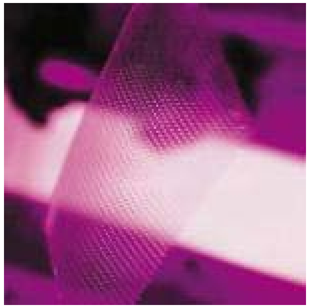
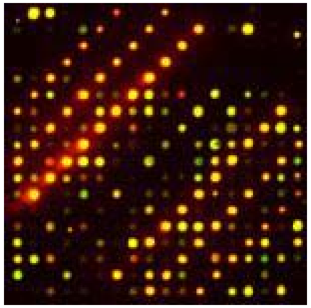
Ink Formulation for the Inkjet Printing of Functional Core-Shell Nanoparticles for Automated Preparation of Multi Feature Biofunctional Surfaces

Fraunhofer Institute for
Interfacial Engineering and Biotechnology

K. Borchers, J. Plankalayil, T. Hirth, G.Tovar, Achim Weber

Formula VI & Nanoformulation2010, Stockholm, 10.06.2010



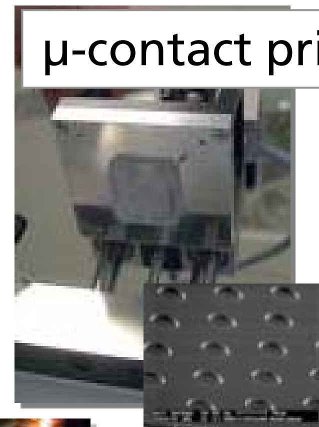


Fraunhofer
IGB

Bio-functionalization of surfaces

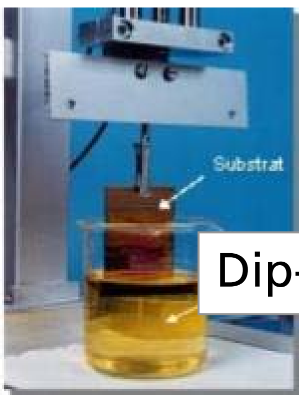
- Biosensors
- Biomaterials
- Cell culture

Spin-coating



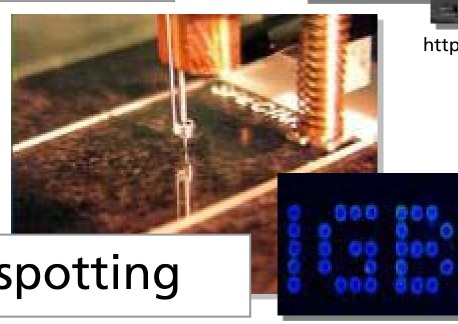
µ-contact printing

http://www.gesim.de



Dip-coating

http://www.iwt-bremen.de



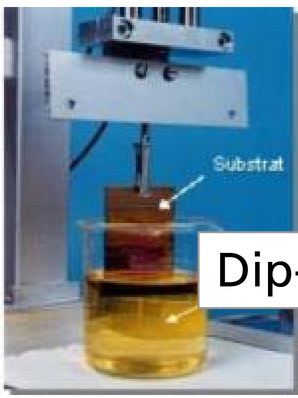
Microspotting

Bio-functionalization of surfaces

- Biosensors
- Biomaterials
- Cell culture

Spin-coating

Dip-coating

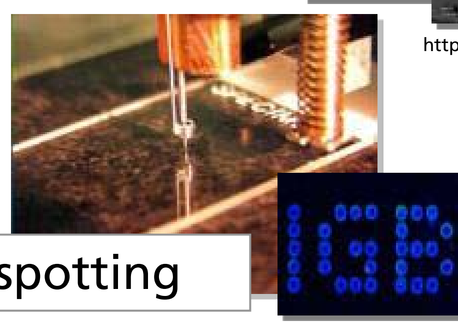


http://www.iwt-bremen.de

µ-contact printing

http://www.gesim.de

Microspotting



Piezo-electric inkjet-printing

- room temperature process
- digital technique
- scalable
- avoids material spill over

Overview of the talk

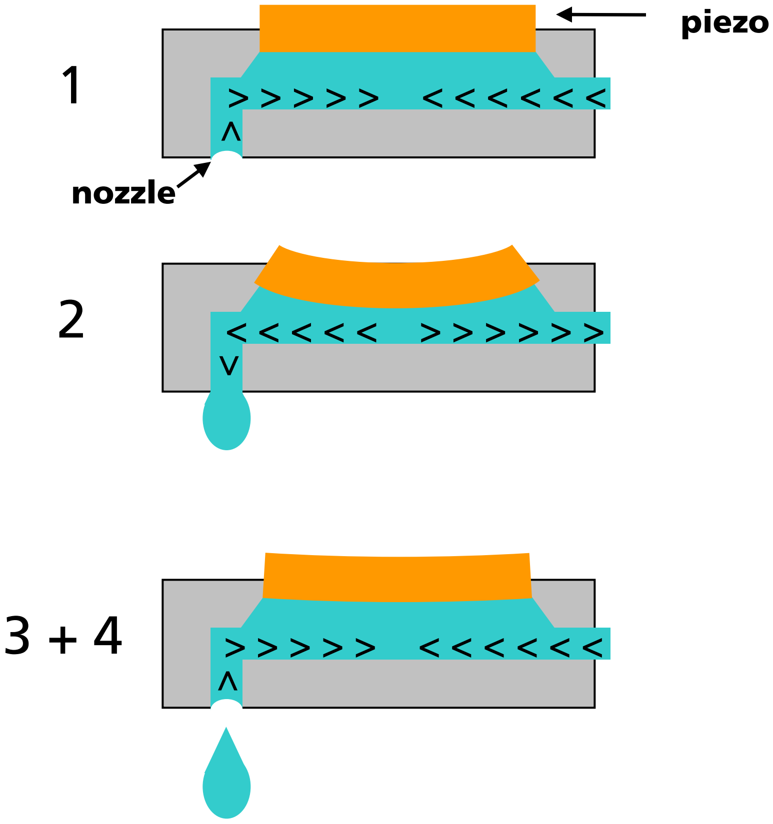
- Demands for ink jetting of biological probes

