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OMICS Group International is a pioneer and leading science event organizer, which publishes around 400 open access journals and conducts over 300 Medical, Clinical, Engineering, Life Sciences, Pharma scientific conferences all over the globe annually with the support of more than 1000 scientific associations and 30,000 editorial board members and 3.5 million followers to its credit.

OMICS Group has organized 500 conferences, workshops and national symposiums across the major cities including San Francisco, Las Vegas, San Antonio, Omaha, Orlando, Raleigh, Santa Clara, Chicago, Philadelphia, Baltimore, United Kingdom, Valencia, Dubai, Beijing, Hyderabad, Bengaluru and Mumbai.

Recent Research on Image Crystals: discovery of shape-controllable cavities surrounded by facets in ceramics

-Artificial formation of Negative Crystal in Ceramics-

Hiroyuki Serizawa
Japan Atomic Energy Agency

Negative Crystal in crystal

Characteristics of the negative crystal

- **N**egative crystal is a cavity that has the form of a crystal and found in a mineral mass by chance.
- **T**he cavity is sometimes filled with liquid containing mineral.
- **F**rom a view point of material science, the negative crystal is a large defect to be improved.

The important point of today's presentation

- Our study clarified that a negative crystal is formed by the precipitation of helium.
- The step free energy model is useful to explain the growth shape of the single crystal.
- The shape of the negative crystal varies depending on the internal pressure.

Outline of My Presentation

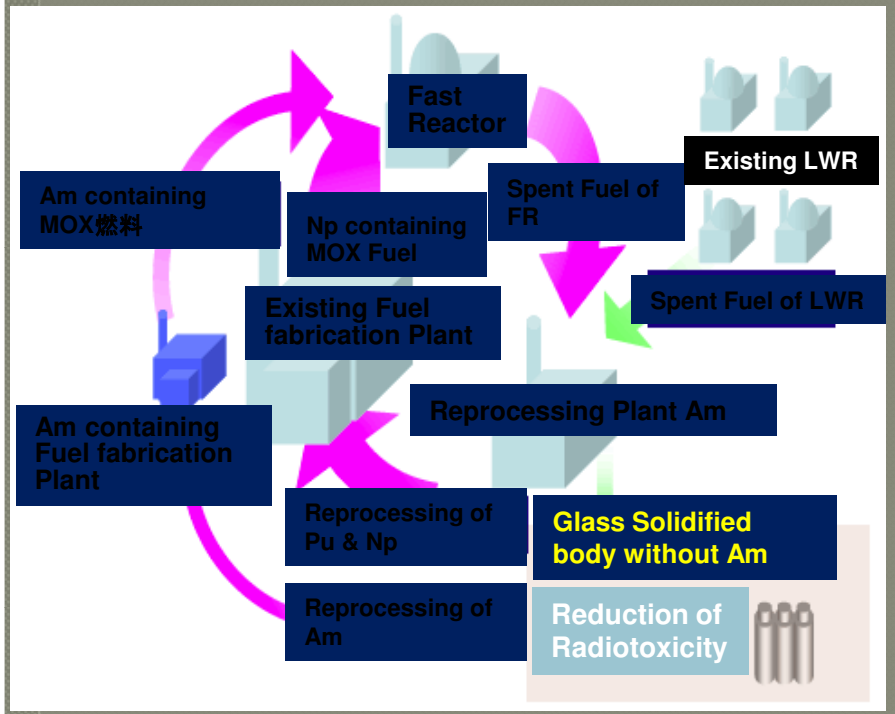
- Back ground of this work
  –Why we started this work?-
- Experimental work
  –Helium behavior in UO_2-
- Consideration on the shape of the negative crystal
  a)Modeling of the shape
  b)Relationship of the attachment energy and the step free energy

☆Recent and future work

MA(Am & Np)-MOX(Mixed Oxide) fuel

Aim of this Research

Reducing the high radiotoxicity of minor actinides accumulated through nuclear power plant operation.



