GERMAN FEDERAL INSTITUTE FOR RISK ASSESSMENT

20 YEARS

BfR
German Federal Institute for Risk Assessment

3D printing – evaluating particle emissions of a 3D printing pen

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Additive Manufacturing - 3D Printing

- Layer-by-layer addition of material
- Materials ranging from poylmers to metals or ceramics

Techniques

- Vat photopolymerization
- Powder bed fusion
- Material jetting
- Material extrusion
- etc.

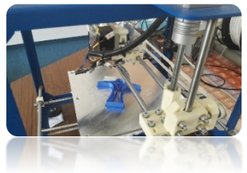
& applications

- Hobby
- Prototyping/ in the lab
- Industrial
- Medical and dentistry
- Housing

- 4D printing – smart materials reacting to stimuli

Source: University of Maine, online: https://composites.umaine.edu/3dirigo-the-worlds-largest-3d-printed-boat/

Source: Tagesschau, online: https://www.tagesschau.de/wirtschaft/haus-aus-dem-drucker-101.html



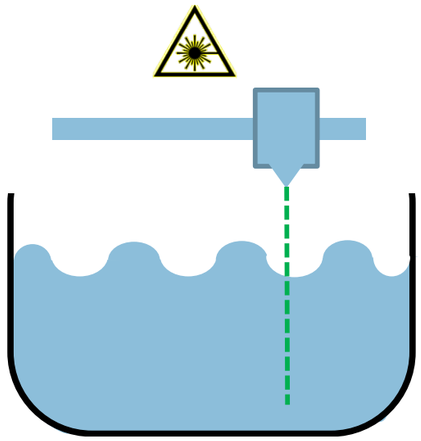
3D Printing – Techniques @ home

Fused Deposition Modeling (FDM)

- Melted thermoplastics
- Cheapest method
- Most used by consumers

- Release of particles and VOCs during printing
- Toxicity unclear

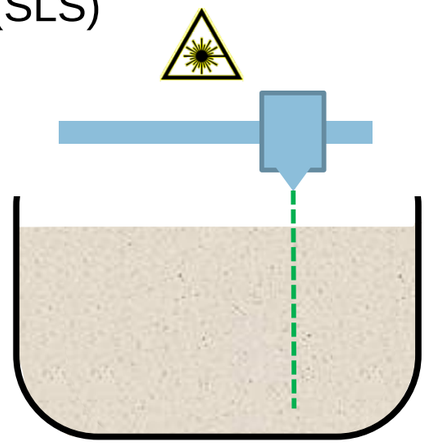
Stereolithography (SLA)



- UV laser on photopolymer resin
- Photochemically solidified
- Reached consumer price range

- Release of particles and VOCs during printing reported

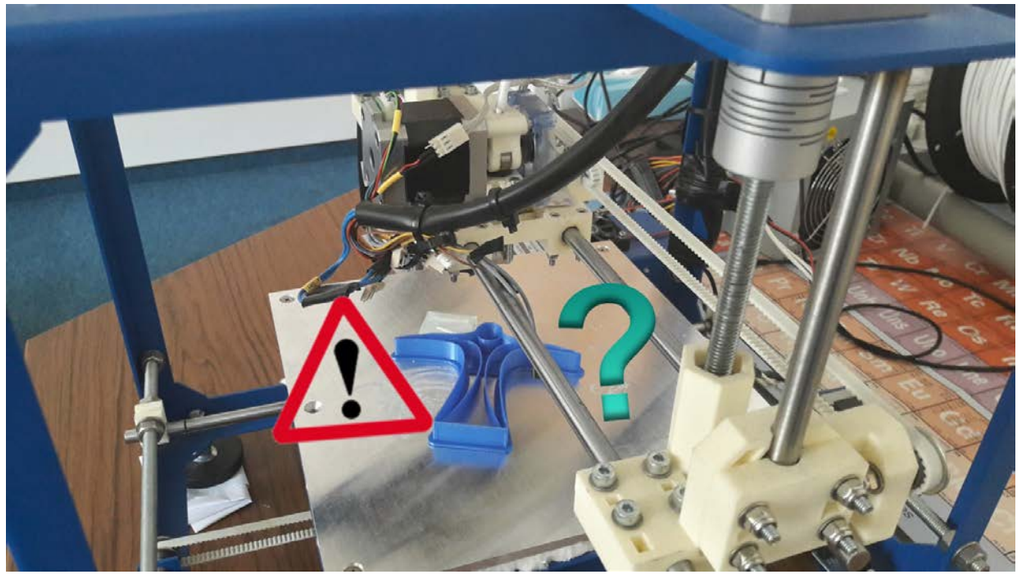
Selective Laser Sintering (SLS)

