Cluster decorated functional DNA origami based biosensor: Towards safe nano-innovations

Susanne Resch*[1], Nerea Argarate[1], Clemens Wolf[1], Johanna K. Scheper[1], Andreas Falk[1]

[1]BioNanoNet Forschungsgesellschaft mbH, Graz, Austria

BioNanoNet Forschungsgesellschaft mbH
Kaiser-Josef-Platz 9, 8010 Graz, Austria
*susanne.resch@bnn.at
www.bnn.at

DNA origami based biosensor

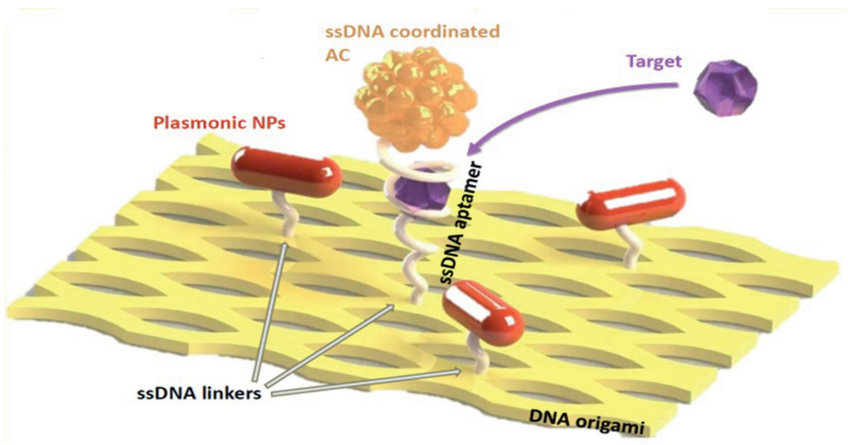

Figure 1. Cluster decorated DNA origami based biosensor.

The DeDNAed project intends to:

- Develop a **cutting-edge bioanalytical biosensor platform** with advanced sensitivity and versatility using **SERS** as an **ultrafast optical analysis method.**
- Assemble and integrate sensing elements using **DNA origami** as a **"nano-breadboard"**.
- **Use single-stranded DNA (ssDNA)** as "**solder**" to attach elements to DNA origami.
- Design and synthesize an appropriate DNA origami platform.
- Use atomic nanocluster decorated aptamers as bioreceptor elements for aflatoxin B1 detection and use atomic nanocluster decorated antibodies as bioreceptor elements.
- **Design appropriate plasmonic nanoparticles** for SERS and their surface functionalization.
- Integrate the DNA origami hybrids onto solid and flexible surfaces.
- **Integrate and validate** the DeDNAed SERS biosensor for potential application in the Biomedical and Food Safety sectors.

Aflatoxin B1 detection - A potent carcinogen

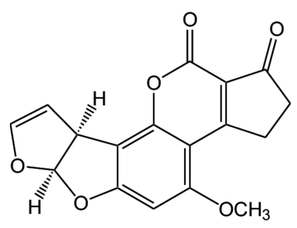

Figure 2. Aflatoxin B1 structure.

- Detection of Aflatoxin B1 (AFB1)
- Most potent genotoxic and carcinogenic mycotoxin
- Linked to hepatocellular carcinoma (HCC)
- High risk for grain mill workers
- Contaminant in food such as cereals
- MRL limits = 2 µg/kg in cereals

Nanomaterials in SERS readout strategies

- **Surface-enhanced Raman Scattering (SERS) enhancement**[1,2], **Raman hot spot,** is formed in the interparticle gaps of DNA origami functionalized with gold NPs specific spatial arrangement due to coupling of the surface plasmon resonance.
- However, nanocomponents' effects on humans and environment need to be studied using SbD actions during the product life-time.

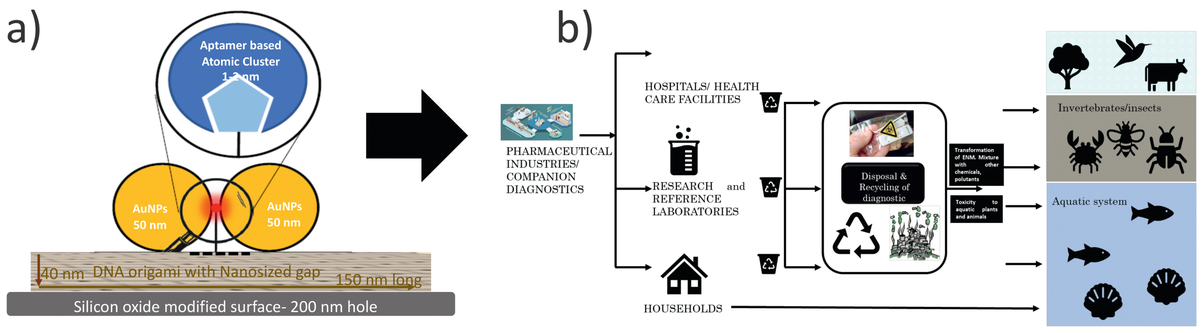

Figure 3. a) Integration of nanoscale components in DeDNAed biosensor, and (b) risks of nanoIVD devices life-cycle.