New reprocessing System

The most feasible plan to realize the new fuel reprocessing cycle by MEXT

(MEXT: Ministry of Education, Culture, Sports, Science and Technology)

・SODIUM-COOLED FAST BREEDER REACTOR

&

・MA-MOX fuel

Behavior of helium emitted by MA

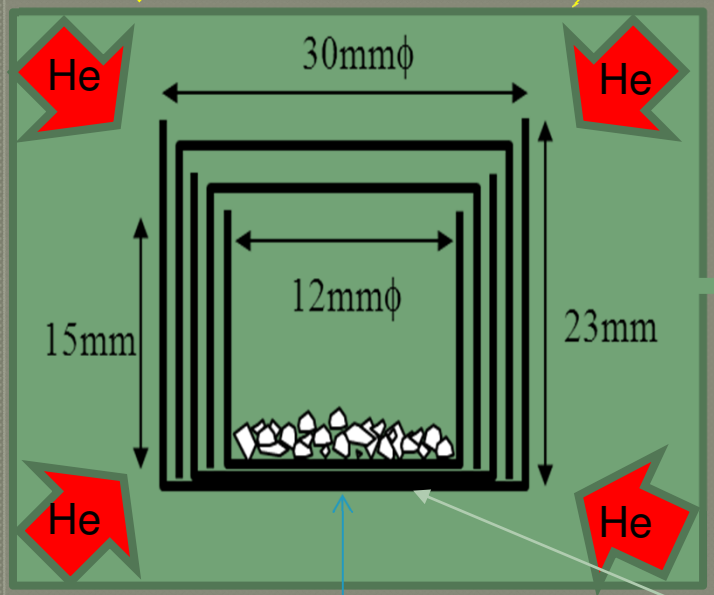
When helium precipitates in the fuel matrix
⇒Swelling of the fuel Pellet
⇒Fuel-Cladding mechanical interaction.

When helium is released from the fuel pellet
⇒Internal pressure of the cladding increase
⇒Revision of pressure tightness of the cladding.

Experimental : Diffusion coefficient of Helium in UO_2

Helium injection by HIP

(1473 K 90MPa 100h)

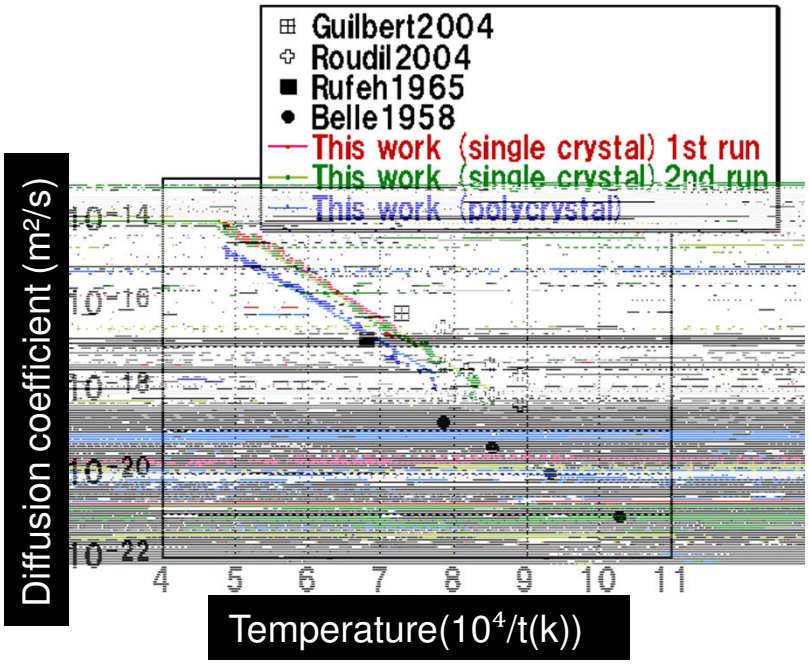


Single-crystal UO_2

Poly crystalline UO_2

Chemical Vapor transport method

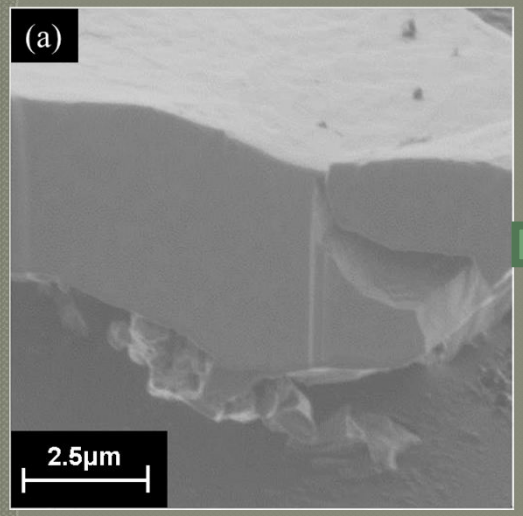
Analysis by High Temperature Mass spectrograph with Booth model



Diffusion coefficient of single-crystal and poly crystalline samples agree in the scatter of the data.