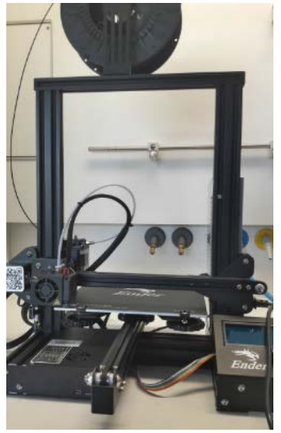


- Laser used to sinter powder
- Still expensive
- Mainly professional use

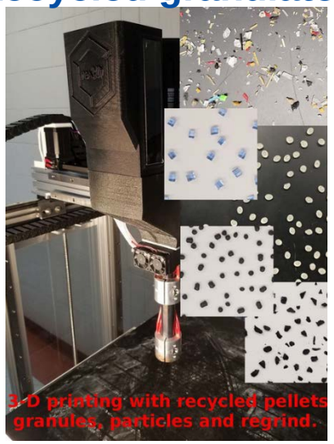
- Often fully encased
- Powder dust release possible during opening

3D printing – Aerosols @ home?





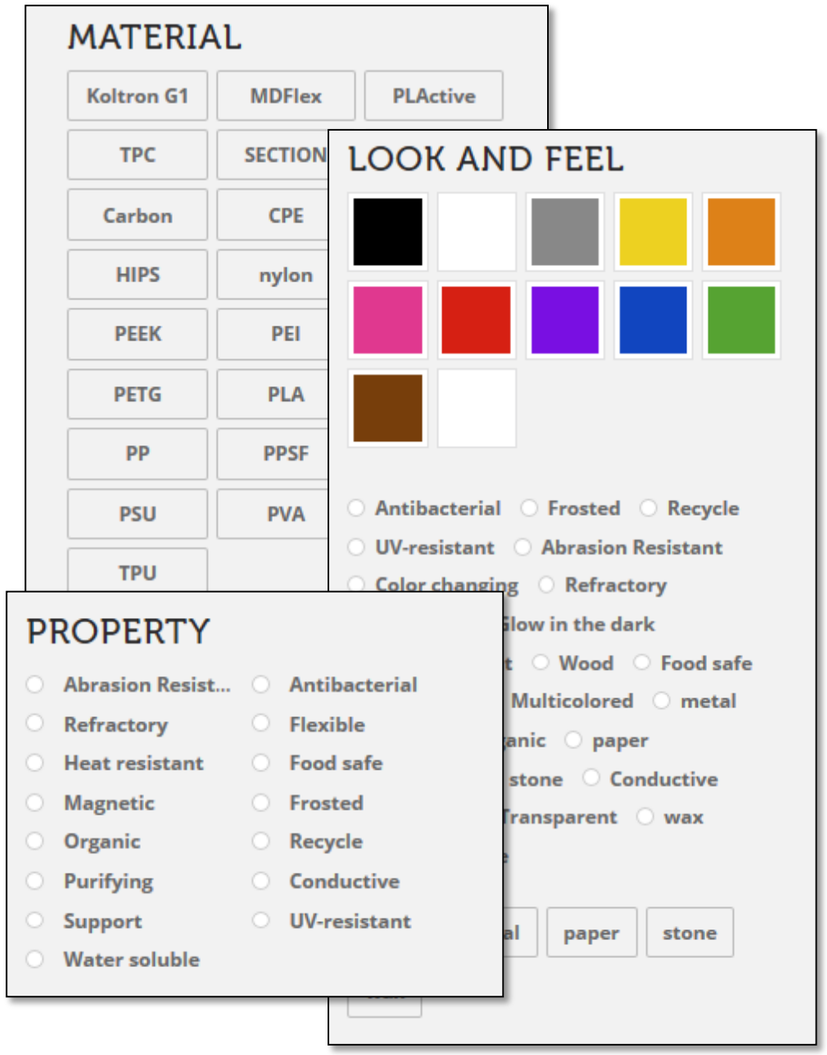
FPF 3D printing – Recycled granulates

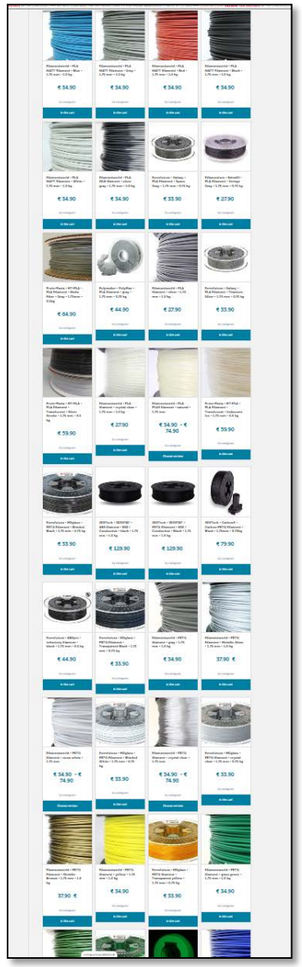


Woern et al., 2018, *Materials*, https://doi.org/10.3390/ma11081413

FDM 3D printing pens – Handheld emmissions

FDM-3D Printing – Materials & complexity





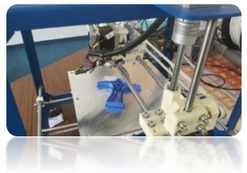
Source: https://www.filamentworld.de/

Copper Filament

- 70% copper (w/w% ICP-MS)