- Ink formulation & protein stability
- Substrate preparation

- (Bio)functional nanoparticles
- Printing
- Evaluation

Piezoelectric drop-on-demand ink jetting

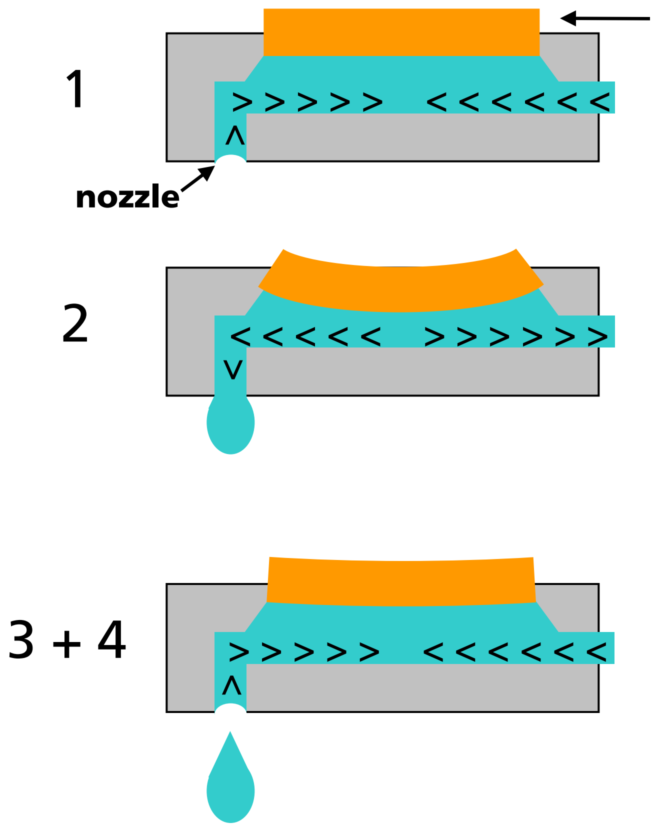
Jetting process



Source: Dimatix

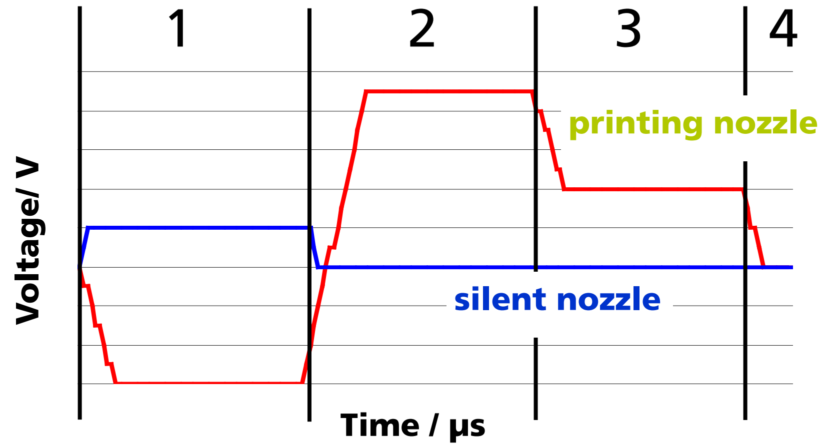
Piezoelectric drop-on-demand ink jetting

Jetting process

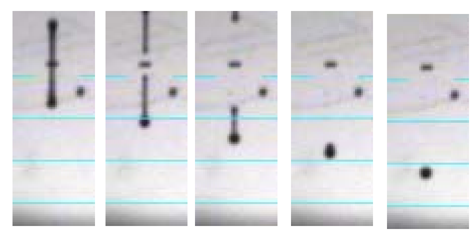


Source: Dimatix

Wave form

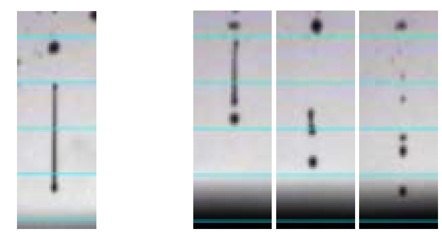


Accurate drop formation



20 µs 30 µs 40 µs 50 µs 60 µs

In-accurate drop formation



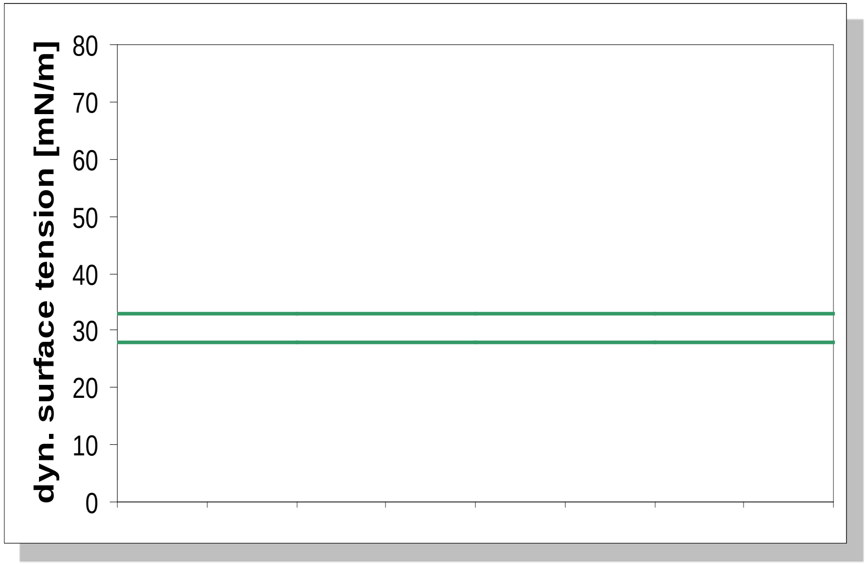
Distinctive tail

satellites

Ink specification

as indicated for the DMP 2800 Printer by FUJIFILM Dimatix

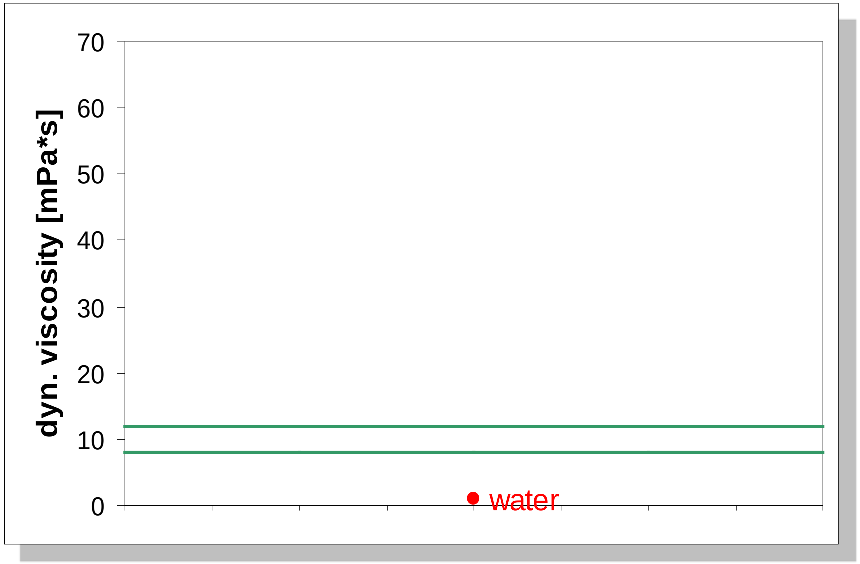
Dynamic viscosity: 8 – 12 mPa s
Dynamic surface tension: 28 – 33 mN/m

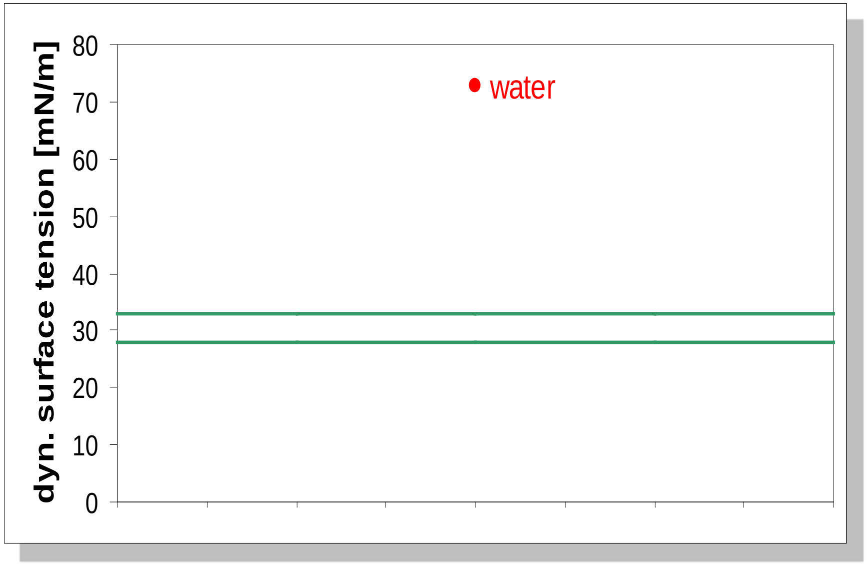


Ink specification

as indicated for the DMP 2800 Printer by FUJIFILM Dimatix

Dynamic viscosity: 8 – 12 mPa s
Dynamic surface tension: 28 – 33 mN/m





Overview of the talk

- Demands for ink-jetting of biological probes

- Ink formulation & protein stability
- Substrate preparation

- (Bio)functional nanoparticles
- Printing
- Evaluation

Ink formulation

Water

(Bio-)functional compound

Viscocity modifier

- Glycerol
- Poly(ethylen glycol) PEG
- Poly(vinyl alcohol) PVA
- Dimethyl sulfoxide DMSO

