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IOHA

Hazardous agent emissions including
nanoparticle and aldehydes from desktop
3D printers

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BOHS
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IOHA

IOHA & BOHS 2015
London: Building on Occupational Hygiene Together

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- **Three-dimensional printer (3D printer)**

- used for various purposes

education, car, airline parts, medical science, art etc.



- **Printing method**

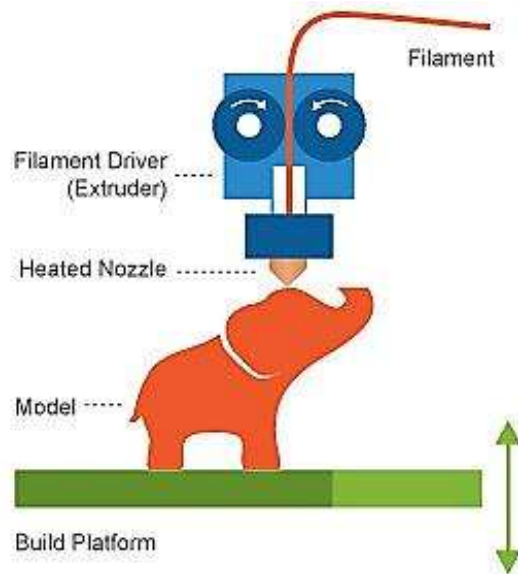
- Selective Laser Sintering (SLS)

- Stereo Lithographic Apparatus (SLA)

- **Fused Deposition Modeling (FDM)**

- **Most popular**

● FDM method



- Additive principle by laying down material in layers

- Mostly used filaments (filler material)

: acrylonitrile-butadiene-styrene (ABS)

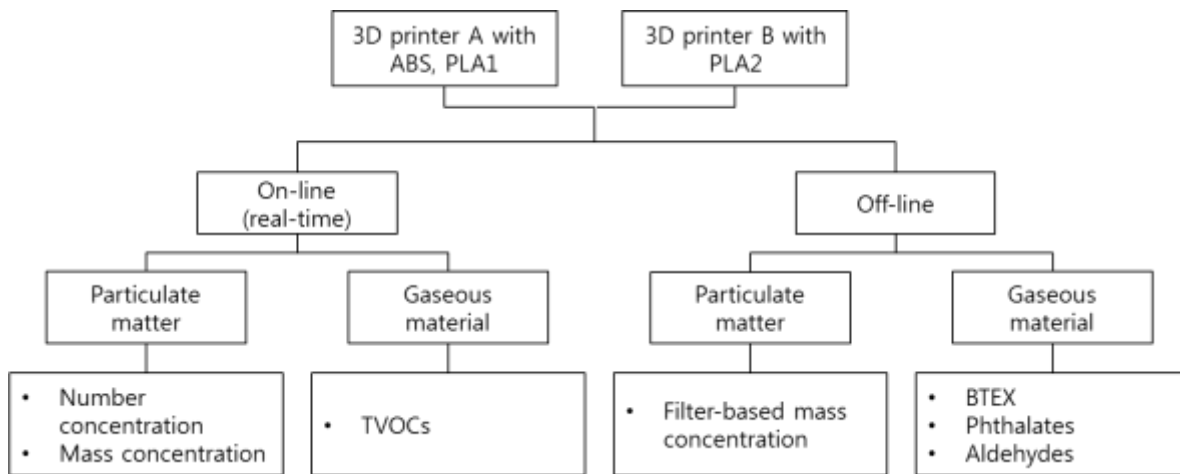
: poly lactic acid (PLA)