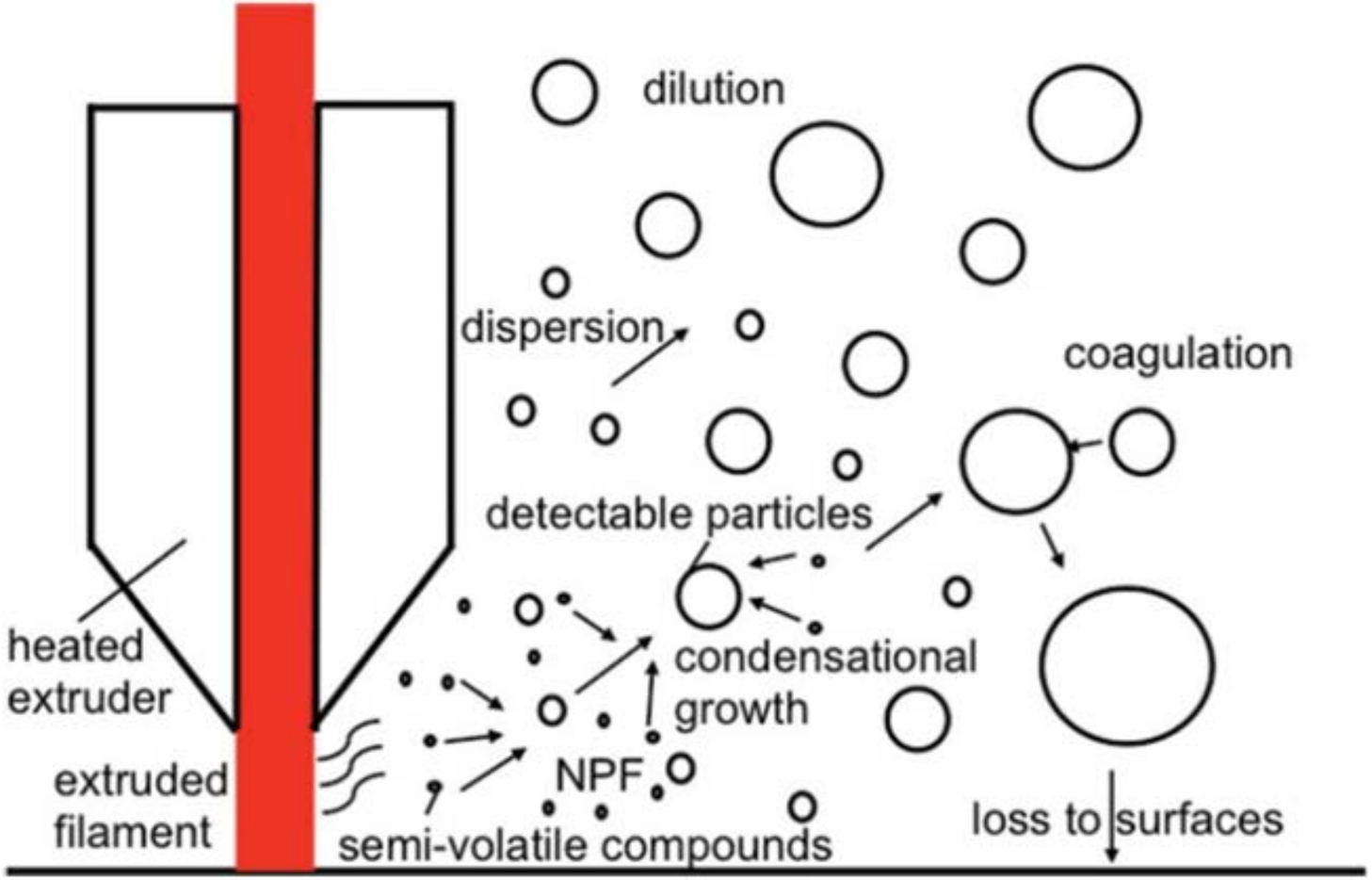
Steel Filament

- 30% Fe, 8% Cr, 6% Ni (w/w% ICP-MS)



3D printing – Emissions

Based on Polymer



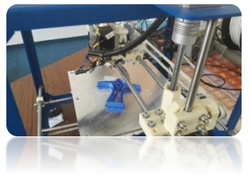
Source: Zhang et al., 2017, *Aerosol Science and Technology*, doi: 10.1080/02786826.2017.1342029

& particulate additves

- CNTs, graphene
- Metal, metal oxide
- Wood, cellulose
- Stones
- etc.

Micro- and nano-sized

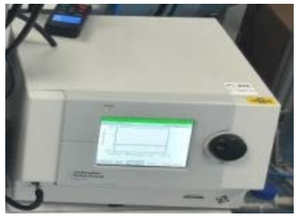
3D printing pen – Online aerosol measurements

