INTRODUCTION TO ACTIVITIES ON IAEA DUST DATABASE

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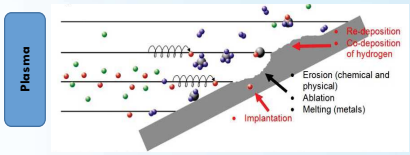
NFRI 국가핵융합연구소 National Fusion Research Institute

CONTENTS

I. Why dust database is important?

Plasma-Surface Interaction



https://www.differ.nl/research/plasma_surface_interactions

Erosion, redeposition, codeposition

↓

Production of dusts

I. Why dust database is important?

Production of dusts

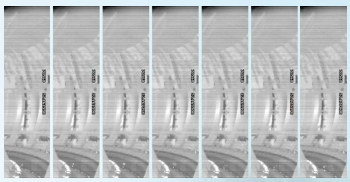
What are the problems?

1. Radioactivity (ITER: 50 mSv=350 Kg W dusts)
2. Chemical activity (hot surface)
3. Fuel retention (ITER: 700g T in-vessel inventory)
4. Uncontrolled „pellet" injection
   → plasma density, impurity density cannot be controlled.
5. Damage of in-vessel components through collision of high speed dusts (~several ten to several hundred m/s, even 20Km/s is reported).

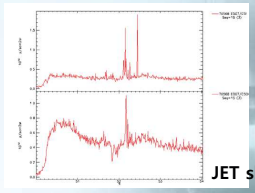
I. Why dust database is important?

Uncontrolled pellet injection → impurity influx

JET shot #69481



CIII line



JET shot #70568

I. Why dust database is important?

Production of dusts

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Information on size, composition, and origins of dusts are essential!

II. Introduction to IAEA Dust Database

IAEA Coordinated Research Project (CRP) on
"Characterization of Size, Composition and Origins of Dust in Fusion Devices"

II. Introduction to IAEA Dust Database

Purpose of CRP on
"Characterization of Size, Composition and Origins of Dust in Fusion Devices"

- Past experience with tokamaks such as TFTR and JET has shown that significant amounts of dust are formed in these machines.
- Dust can arise from a variety of plasma-facing components, including C, W and Be as well as other materials used in some fusion devices such as Mo, B and Ti.
- Dust may also come from other components in the machine, such as RF antennas. Accumulation of dust can become a significant safety hazard due to flammability, toxicity, potential respiratory problems and radiation concerns with tritium.
- Furthermore, a significant uptake of hydrogen isotopes occurs in dust, making the transport behaviour of this material a significant factor in **tritium inventory** studies of next generation machines such as ITER and DEMO.

Purpose of CRP on
"Characterization of Size, Composition and Origins of Dust in Fusion Devices"

- Dust contaminated with tritium can become electrically charged from **radioactivity**, leading to the interaction of the dust with the plasma and electric fields.
- These issues are not of high importance for operational machines, but will become significant for ITER and later machines due to the significant increased size of the plant.
- Therefore, there is **a need for information** on properties of dust, such as **particle size distribution** (physical and aerodynamic mass median diameter), **composition** (elemental and chemical) and their **origins** in fusion machines.
- There is currently a lack of data on these fundamental physical and chemical properties; the primary goal of this CRP is to address these data needs.

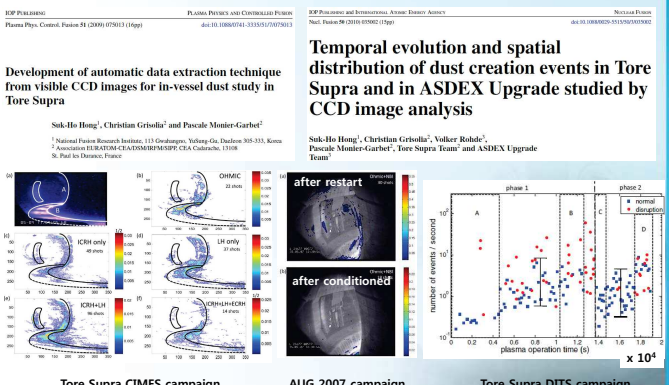
Final RCM, Vienna, 30 November - 2 December 2011
Meeting report and presentations