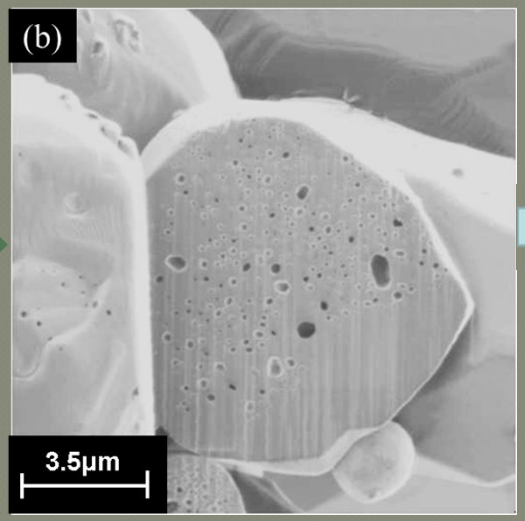
Grain boundary of poly crystalline sample can be regarded as a free surface

Experimental :
Matrix Observation of Single-Crystal UO_2 by SEM



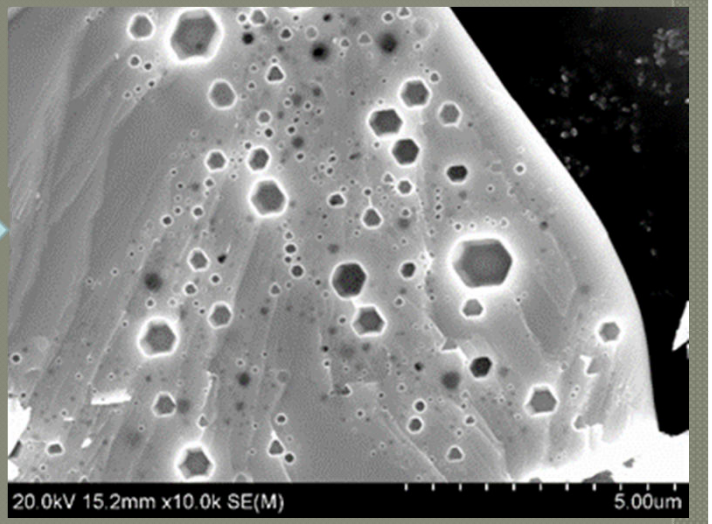
Section of UO_2 particle before He injection

No gas bubbles and voids are formed



Section of UO_2 particle just after He injection by HIP

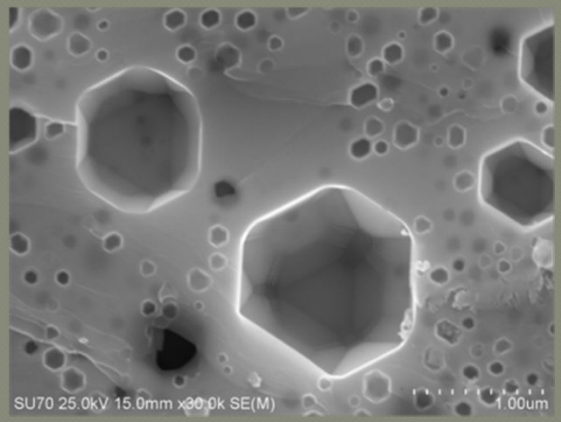
Round Cavities are formed (Gas bubble is formed)



