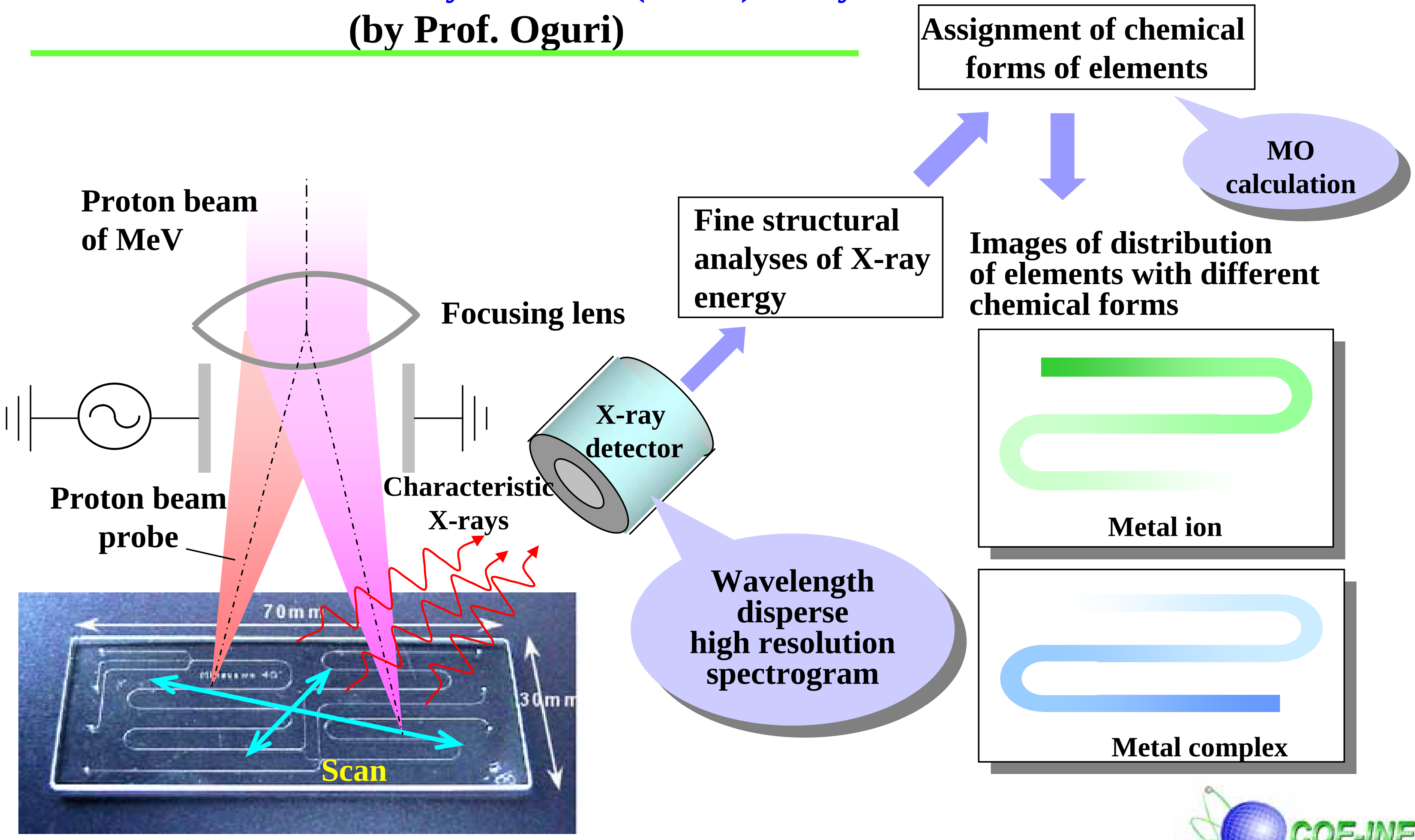
High sensitive nano-level analytical methods (2):

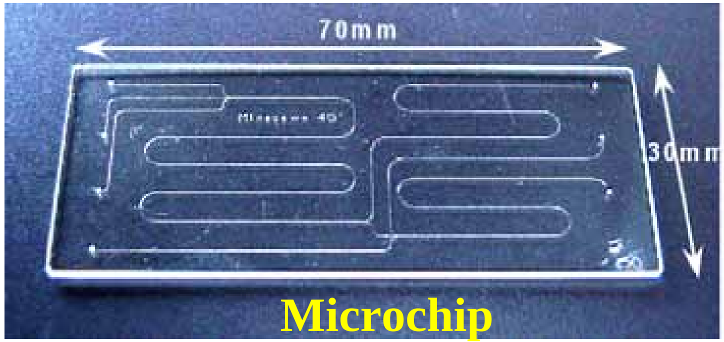
Particle-induced X-ray emission (PIXE) analysis