Second RCM, Vienna, 21-23 June 2010
Meeting report and presentations

First RCM, Vienna, 10-12 December 2008
Meeting report and presentations

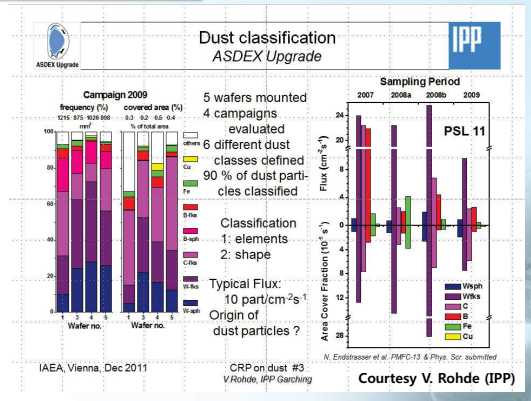
CRP Members
Christian Grisolia
Volker Rohde
J□rg Winter
Carmine Castaldo
Naoko Ashikawa
Anna Widdowson
Phil Sharpe
Charles Skinner
Suk-Ho Hong

Finding origins and temporal behavior

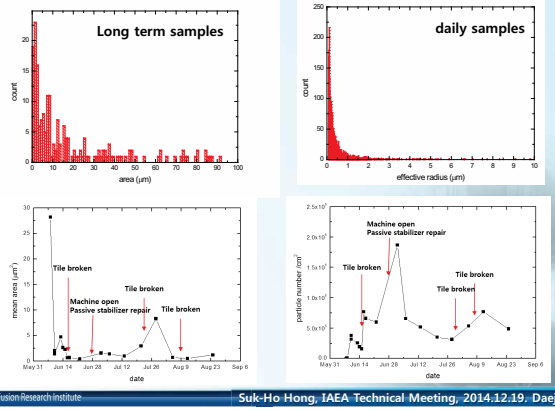


Tore Supra CIMES campaign | AUG 2007 campaign | Tore Supra DITS campaign

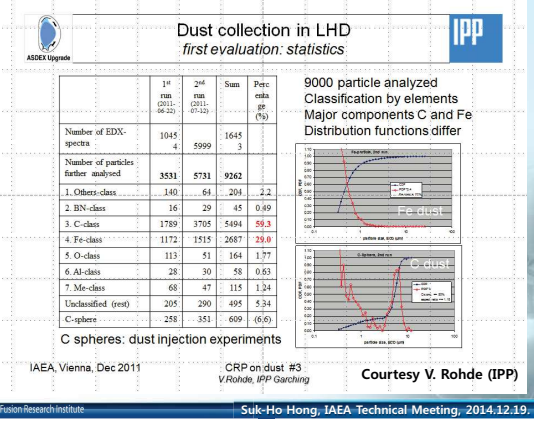
Finding compositions



Finding size distributions and temporal evolution



Finding size distributions and temporal evolution



	1st run (2011-06-22)	2nd run (2011-07-12)	Sum	Percentage (%)
Number of EDX-spectra	10454	5999	16453	
Number of particles further analysed	3531	5731	9262	
1. Others-class	140	64	204	2.2
2. BN-class	16	29	45	0.49
3. C-class	1789	3705	5494	59.3
4. Fe-class	1172	1515	2687	29.0
5. O-class	113	51	164	1.77
6. Al-class	28	30	58	0.63
7. Me-class	68	47	115	1.24
Unclassified (rest)	205	290	495	5.34
C-sphere	258	351	609	(6.6)