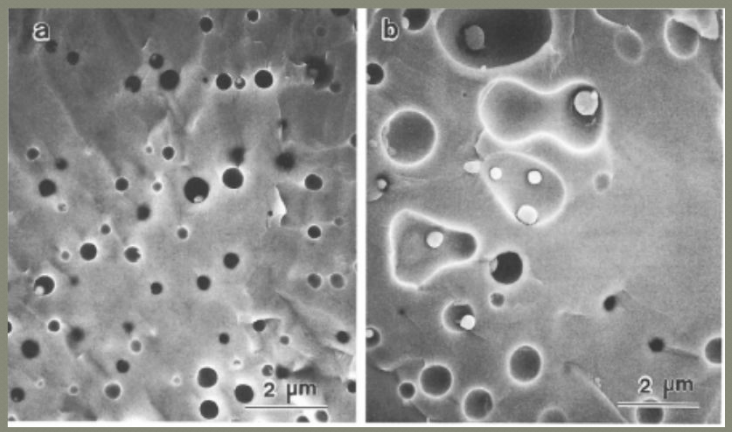
Cleavage surface {111} of UO_2 particle after annealed at high temperature

So many Negative crystal is formed!! on the cleavage {111} surface.

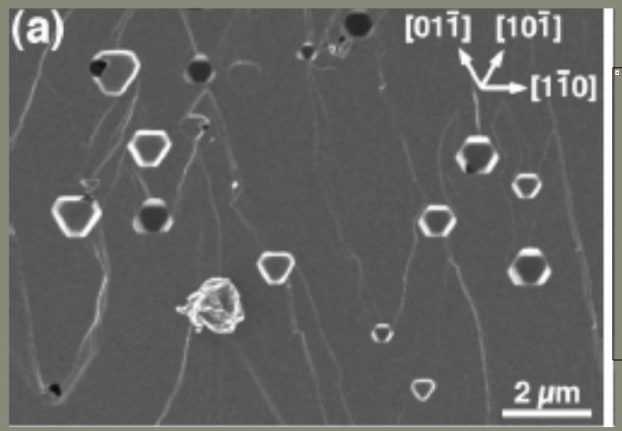
Magnified figure of Typical Cavities seen in UO_2



Negative crystal seen on the broken surface of the sample

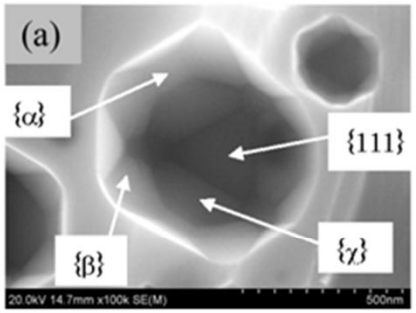
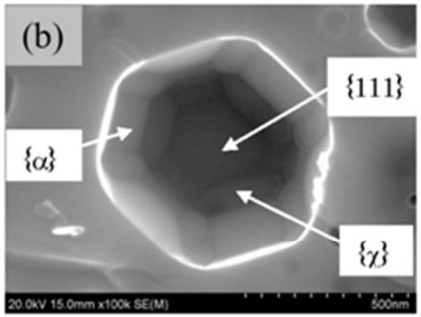
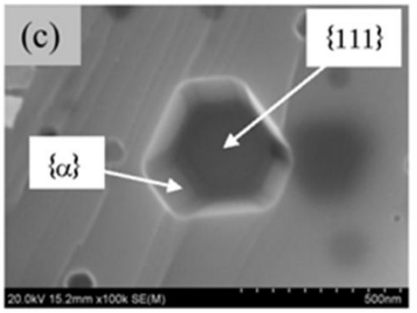
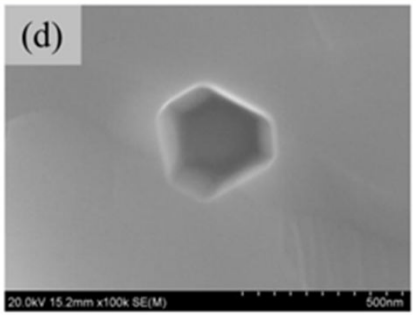
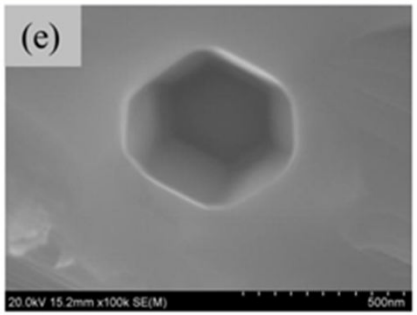
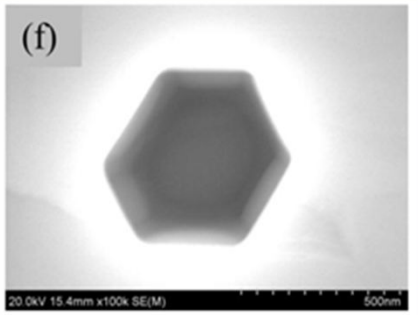