Surface tension modifier

- surface active compounds
  - detergents
- low surface tension compounds
  - 2-propanol

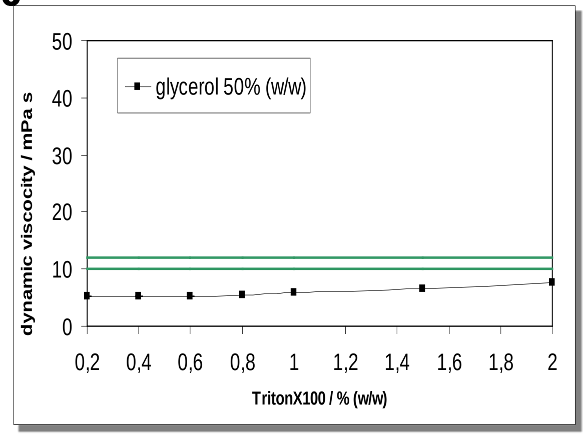
Formulation and characterization of inks

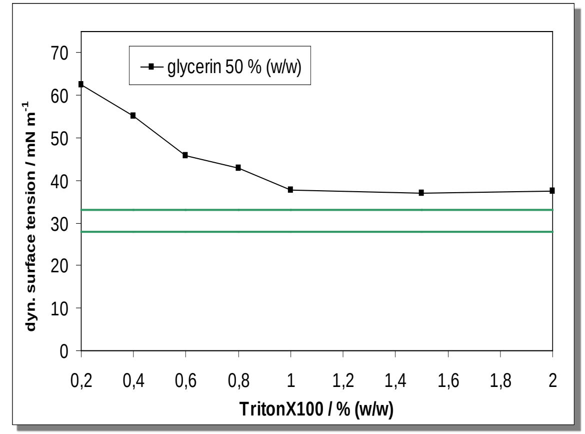
Glycerol / TritonX100

η

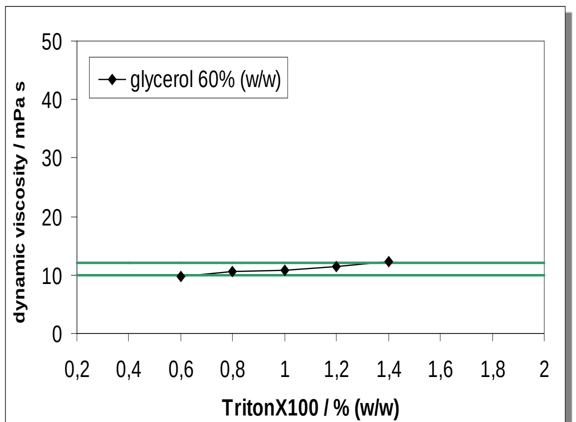
σ

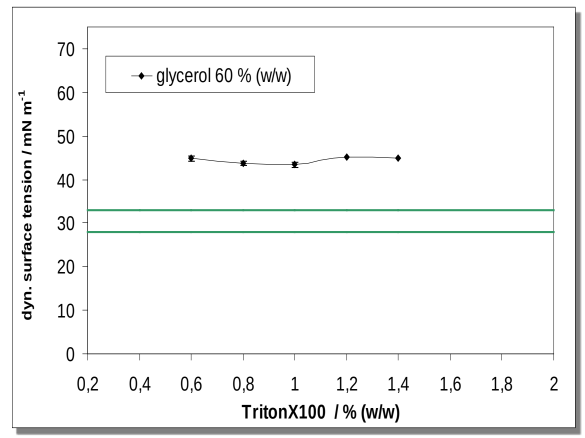
50% glycerol





60% glycerol





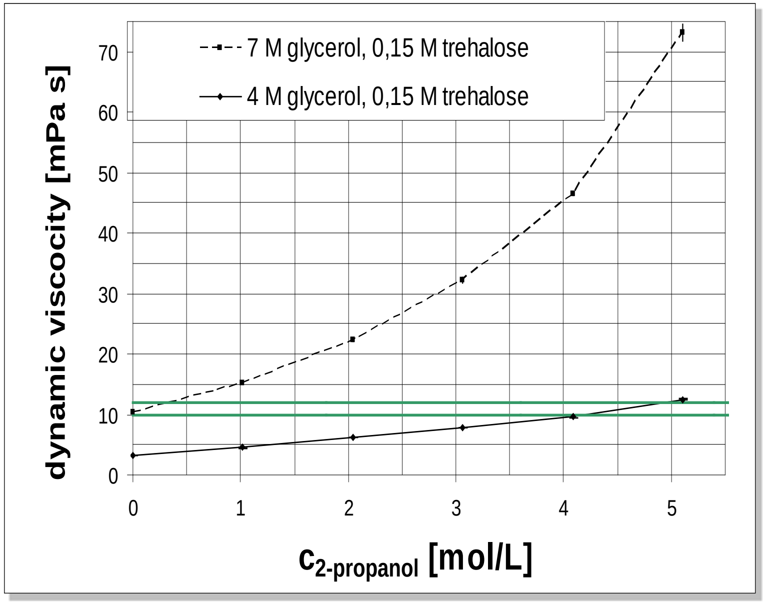
University of Stuttgart
Institute for Interfacial Engineering

Fraunhofer
IGB

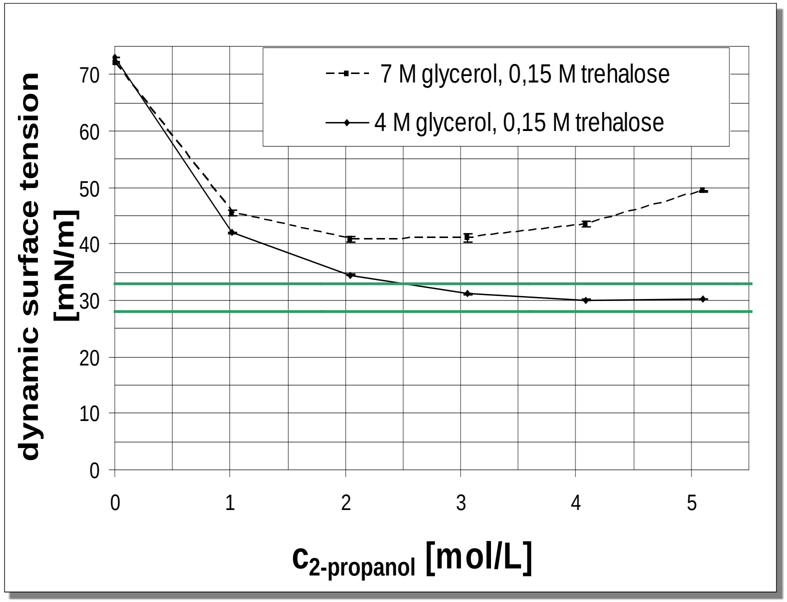
Formulation and characterization of inks