PROs

1. **IPP Garching has automated SEM equipped with EDX.**
2. **"Ultra high speed" measurements: 10000 part/weekend.**
3. **Better statistics on compositions.**

CONTRAs

1. **Generation and evaluation are completely dependent on the SEM schedule of IPP Garching.**
2. **Others cannot contribute the database without help of IPP Garching.**
3. **Measurement itself is "ultra fast", but takes much longer time for transport of samples.**
4. **Incompatible data format due to the use of commercial software.**

Consultancy by S. H. Hong, National Fusion Research Institute, Korea, 2013
Report on Standard Procedures for the IAEA Dust Database: Preparation, Measurements, and Upload

Final RCM, Vienna, 30 November - 2 December 2011
Meeting report and presentations

Second RCM, Vienna, 21-23 June 2010
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Suk-Ho Hong

Find a way to solve CONTRA issues
→ establish a standard procedure for dust database.

Ⅲ. Procedures for IAEA dust database

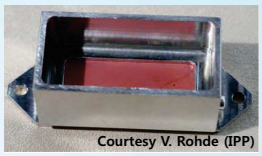
- **Several careful considerations are needed to establish dust database on size and compositions by different contributors**

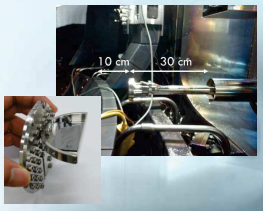
1. Standard procedures
   - Collection method
   - Characterization method and settings
   - Analysis tools and methods
   - File upload and maintenance strategy
2. Database access and maintenance
   - GUI user friendly interface
   - Easy to use and maintenance
   - Analysis tools and method
   - File upload and maintenance strategy

Ⅳ. Standard procedures

Collection method

- To be sure that dusts are created by plasma-surface interaction, and not during the maintenance, the use of fresh silicon wafer samples is recommended.
- To avoid contamination, wafers should be installed after the maintenance, just before the machine closing.
- To establish time-resolved database for temporal evolution of dust creation, shape, number density, silicon wafers should be installed everyday, in the morning.


Courtesy V. Rohde (IPP)



Ⅳ. Standard procedures

Characterization method and settings

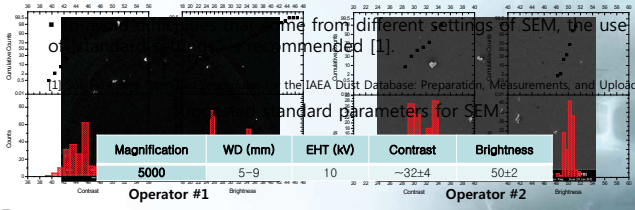
- Basic characterization method is SEM equipped with EDX.
- Every SEM operator has their own preferential settings for measurements, e.g., brightness and contrast, beam energy, distance from the gun to stage.
- Two operators made test to find optimum values.

Operator	WD (mm)	EHT (kV)	Iprobe (nA)	Contrast	Brightness	No. of images
1	23–25	10	35–143	39.3–54.9	19.5–47.4	209
2	5–9	10	–	28.9–35.5	48.2–51.5	123

- [illegible]me from different settings of SEM, the use of [illegible]mmended [1].

[1] [illegible] the IAEA Dust Database: Preparation, Measurements, and Upload [illegible]andard parameters for SEM.

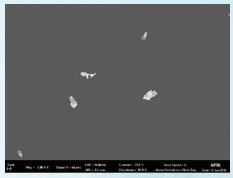
Magnification	WD (mm)	EHT (kV)	Contrast	Brightness
5000	5–9	10	~32±4	50±2



Ⅳ. Standard procedures

Characterization method and settings

- Chemical composition of individual dust can be measured by EDX.
- EDX measurements are performed separately by operators.
- Each dust measured by EDX are counted and enumerated on a copy of the SEM image to match both measurements for the dust database.