SEM image of the high burn up fuels after annealing at 1800 ℃ for 5 h
(a) 44GWd/t; (b) 83GWd/t
Kashibe et al., J. Nucl. Mater 206(1993)22



Typical area of a (111) cleavage surface through UO_2 single crystal produced by high temperature treatment.
Castel, Phys. Rev. B, 68(2003)235411.

The Shape of the Negative Crystal

Observed spot	Anneal temperature (K) (for 1 hour)		
	1573	1773	1993
Broken surface of single-crystal sample			
Broken surface of poly-crystalline sample			

Consideration of the difference in the shape

Single-crystal ⟷ Polycrystalline

The grain boundary exists or not

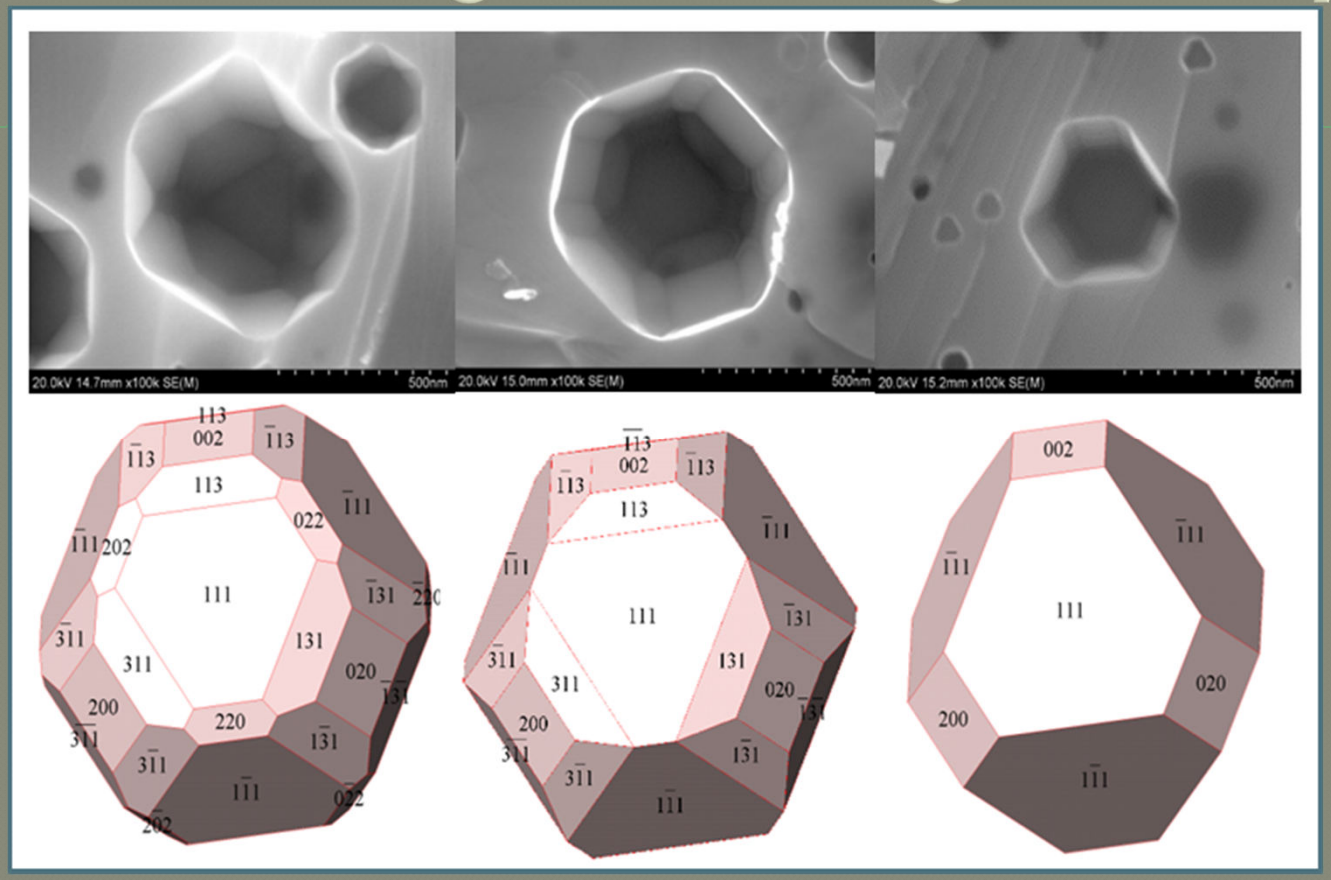
＞The amount of Residual He＞

Anneal Temp. ⟷ Anneal Temp.

Low — **The value of the diffusion coefficient** — **High**

Modelling of the Negative crystal

S. C.1573K S. C. 1773K S. C.1973K & P. C.



Caution!! {113} appears faster than {011} on the surface, which is strange from thermodynamic point of view.

Consideration of free energy

- **Attachment Energy (A.E.)**