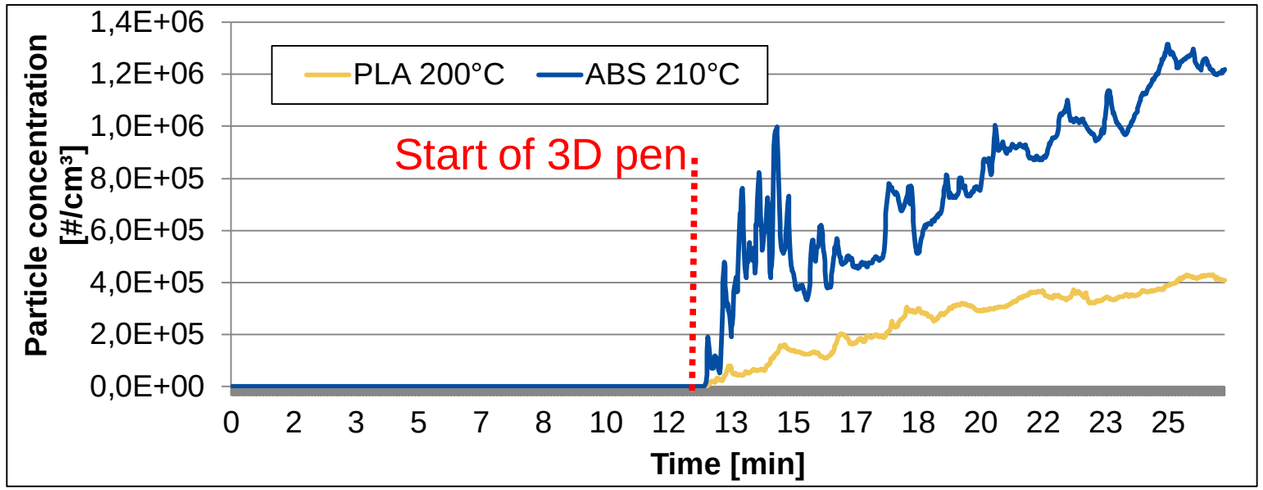


Online coupling

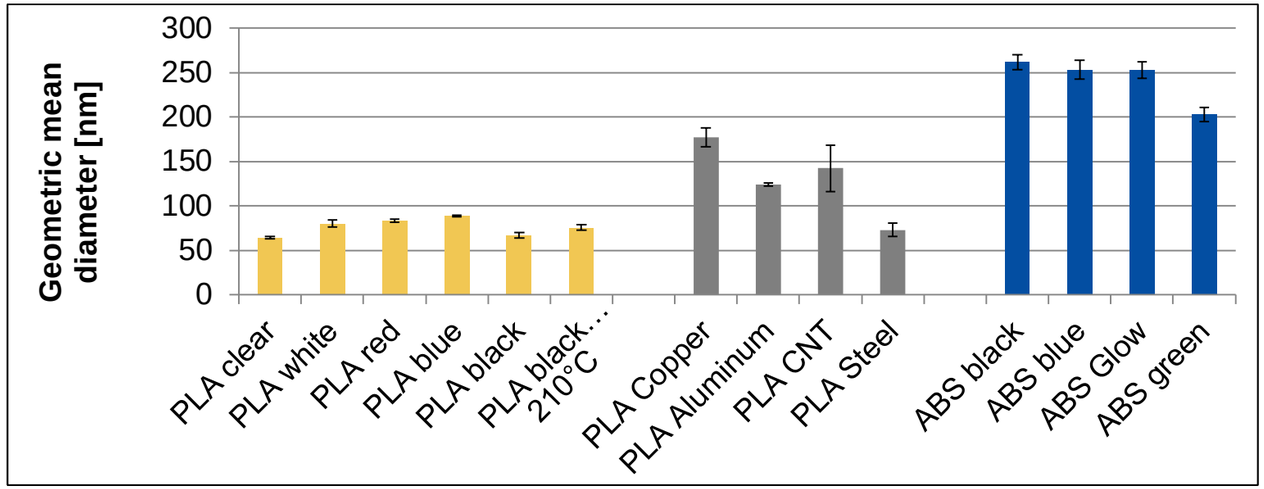
Sigloch, H., Bierkandt, F.S. et al. 3D Printing - Evaluating Particle Emissions of a 3D Printing Pen. *J. Vis. Exp.* (164), e61829, doi:10.3791/61829 (2020)