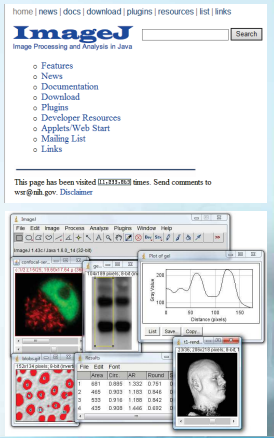


	C–K	O–K	Si–K	Fe–L
Point 1	5.45	3.43	87.65	3.47
Point 2	4.95	4.53	88.00	2.52
Point 3	5.98	4.01	85.36	4.65
Point 4	8.10	7.50	81.53	2.87

Ⅳ. Standard procedures

Analysis tools and methods

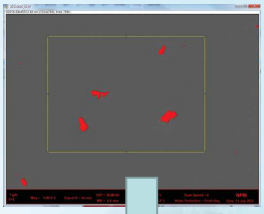
- Standard image analysis tool "ImageJ" developed by Research Services Branch (RSB) of the National Institute of Mental Health (NIMH), part of the National Institutes of Health (NIH).
- Through the dust CRP, IPP Garching has modified some functions of ImageJ for dust database (will be distributed).

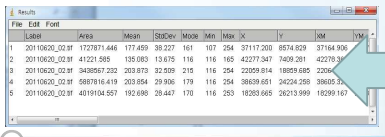


Ⅳ. Standard procedures

Analysis tools and methods

- ImageJ analyzes SEM TIFF files to get outlined image and physical parameters.
- Output file contains physical parameters such as size and shape descriptors, which will be uploaded for database.





Ⅳ. Standard procedures

ImageJ output and EDX indexed file

	C–K	O–K	Si–K	Fe–L
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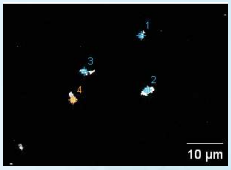
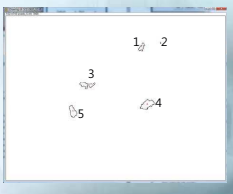
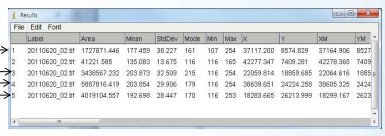


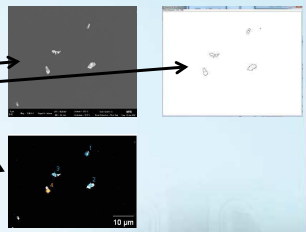




Ⅳ. Standard procedures

Upload preparation

- Files to upload
1) Original SEM image
2) Outlined image
3) EDX indexed image
4) ImageJ output file
5) EDX indexed file
6) Other diagnostic files