Glycerol / 2-Propanol

η



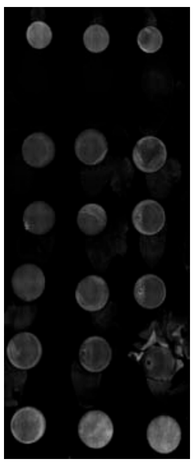
σ



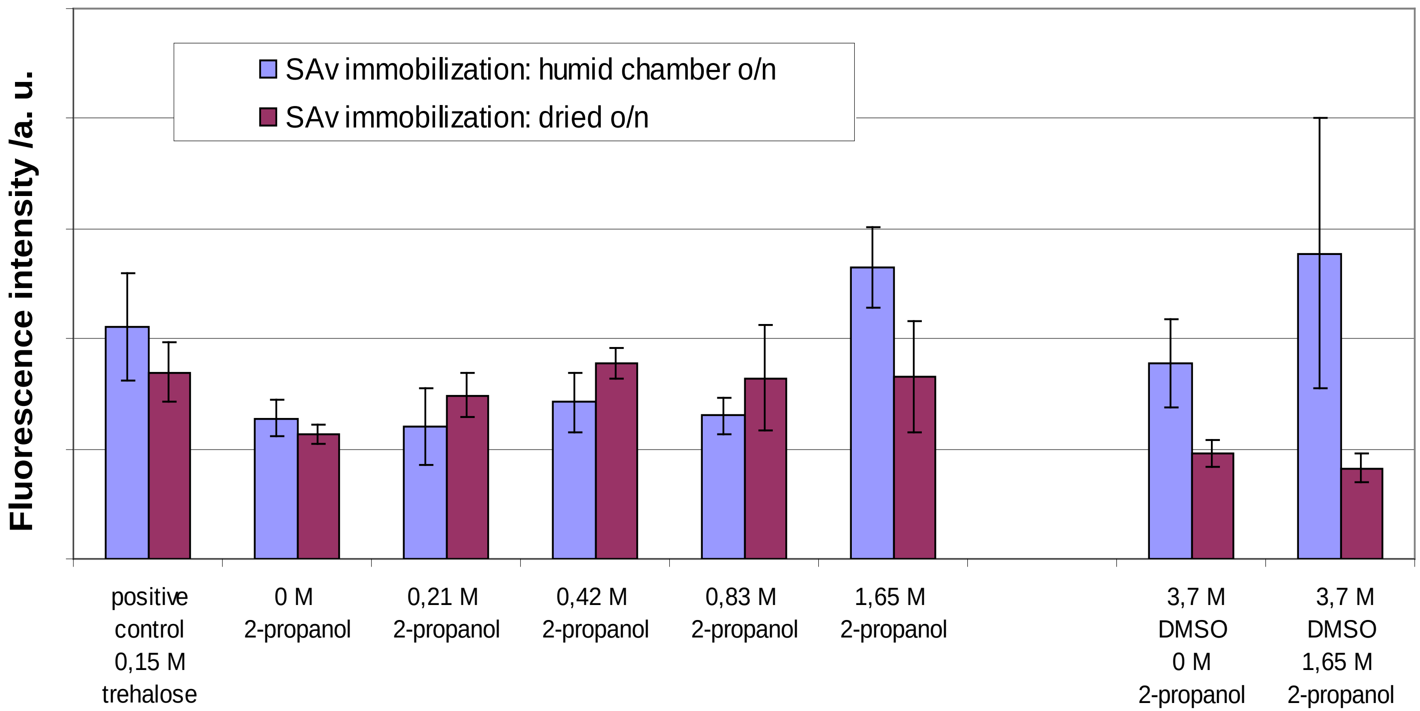
→ **4 M glycerol, 4 -5 M 2-propanol**

Protein compatibility of ink

Effect of **increasing 2-propanol concentration** on **biotin binding-capability of streptavidin**



Nexterion E®, Schott

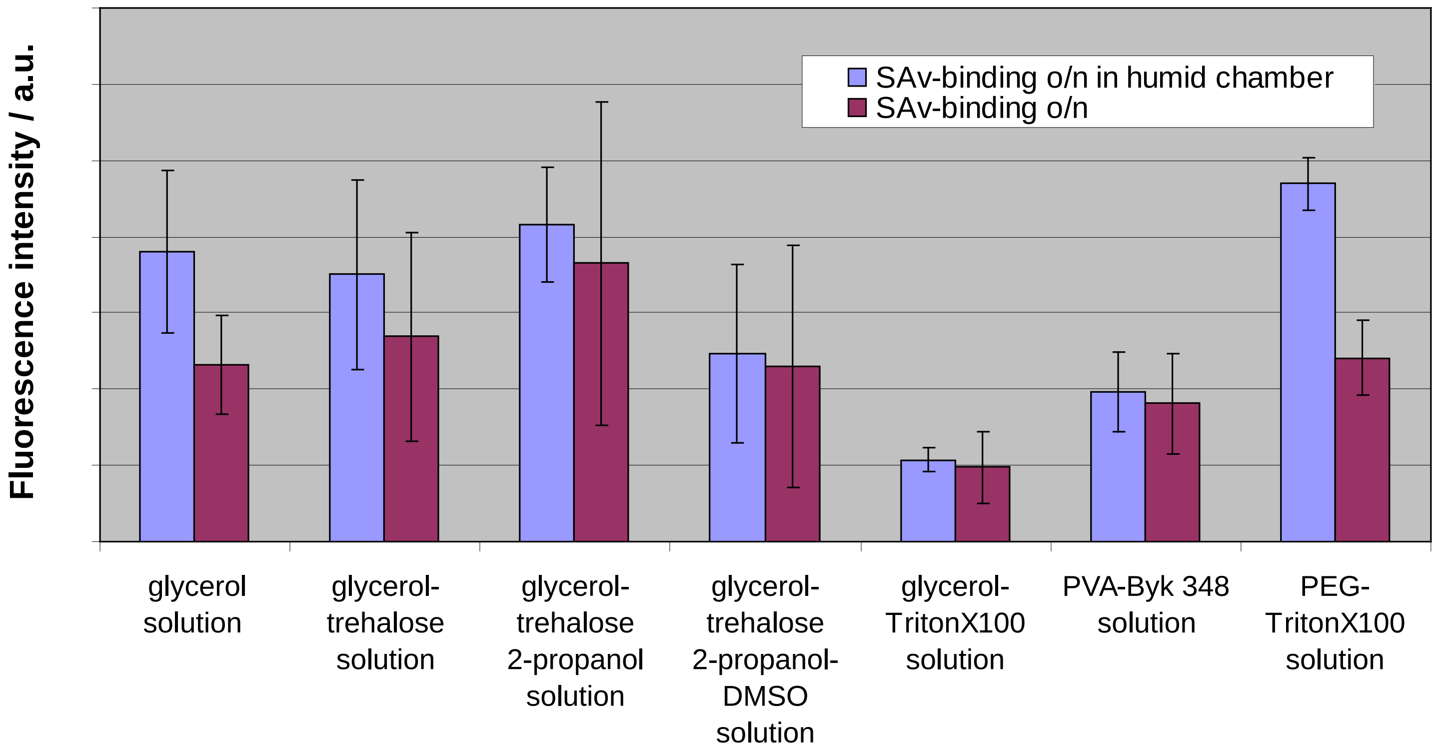


University of Stuttgart
Institute for Interfacial Engineering

Fraunhofer IGB

Protein compatibility of ink

Biotin binding-capability of streptavidin after deposition in **various ink-compositions**



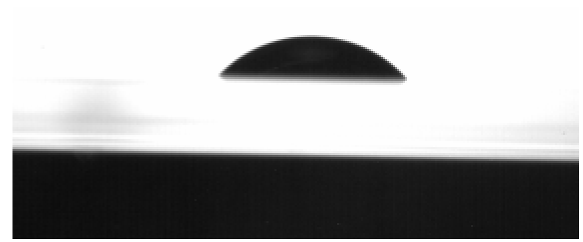
University of Stuttgart
Institute for Interfacial Engineering