● The objective of this study

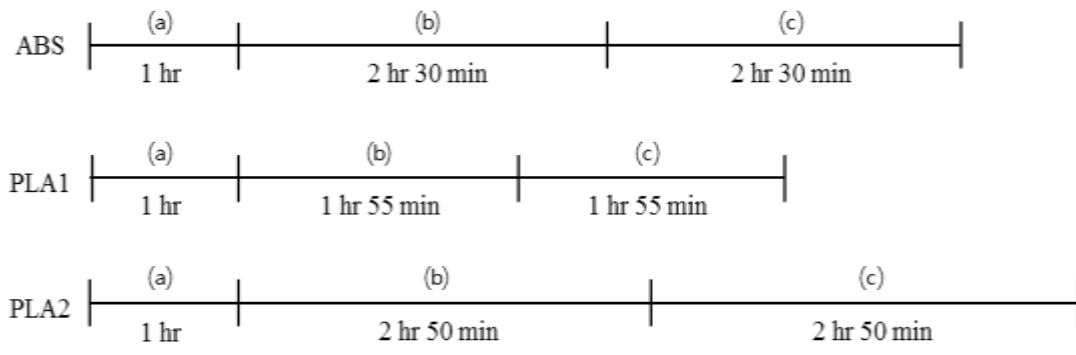
- to evaluate the emission characteristics of the particulate matter and gaseous material during 3D printing



● Outline of sampling



● Measurement period



(a) before operation
 (b) during operation
 (c) after operation



SMPS



CPC



ppbRAE



Sampling head

Introduction



printer A

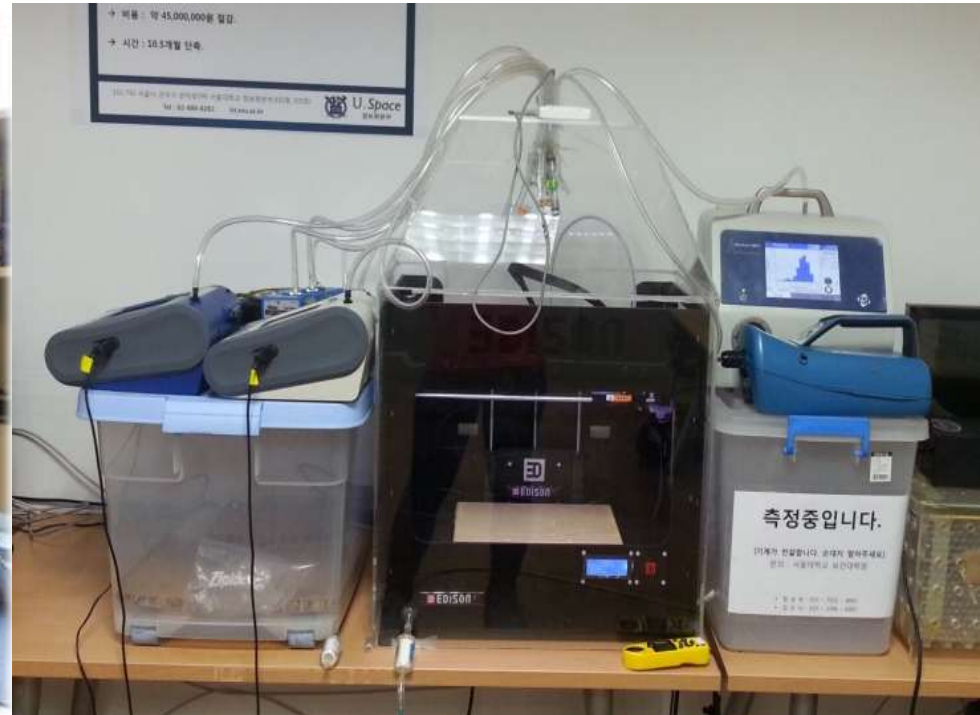
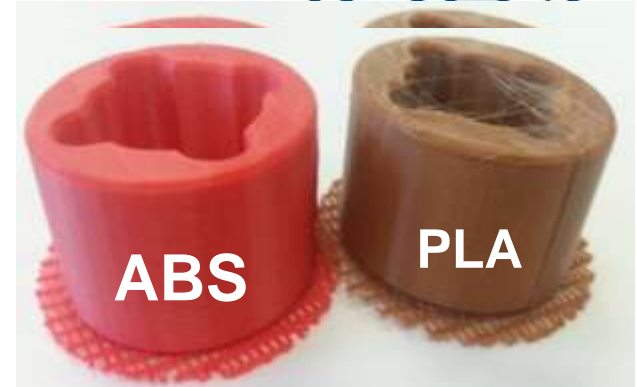
Methods