The A.E. is the energy released when a growth slice of thickness is attached to the surface from infinity.

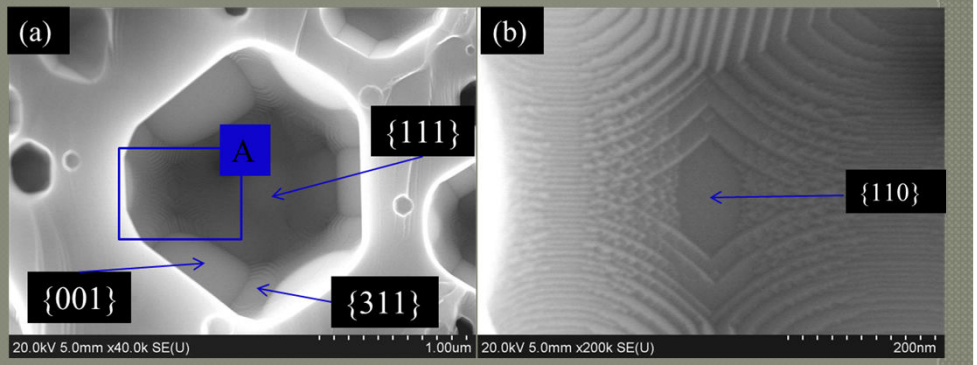
⇒The material tends to be added adjacent surfaces with the lower attachment energy to form the surface with the highest A. E.

- **Step Free Energy (S.F.E.)**

The S.F.E is regarded as a 2D or 3D analogue of the surface free energy.

⇒the smaller the step free energy is, the smaller the size of the critical nucleus is.

Morphological Importance (A.E.)
MI{111}>MI{001}>MI{011}>MI{113}
Experimental (A.E. & S. F. E.)
MI{111}>MI{001}>MI{113}>MI{011}



SEM Images of Octa-Triacontahedron type-negative crystal

A full grown {113} facet appears, whereas the {011} facet is almost invisible. However, a high-magnification SEM image of area A shows that {011}appears where center of the image.

Our work shows

The equilibrium shape of the single crystal is determined by A.E., but we have to take into account S.F.E. when we consider the real shape. S.F.E. corresponding to the activation energy of velocity theory.