Fraunhofer IGB

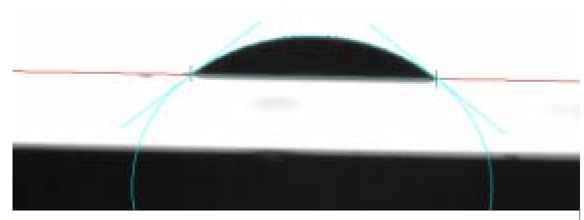
Substrate wetting: Impact of ink-composition

Nexterion® E surface (θ_{water} = 50°)

$\theta_{water/glycerol}$ = 52°



$\theta_{water/glycerol/DMSO}$ = 38°



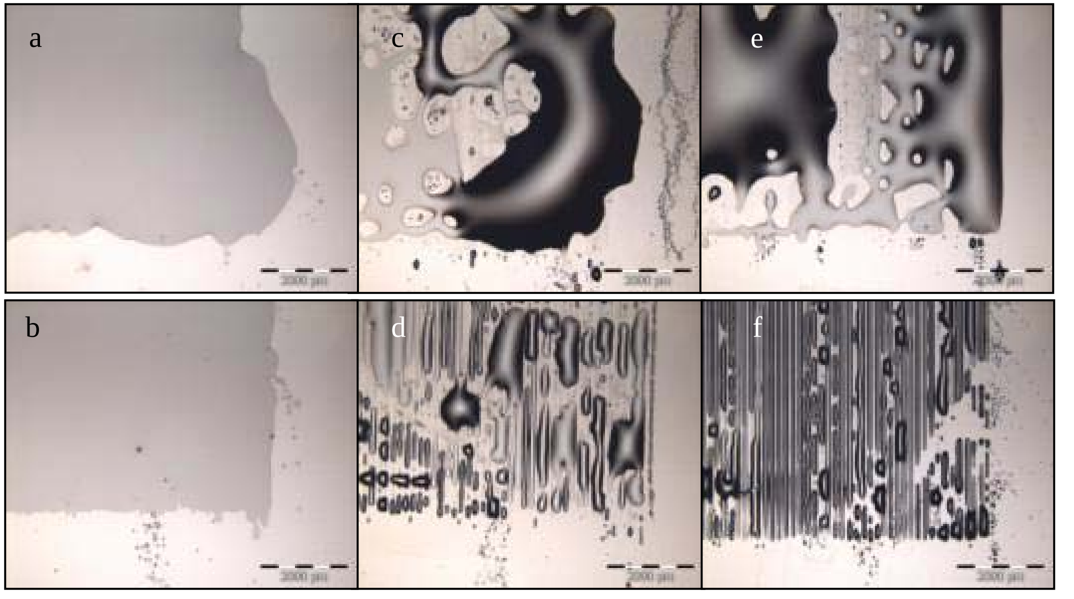
$\theta_{water/glycerol/DMSO/alcohol/additive}$ = 12°

Preparation and characterization of substrates

Ink: 5 M glycerol, 0,15 M trehalose, 3 M 2-propanol
Substrate: TiO_x coated glass slides

drop spacing 5 µm

drop spacing 10 µm



TiO_x coated glass cleaned | TiO_x coated glass polykation (PDADMAC) coated | epoxy-silan (GPTS) pre-treatment

Pattern generation:
→ **surface-ink interaction (contact-angle)** → **volume-deposition per area**

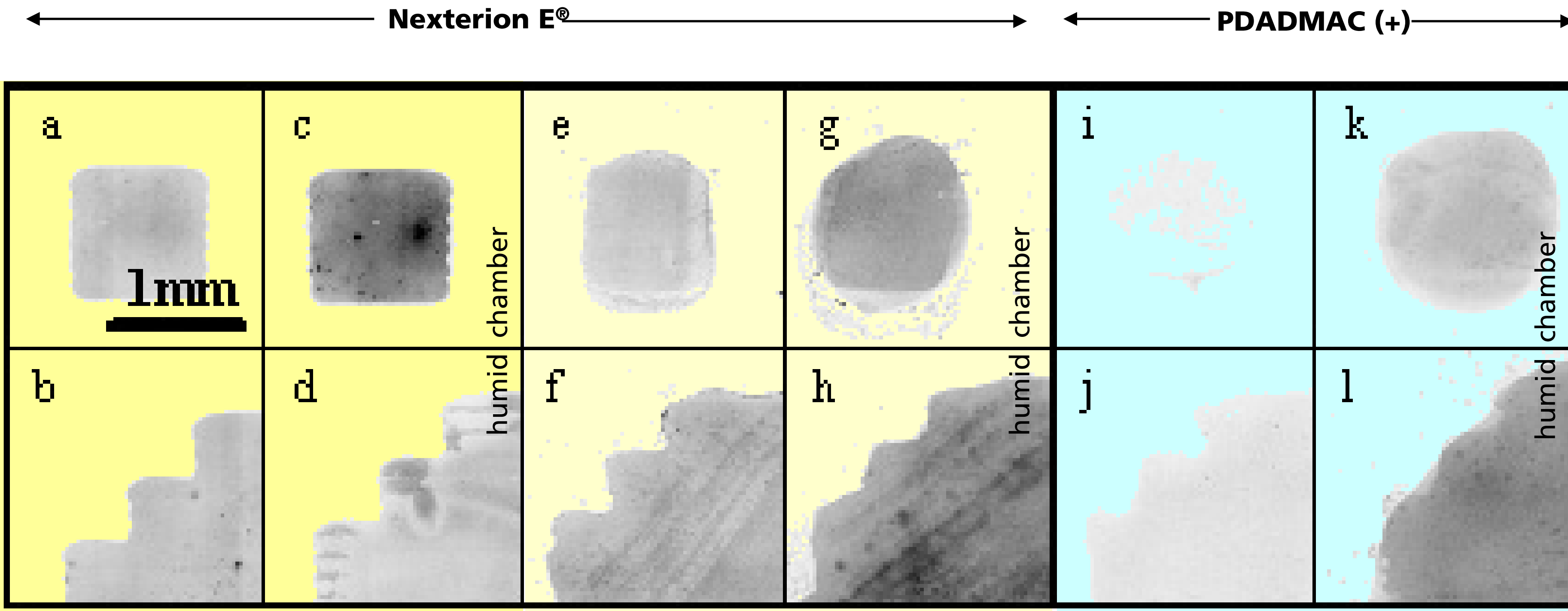
Preparation and characterization of substrates

Wetting behaviour

	ddH_2O	4 M glycerol, 150 mM trehalose, 3 M 2-propanol	4 M glycerol, 3 M DMSO, 150 mM trehalose, 3 M 2-propanol
interface	contact angle θ		
Nexterion E	53 ° ± 2 °	23 ° ± 3 ° **(+)**	20 ° ± 4 ° **(+)**
glass_ PDADMAC	17 ° ± 5 °	4 ° ± 6 ° **(+)**	14° ± 14 °
TiO_x_Hellmanex	21 ° ± 4 °	wetting **(+)**	wetting **(+)**
TiO_x_PDADMAC	28 ° ± 3 °	24 ° ± 5 ° **(-)**	25 ° ± 9 ° **(-)**
TiO_x_GPTS	63 ° ± 4 °	35 ° ± 6 ° **(-)**	36 ° ± 3 ° **(-)**