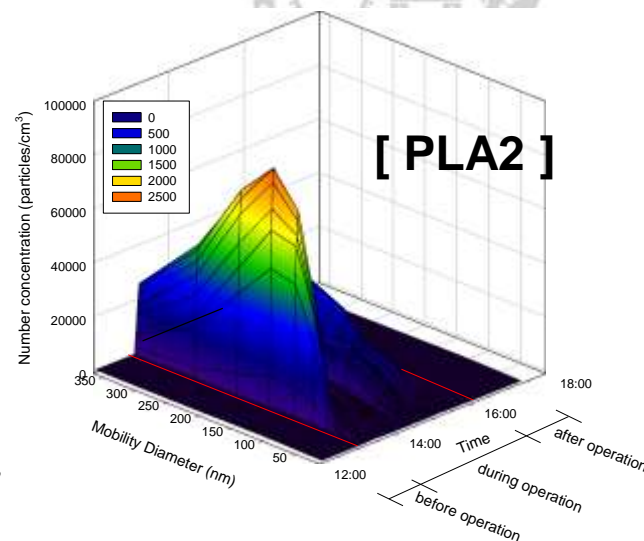
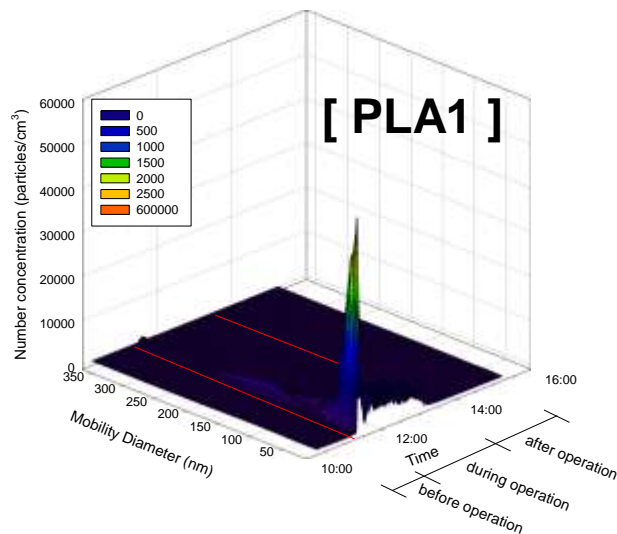
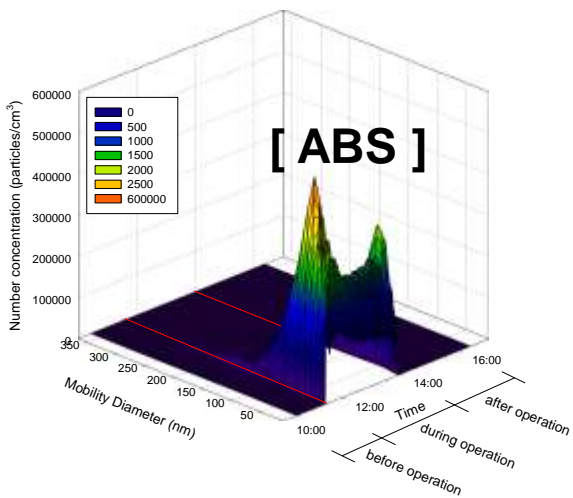
printer B