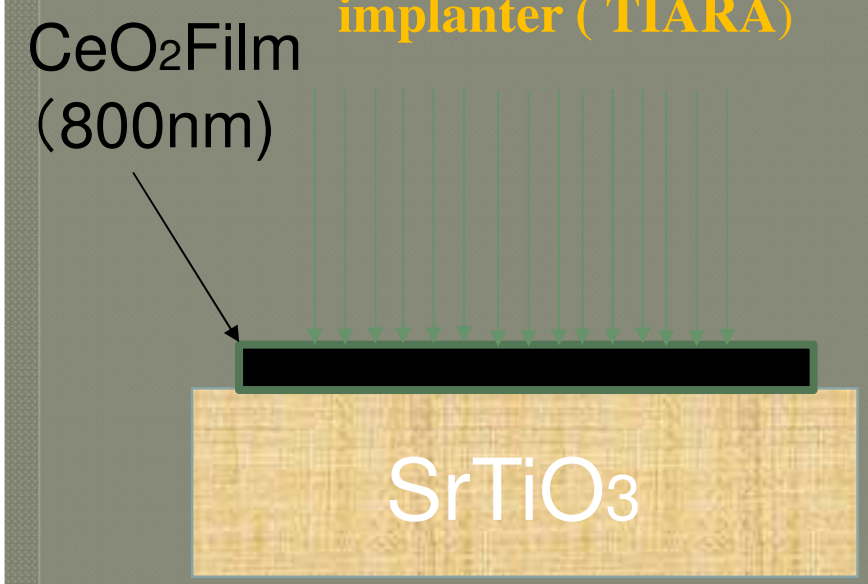
Recent job on Image crystal

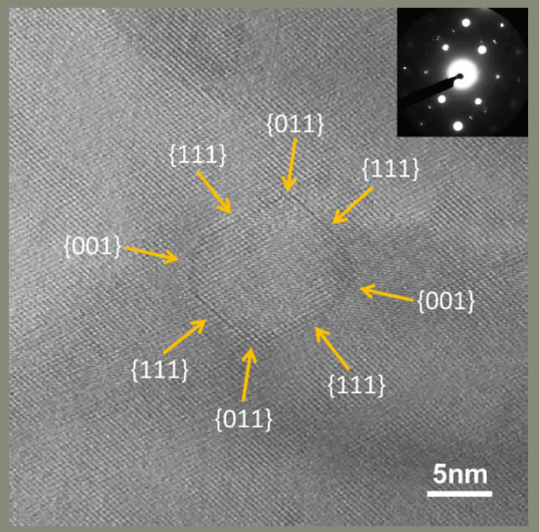
Development of Functional Material with Negative Crystal

☆Preparation of CeO_2 thin film containing negative crystal

130-keV He^{4+} ions from 400-keV ion (1x1015n/cm²) implanter (TIARA)

Anneal at high temperature



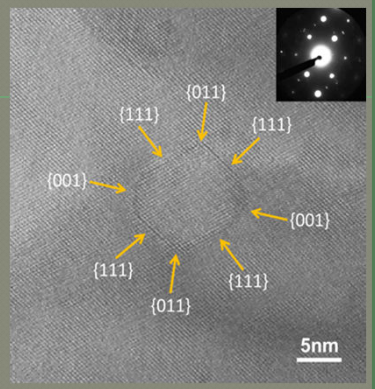


Nano-scale Negative Crystal was Formed by the precipitated Helium (TEM image).
(Examined by Wakasa Energy Research Center)

Tow Hot Subjects on Our Research

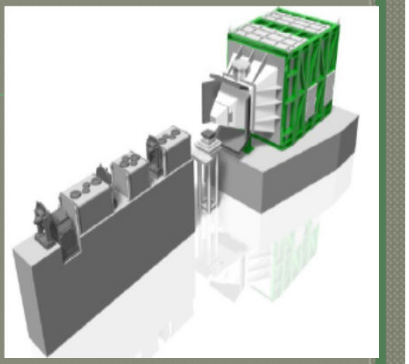
・Shape Control of Nano-Negative Crystal

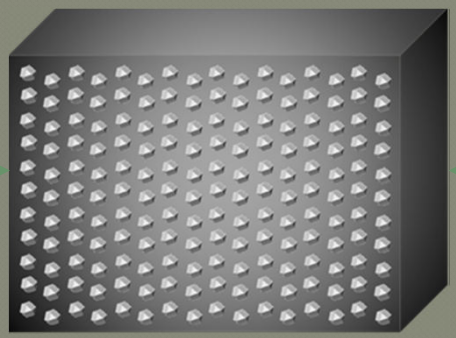
Evaluation of the Amount of Residual Helium in Negative Crystal By High Temperature Mass Spectrograph



・Size Control of Nano-Negative Crystal

Evaluation of the Size of Negative Crystal By Neutron Small Angle Scattering beam line 「大観」(TAIKAN) in J-PARC