Film-formation: θ **« 25 °**

Inkjet printing



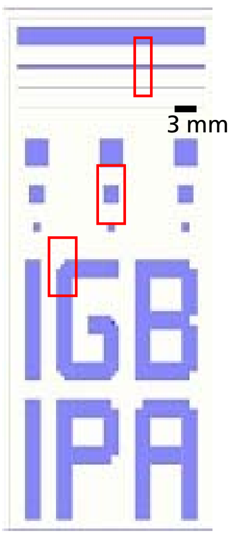
Glycerol/2-prop ink
- inclusive DMSO
η ~ 13,5 mPA s
σ ~ 35 mN/m

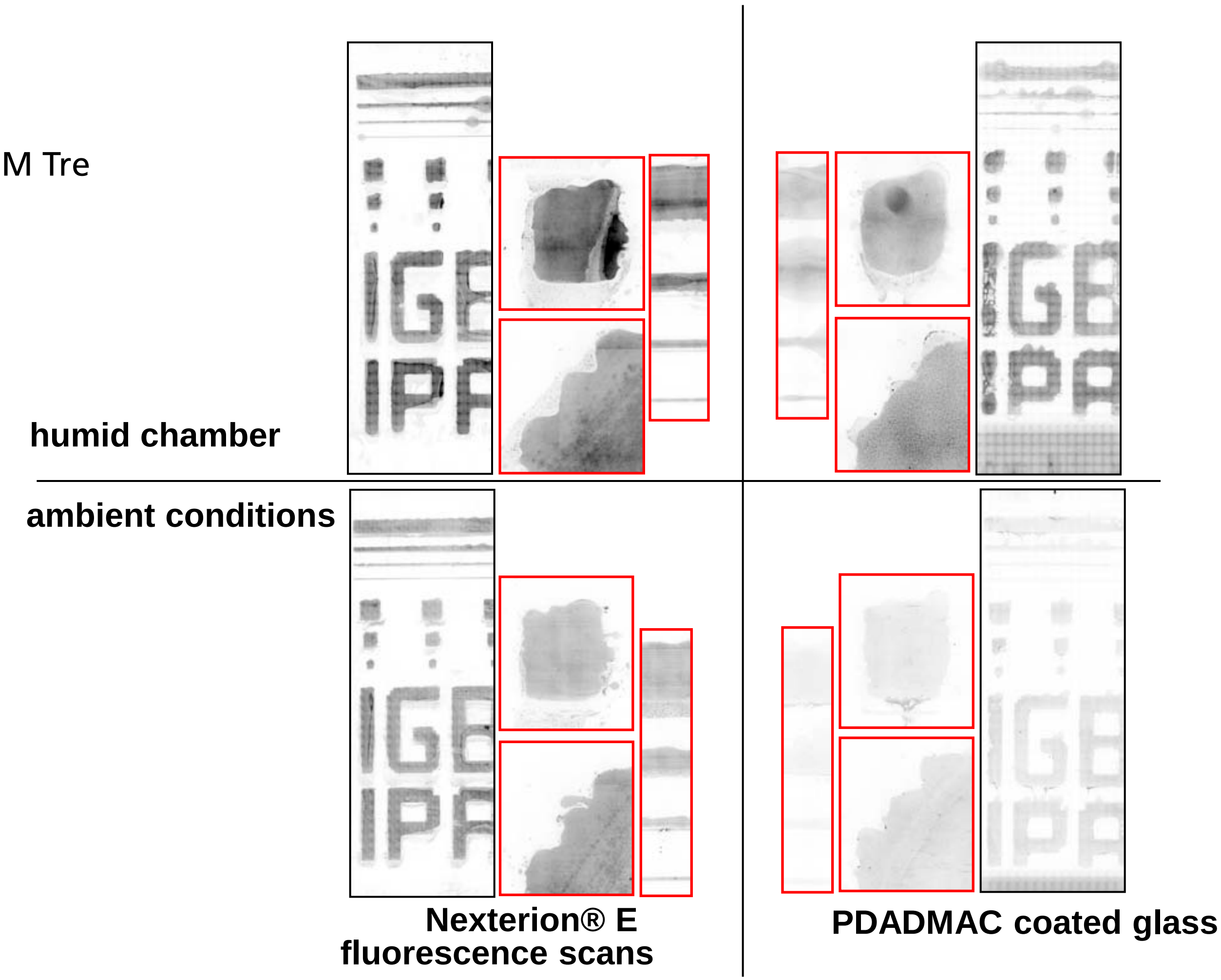
Glycerol/2-prop ink
- exclusive DMSO
η ~ 7,8 mPA s
σ ~ 31 mN/m

Glycerol/2-prop ink
- exclusive DMSO
η ~ 7,8 mPA s
σ ~ 31 mN/m

Inkjet printing of streptavidin

c_{SAv} = 660 µg/mL
4 M Gly, 2,7 M 2-Prop, 0,15 M Tre
Nexterion® E





Overview of the talk

- Demands for ink-jetting of biological probes

- Ink formulation & protein stability
- Substrate preparation

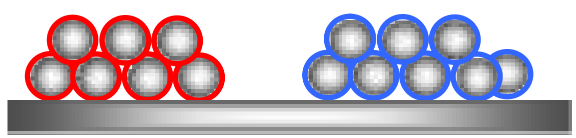
- (Bio)functional nanoparticles
- Printing
- Evaluation

NANOCYTES®-based Microarrays

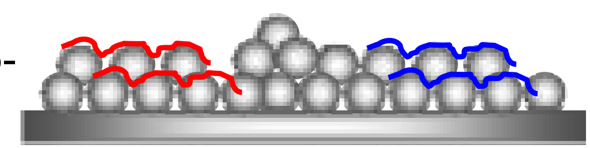
State of the art

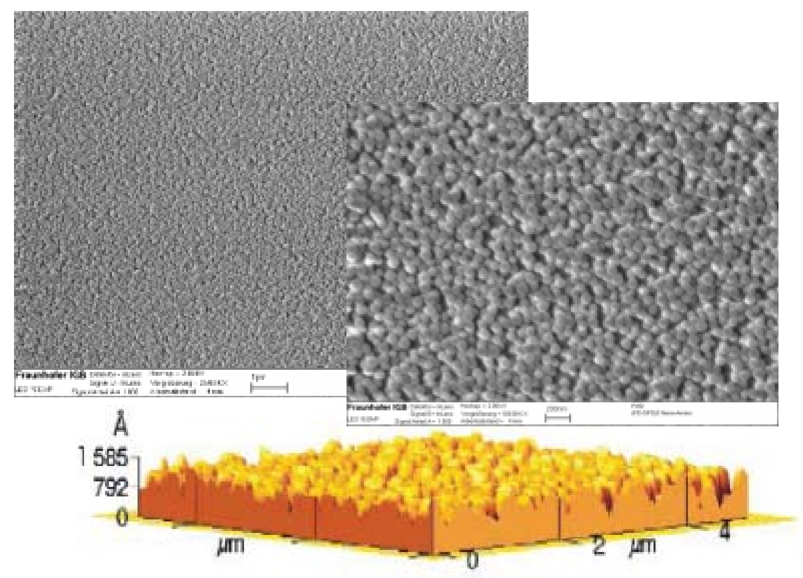
Surface-enlargement, flexible surface chemistry