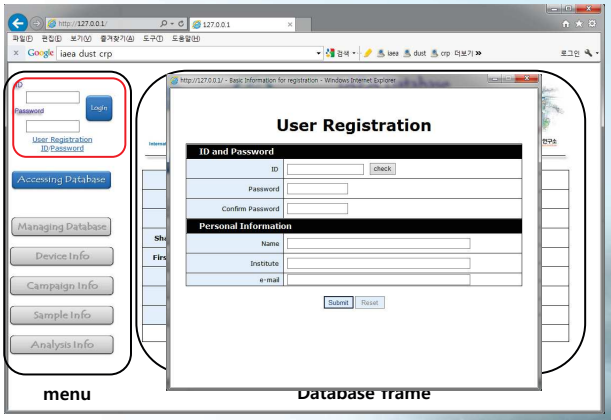


- Rules for file names

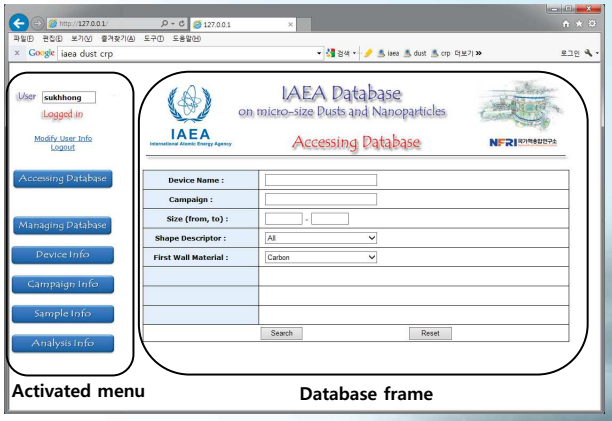
[DEVICE][YEAR][SAMPLE LOCATION][SAMPLE ID][IMAGE ID][DIAGNOSTIC ID]

[DEVICE] : machine name, for instance, [DEVICE]=KSTAR
[YEAR] : Campaign year
[SAMPLE LOCATION] : location of the sample, for instance, [SAMPLE LOCATION]=D-port.
[SAMPLE ID] : identification of the specific sample at the [SAMPLE LOCATION]
[IMAGE ID (Areal ID)] : areal point where the SEM measurement is made
[DIAGNOSTIC ID] : identification of the diagnostic data file.

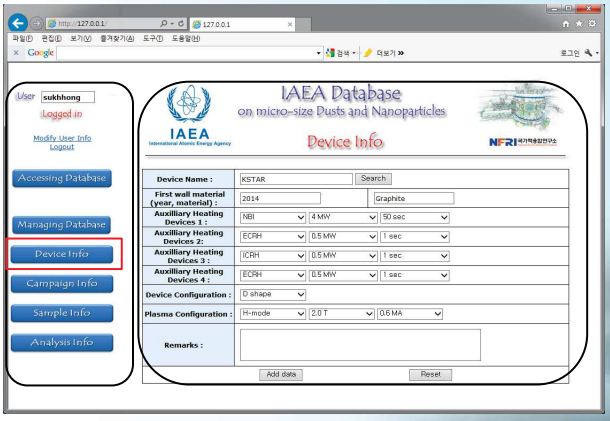
e.g., **KSTAR_2011_D-port_Sample01_Area01.TIFF**