Particle concentration by CPC

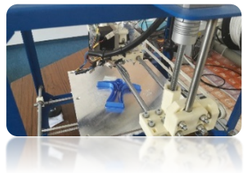




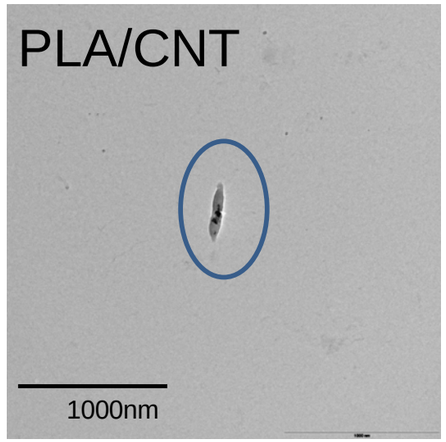
Particle size by SMPS

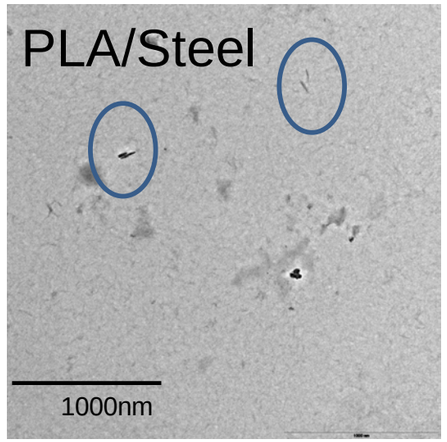


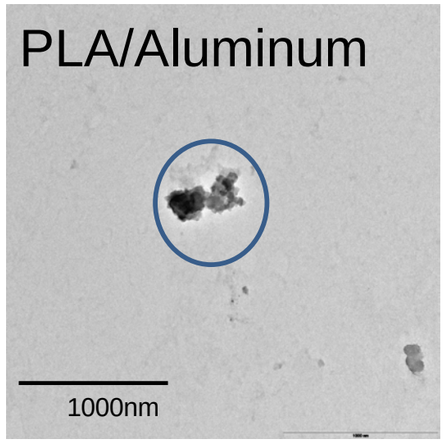
3D printing pen – Offline aerosol assessment