Safe-by-Design (SbD) actions

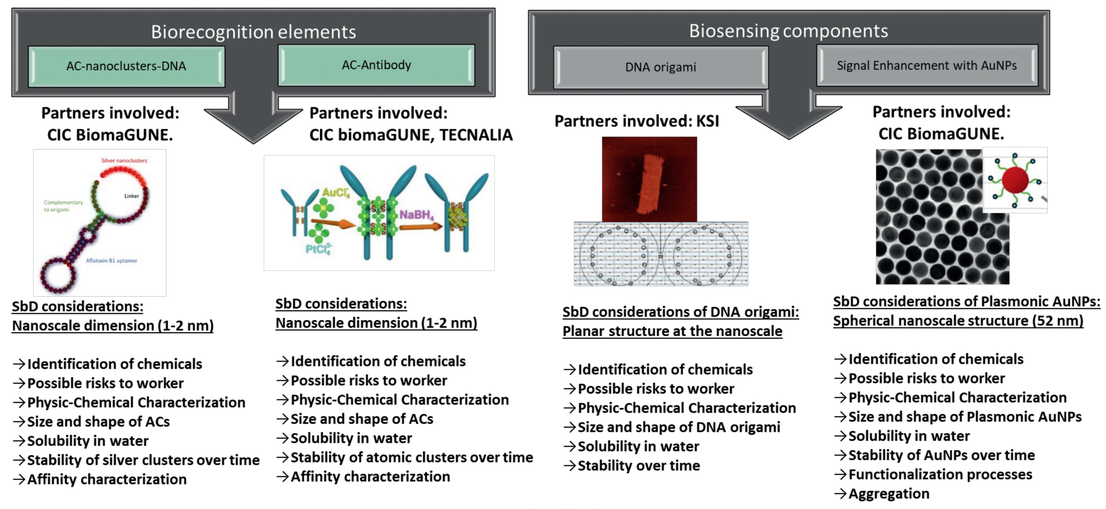

Figure 4. Suggested Safe-by-Design actions.

Risks of integrating nanoscale dimension materials:

Phase 1: Design, synthesis of nanoscale dimension materials

- **SbD assessment –** Several types of nanoscale materials are in development phase
  → Define complete Phys-Chem characteristics

Phase 2: Integration of nanoscale materials to DNA origami

- **SbD assessment –** Integration of nanoscale materials to DNA origami surface by complementary short oligo
  → Consider size, shape, stability

Phase 3: Integration of DNA origami hybrids on surfaces

- **SbD assessment –** Integration of DNA origami hybrids to SiO_2 modified wafer (nanometer surface 200 nm holes), stability of DNA origami hybrids on surface and risk of release
  → Check stability of the oligos binding and risk of release

Sustainability-by-Design considerations

Multiplexing consideration

- **SusbD consideration –** detection of multiple analytes in one device

Environmentally friendly components

- **SusbD consideration –** bio-based nanomaterials for SERS

Miniaturization: reduced reagents volumes and samples needed

- **SusbD consideration –** lower cost in reagents and samples

Designing sustainable surfaces

- **SusbD consideration –** recyclable, reusable and friendly design

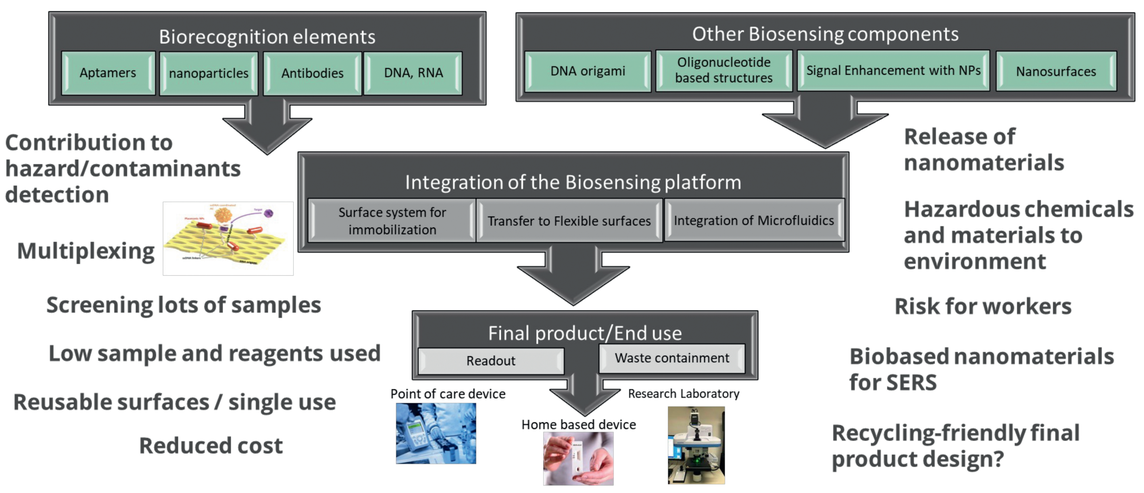

Figure 5. Sustainability-by-Design considerations during the different development stages and use phases.

CONCLUSION

DeDNAed will foster a safer nano-enabled biosensor considering the Safe-by-Design approach and sustainability aspects[3]. Several nanocomponents are in the development stage such as atomic nanocluster-decorated aptamers and antibodies as well as DNA origami and gold NPs. Unique and novel properties and materials attributes need to be checked for unanticipated hazard or exposure behavior. DeDNAed will define a preliminary hazard/risk assessment and control plans for the DNA origami biosensor nanocomponents.

[1] *J. Phys. Chem. Lett.* 2013, 4, 23, 4140–4145. DOI: https://doi.org/10.1021/jz402076b.
[2] *Nat Commun* 5, 3448 (2014). https://doi.org/10.1038/ncomms4448
[3] European Commission, Joint Research Centre, 2022, https://data.europa.eu/doi/10.2760/487955

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