Results

Conclusions



(1) number concentration by SMPS



**345 times higher than before operation (CMD 32.6 nm)
(1,731,578 #/cm³ vs. 5,021 #/cm³)**

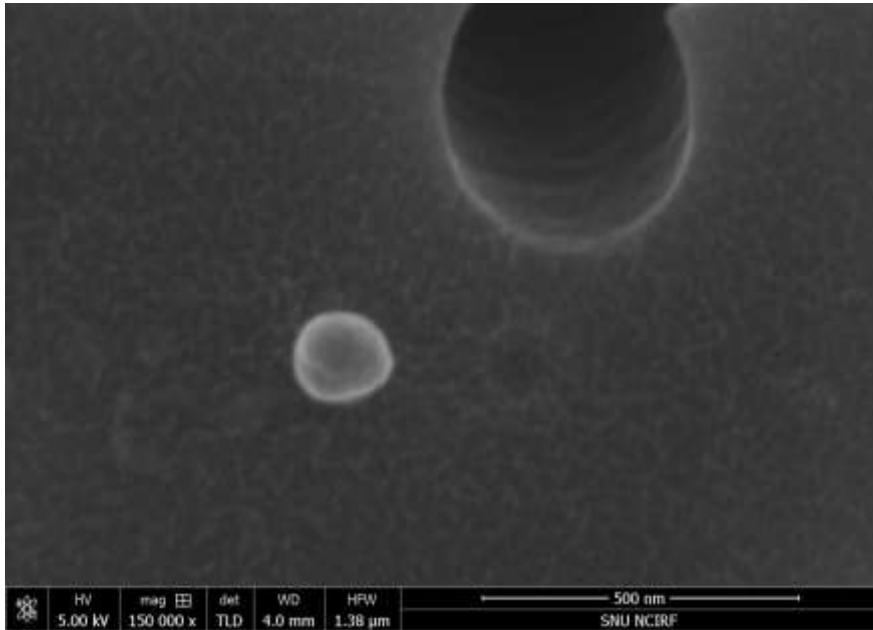
**26 times higher than before operation (CMD 27.9 nm)
(52,252 #/cm³ vs. 1,997 #/cm³)**

**21 times higher than before operation (CMD 188.1 nm)
(45,690 #/cm³ vs. 2,174 #/cm³)**

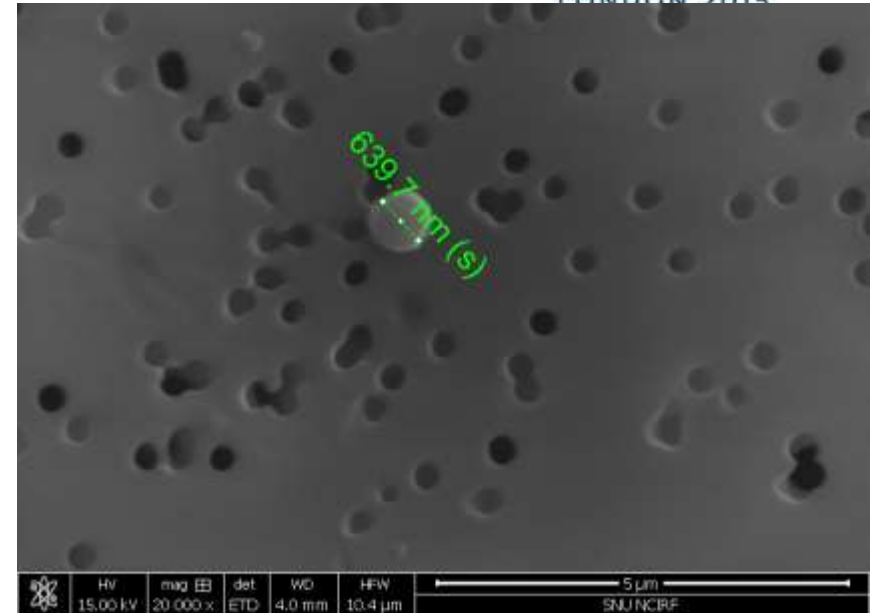
cartridge	GM (GSD)	< 100 nm, %		
	during operation (particles/cm ³)	before operation	during operation	after operation
ABS	1,731,578 (1.47)	66.5	95.7	88.7
PLA1	52,252 (1.98)	79.4	97.5	84.4
PLA2	45,690 (2.50)	54.3	11.9	55.3