TEM

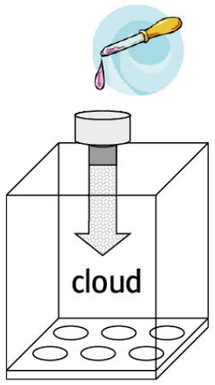




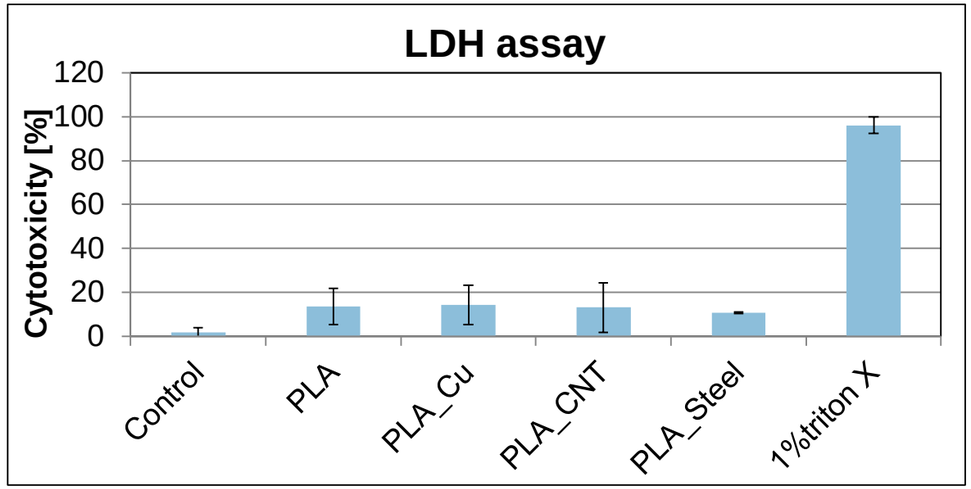


Passive sampling by sedimentation

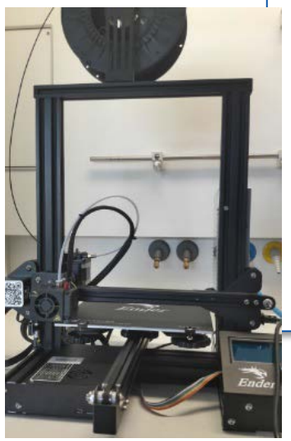
Cell exposure by ALI



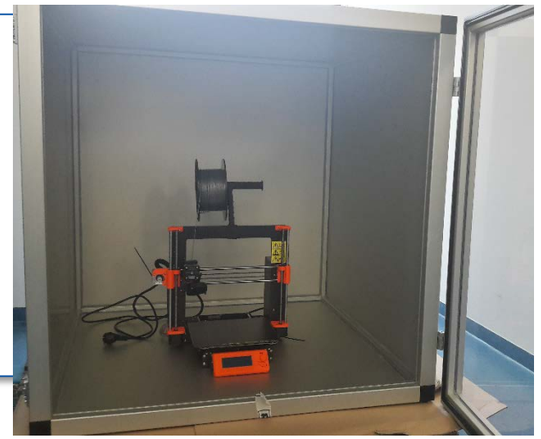
Source: Vitrocell Systems GmbH



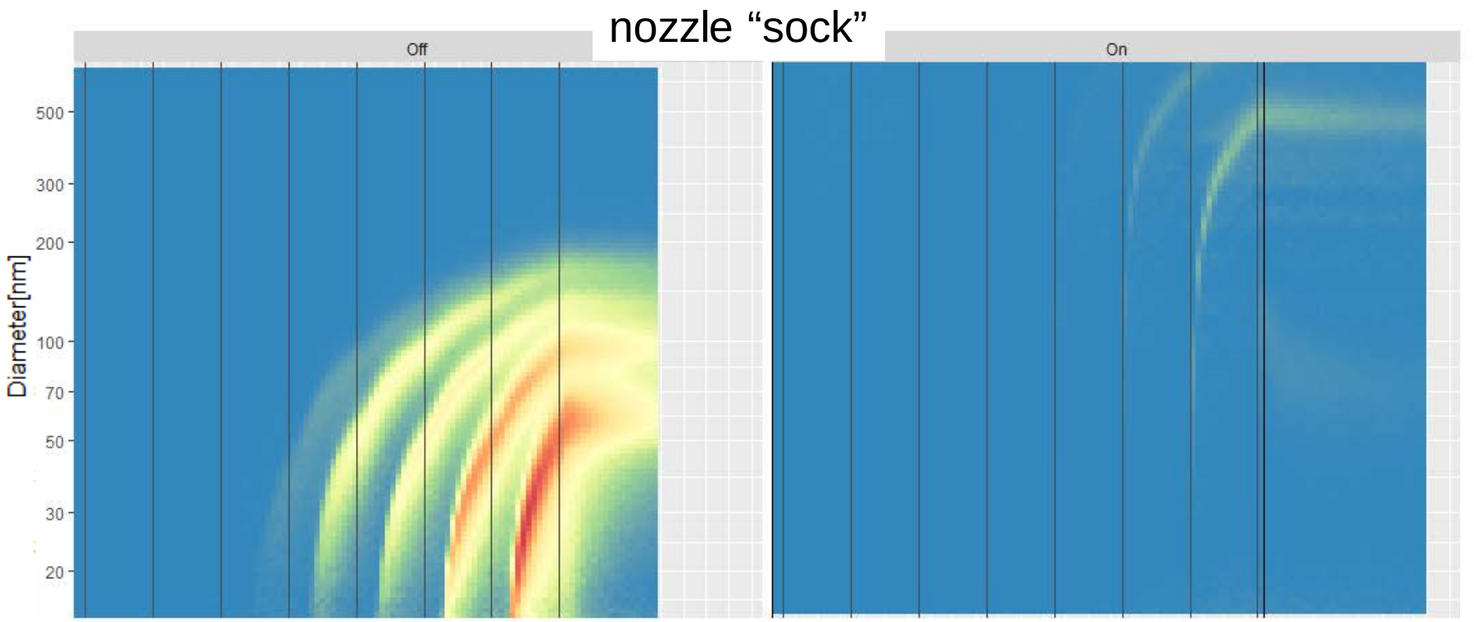
FDM 3D printing – Desktop instruments



- Measurement in 1 m^3 chamber with ventilation/filtration
- Longer printing time & variation of parameters (temperature ramp, nozzle “cleanness”, nozzle “sock”, etc.)

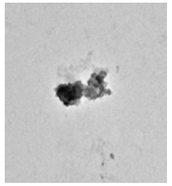


Particle size by SMPS



Conclusion - Outlook

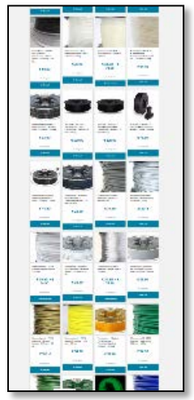
- NP release depending on filament & printing parameters (esp. temperature)
- Release of particulate additives (CNTs, metals)



- Cellular toxicity after sampling and ALI exposure

- ➢ Further filaments & particulate additive/ parameter effects on emissions
- ➢ Online/long-term ALI exposure

- ➢ VOC emission and toxicity



- ➢ Other 3D printing techniques for consumers

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Identify Risks – Protect Health

Thanks for your attention

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