(Bio-)functional nanoparticles



Functional nano-particle films

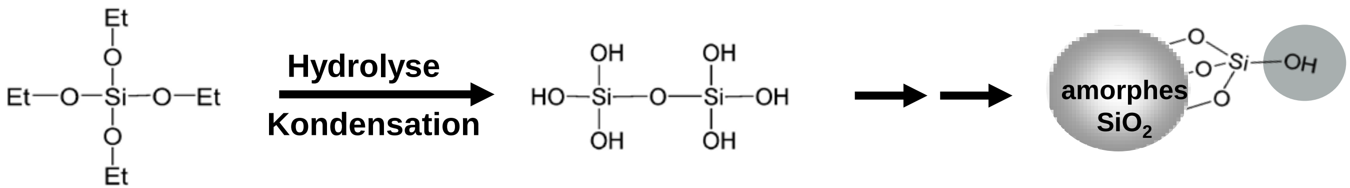




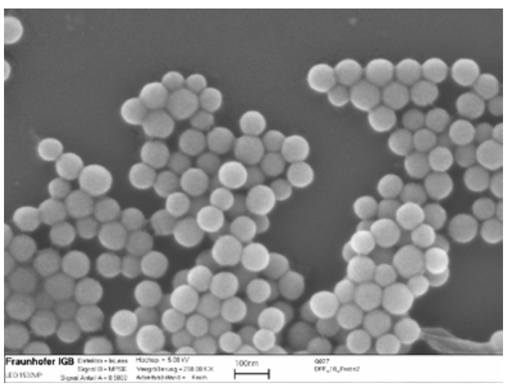
University of Stuttgart
Institute for Interfacial Engineering
Fraunhofer
IGB

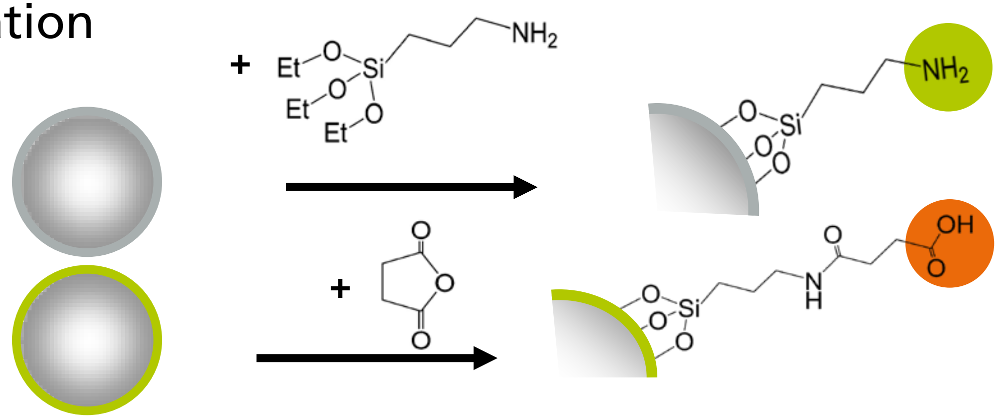
NANOCYTES®: Silica Cores and Functionalization

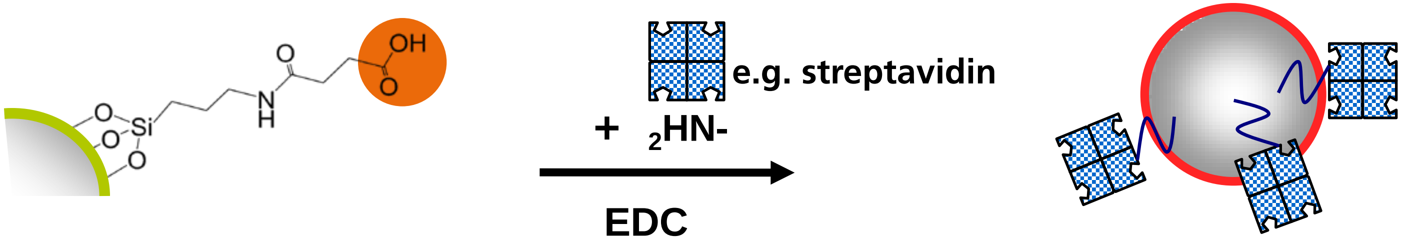
- Synthesis by Stöber



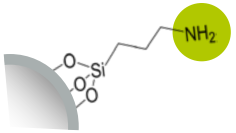
- Some functionalization



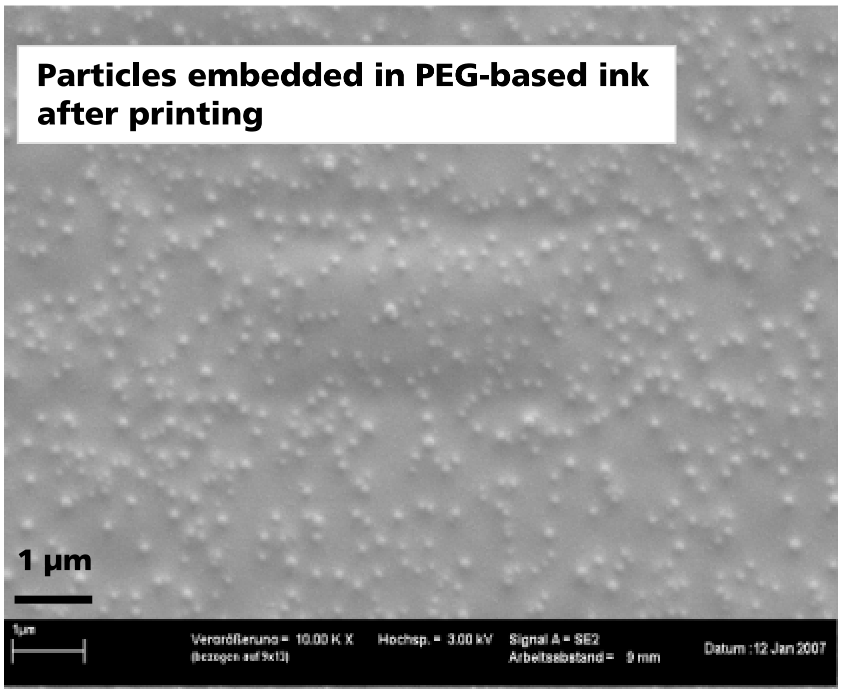


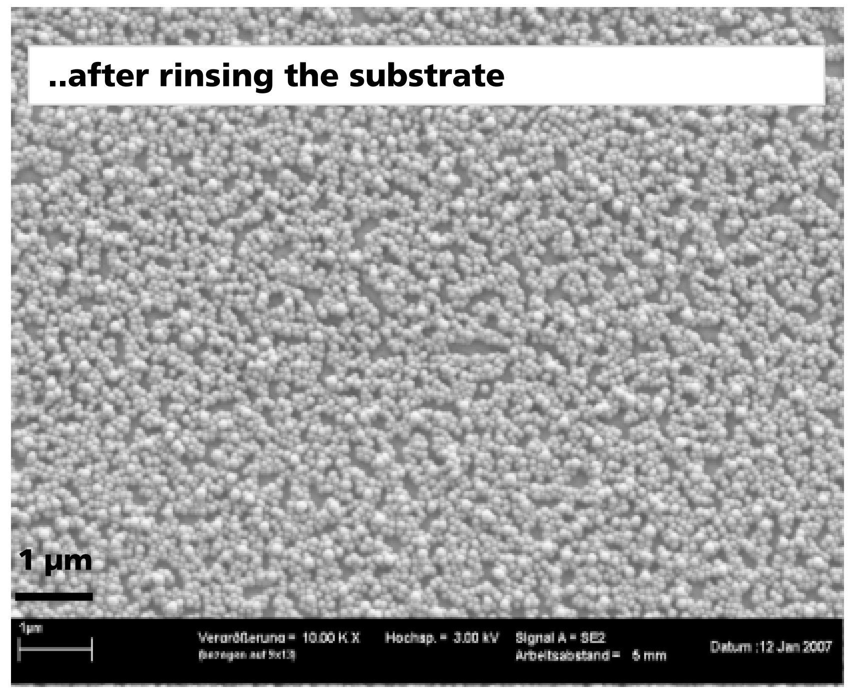


Inkjet printing of functional nanoparticles



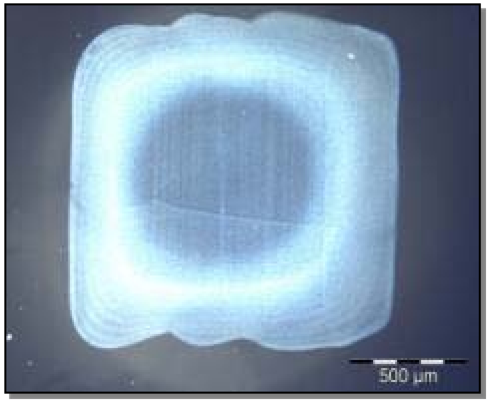
$NH_2 \leftrightarrow NH_3^+$ modified nanoparticles
Substrate: SPS (sodium poly(styrene sulfonate)) coated glass