ABS > PLA1 > PLA2

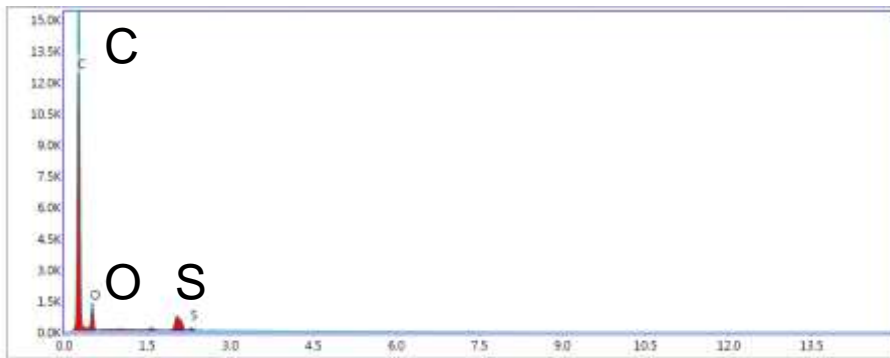
PLA1 > ABS > PLA2



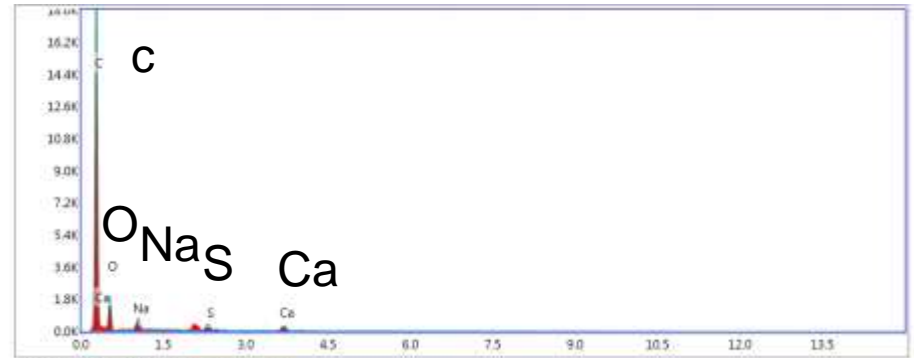
Aerosol during ABS operation
95.7% of <100 nm



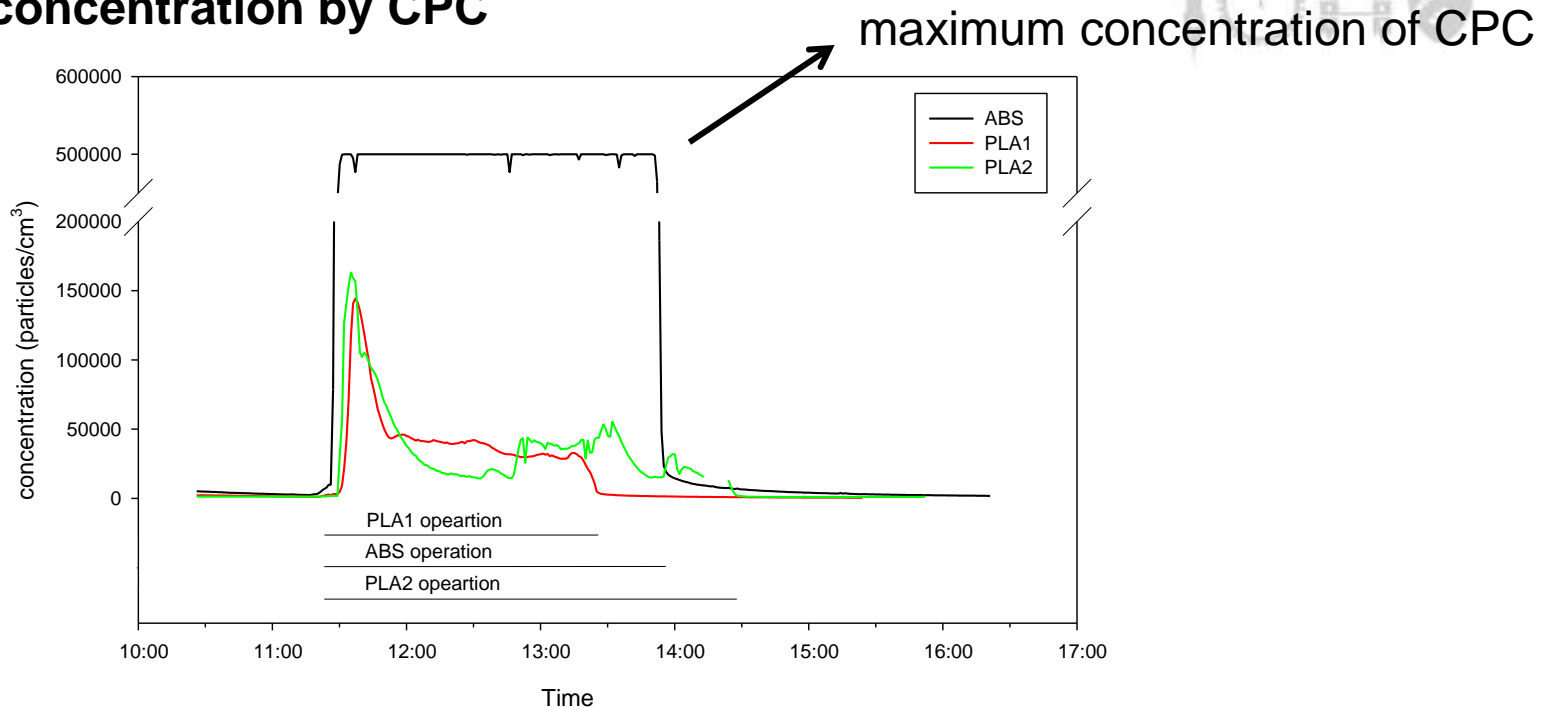
Aerosol during PLA 2 operation
11.9 % of <100 nm