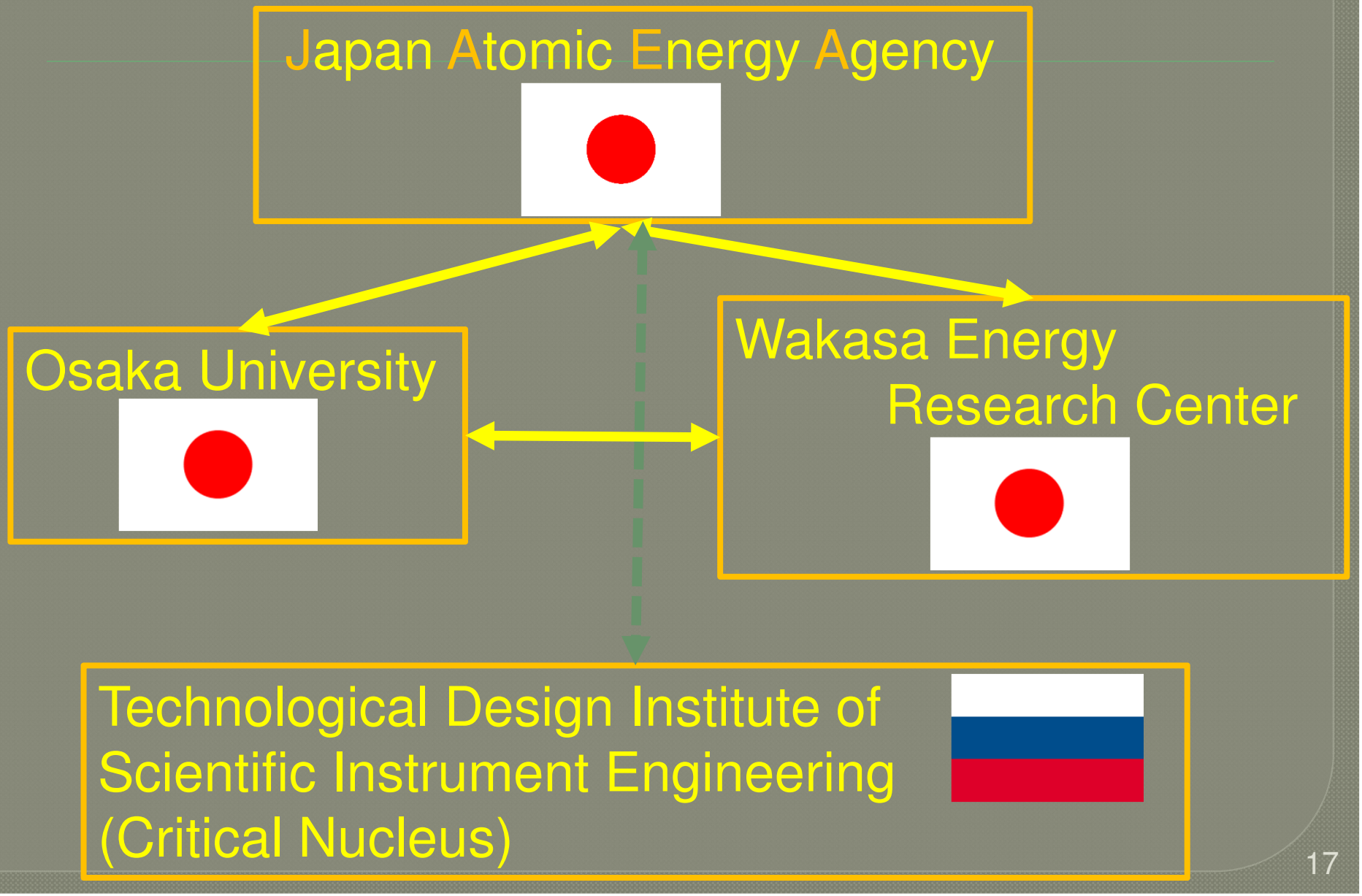


The Image of the Thin Film Containing Nano-Negative Crystal

Our Next Target

Invention of New Functional Material

Framework for this Research



Our investigation is just getting start.

We welcome your offer of corroboration !

Thank very much for your Attention.