(by Prof. Oguri)

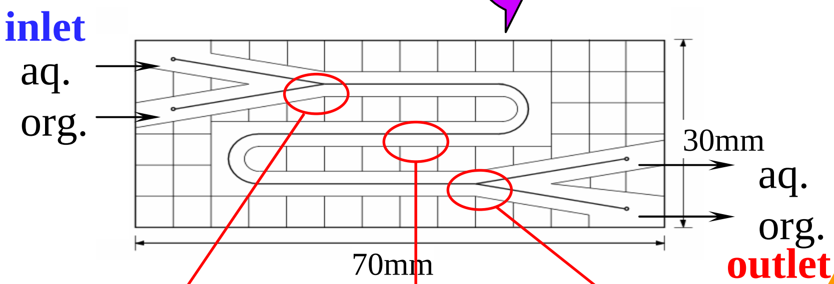


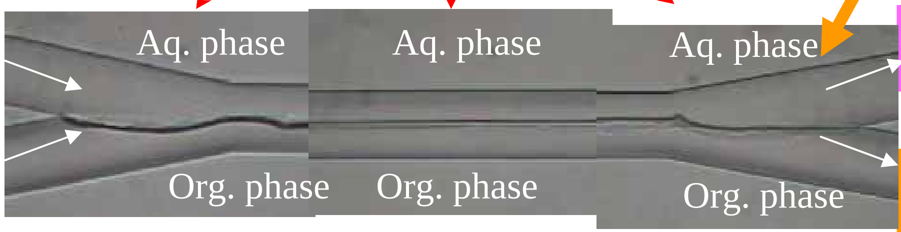
Concept of innovative partitioning system based on micro- and nano-technologies

Integrated micro-channel nuclide separation system



Development of nanomaterials for microchannel processes





Stable laminar flow

High sensitive nano-level analytical methods

- **Nano-spectromicroscopy for single molecule**
- **Particle-induced X-ray emission (PIXE) analysis**

Separated nuclide

Separated nuclide

Laser isotope separation by near-field optics

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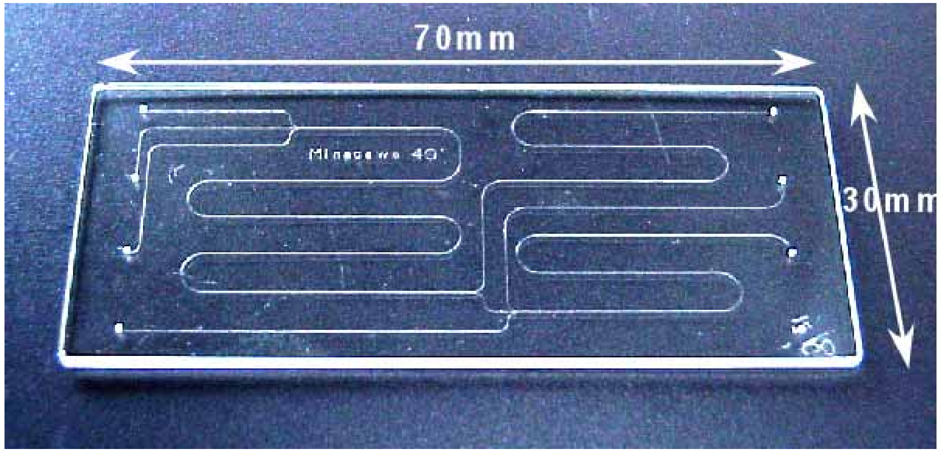
Application of microchannel chip



Photograph: provided by Dr. M. Tokeshi, Prof. T. Kitamori

Application of reactions in the space of 1 – 200 μm

1. Narrow space

Short diffusion distance →Short reaction time

2. Large specific surface area

Large ratio of liquid-liquid contact area to feed reactants → High efficient mixing and separation

3. Small heat capacity

Easy control of temperature

Comparison with conventional reactors (e.g.: comparison between cm and μm scales）

Scale: 1/100

Diffusion time: 1/10000

Reaction time: second order

↓

•Miniaturization of equipments and facilities

•Rapid operation