Lsec: 30.00 Cnts: 0.000 keV Det: Octane Plus Det



Lsec: 30.00 Cnts: 0.000 keV Det: Octane Plus Det

(2) number concentration by CPC

Real-time monitoring by CPC during ABS, PLA1 and PLA2 sampling (maximum concentration of CPC is 500,000 particles/cm³).

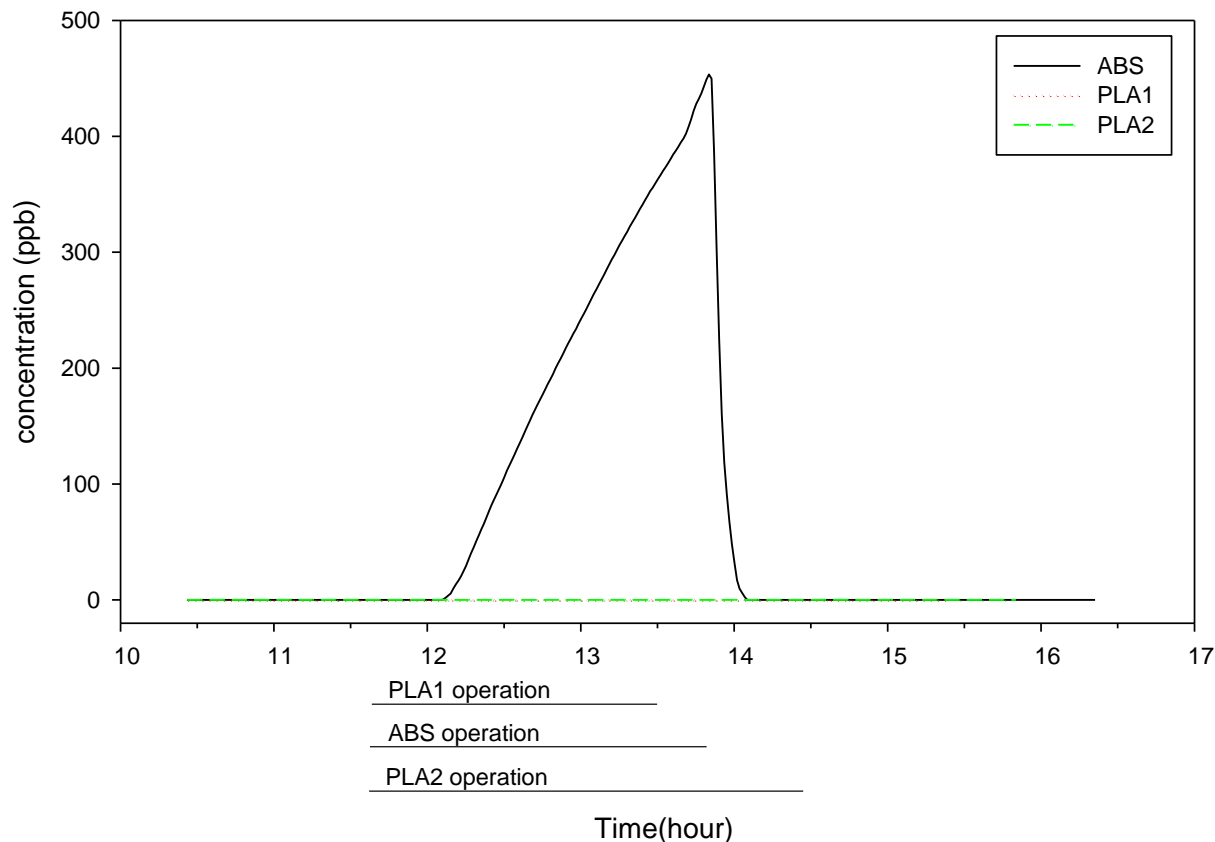
Similar pattern as SMPS

ABS: 129 times

PLA1: 28 times

PLA2: 20 times higher than before operation

(3) TVOC concentration



During operation (ABS)

GM (GSD): 154.9 (3.4) ppb

Range: 0 - 453.3 ppb

Real-time monitoring of TVOC concentration during sampling.

(4) Aldehydes concentration

cartridge	substance	Concentration (AM, SD), ppb			
		before operation	during operation	after operation	outdoor
ABS	Formaldehyde	39.3 (6.6)	68.0 (12.7)	43.8 (21.2)	21.3
	Acetaldehyde	<LOD	31.9 (6.2)	11.6 (1.7)	10.0
	Isovalderaldehyde	<LOD	90.8 (22.5)	37.6 (17.2)	7.7
PLA1	Formaldehyde	26.4 (16.4)	54.0 (23.3)	40.4 (6.0)	23.9
	Acetaldehyde	11.2 (2.1)	30.4 (5.0)	10.8 (1.5)	10.9
	Isovalderaldehyde	<LOD	<LOD	14.6 (12.0)	7.7
PLA2	Formaldehyde	111.0 (59.1)	155.9 (24.3)	114.7 (41.7)	30.2
	Acetaldehyde	<LOD	18.4 (14.7)	<LOD	9.9
	Isovalderaldehyde	<LOD	27.2 (33.9)	<LOD	7.7

LOD (ppb): acetaldehyde 1.94, Formaldehyde 1.26, Isovaleraldehyde 2.44