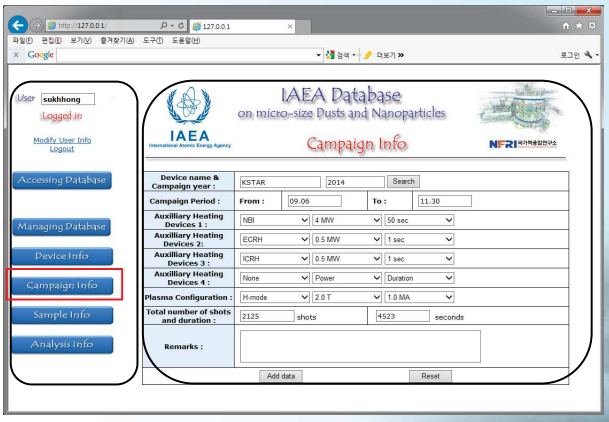
menu Database frame



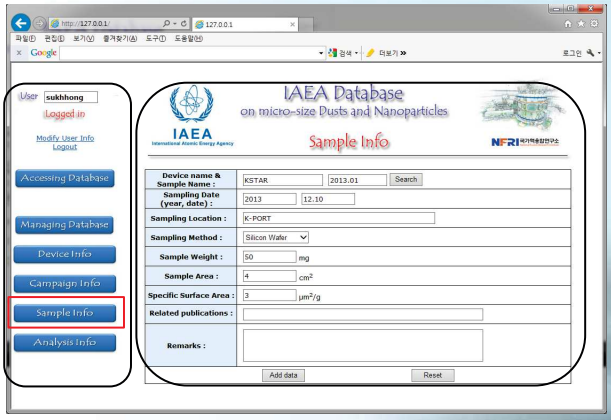
Activated menu Database frame



Activated menu Database frame



Activated menu Database frame



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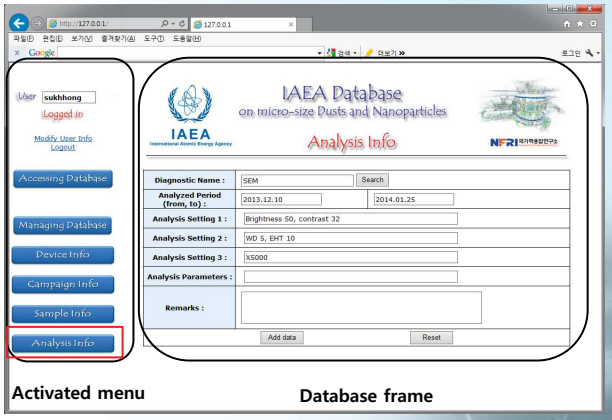

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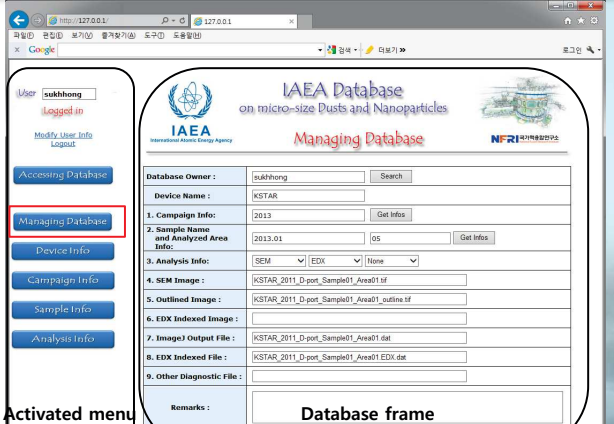

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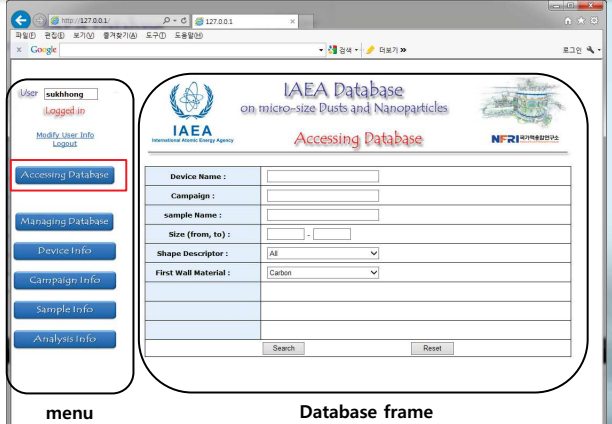
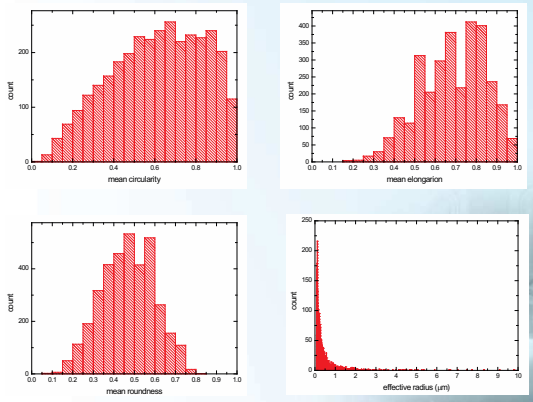


menu Database frame

V. Infrastructure for dust database

NFRI http://www.nfri.re.kr

Example



VI. Summary

NFRI http://www.nfri.re.kr

- Importance of dust database and corresponding IAEA CRP activity are briefly introduced.
- Dust database infrastructure is built.
- The data should be uploaded manually, but wide range of users can contribute to populate the database.
- Still, some functions have to be developed, modified, and optimized.