(5) Phthalates concentration

cartridge	substance	concentration (AM(SD), ppb)		
		before operation	during operation	after operation
ABS	DMP	<LOD ^{b)}	<LOD	<LOD
	DEP	<LOD	2.2 (0.8)	1.0 (0.6)
	DBP	<LOD	0.7 (0.2)	<LOD
	DEPH	<LOD	1.4 (0.3)	<LOD
	DnOP	<LOD	<LOD	<LOD
PLA1	DMP	<LOD	<LOD	<LOD
	DEP	<LOD	0.9 (0.4)	1.0 (0.4)
	DBP	<LOD	<LOD	1.5 (1.2)
	DEPH	<LOD	1.4 (0.2)	<LOD
	DnOP	<LOD	<LOD	<LOD
PLA2	DMP	<LOD	<LOD	<LOD
	DEP	<LOD	<LOD	<LOD
	DBP	<LOD	2.7 (3.2)	<LOD
	DEPH	<LOD	<LOD	<LOD
	DnOP	<LOD	<LOD	<LOD

LOD (ppb) : Dimethyl phthalate (DMP, 0.40), Diethyl phthalate (DEP, 0.67), Dibutyl phthalate (DBP, 0.81), di-2-ethylhexyl phthalate (DEPH, 1.25), Di-n-octyl phthalate (DnOP, 0.75).

1

Hazardous agents including nanoparticles, TVOC and Some aldehydes were emitted during 3D printing

2

Nano particles were emitted much higher when use ABS cartridge compared to the PLA cartridges (ABS > PLA1 > PLA2)

3

TVOC was emitted only ABS cartridge was used.

4

Some aldehydes were emitted high but phthalates levels were low

5

Caution and control should be implemented during FDM 3D printer use

Thank you for your attention

Acknowledgements
Yuna Kim,
Seunghon Ham,
Songha Kim



photo by Seok