SEM

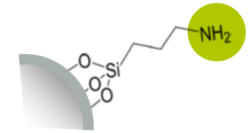
Generating homogeneous particle films

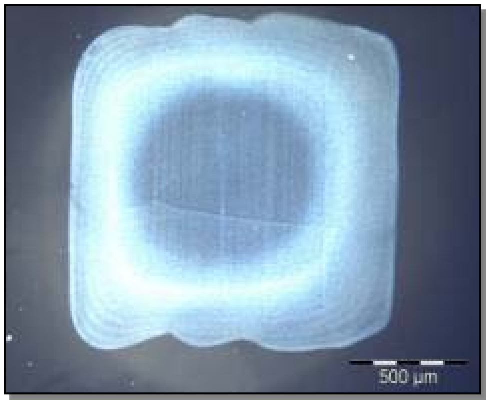


"coffee-ring-"effekt

LM (darkfield modus)

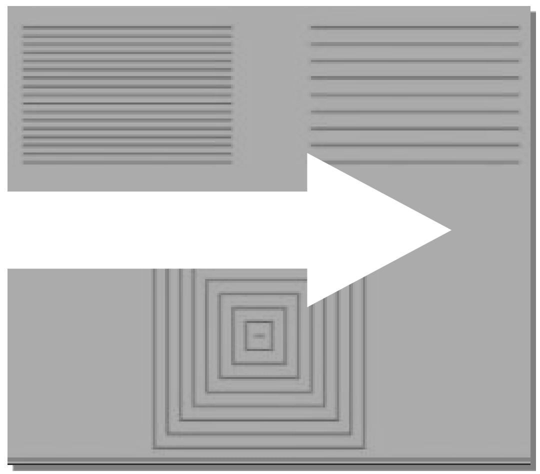
Generating homogeneous particle films

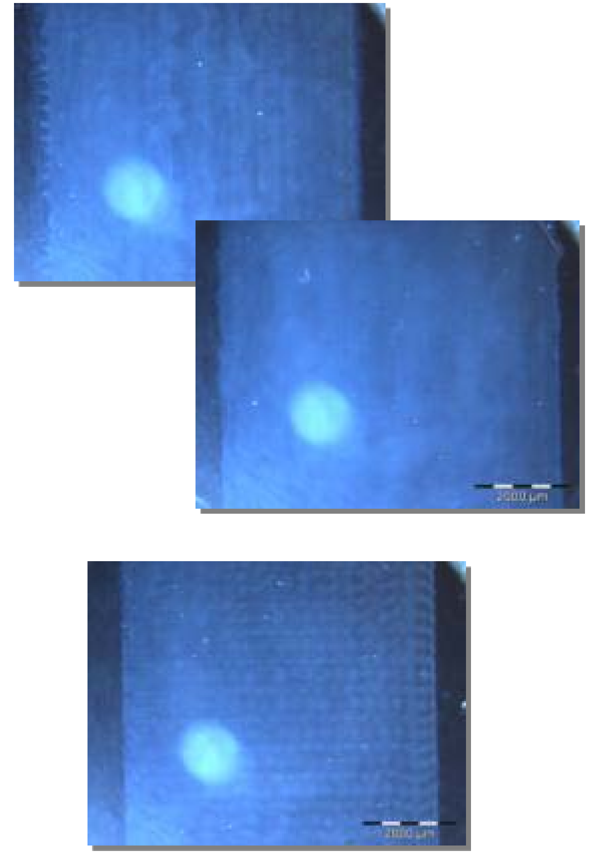




"coffee-ring-"effekt

LM (darkfield modus)





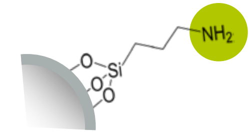
Overview of the talk

- Demands for ink-jetting of biological probes

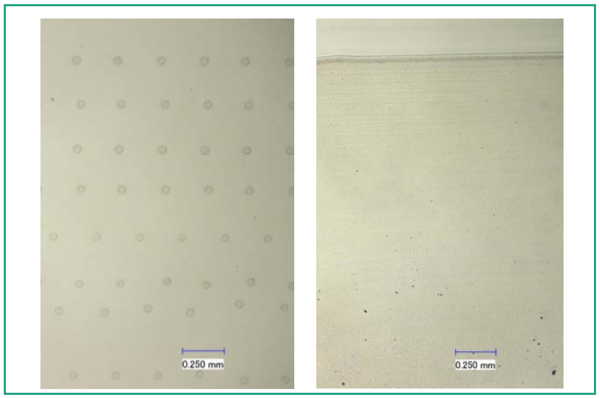
- Ink formulation & protein stability
- Substrate preparation

- (Bio)functional nanoparticles
- Printing
- Evaluation

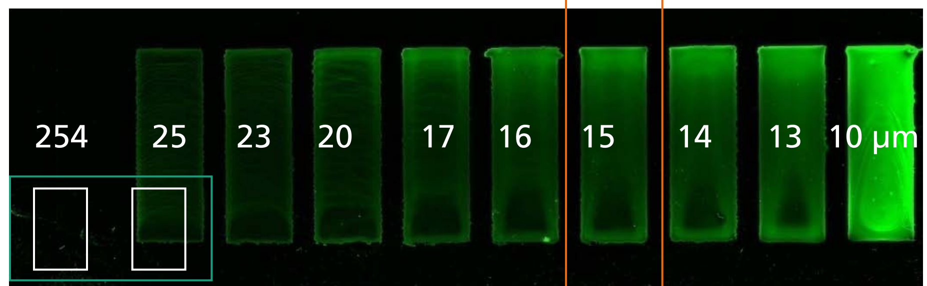
Inkjet printed nanoparticle-silane coatings



532 nm backround signal

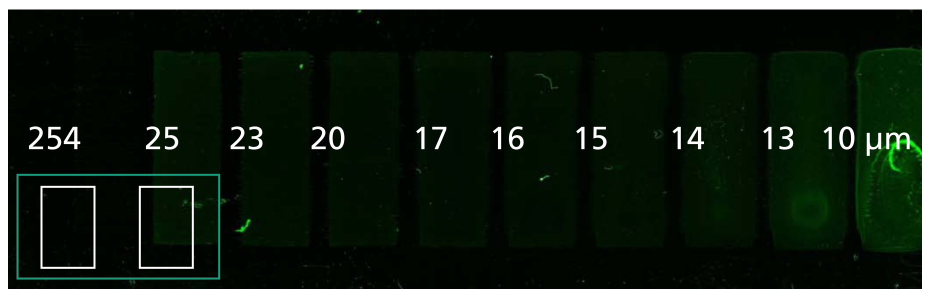


Silane + nanoparticles

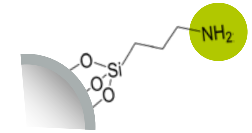


Filter: 532 nm
PMT 400

Pure silane



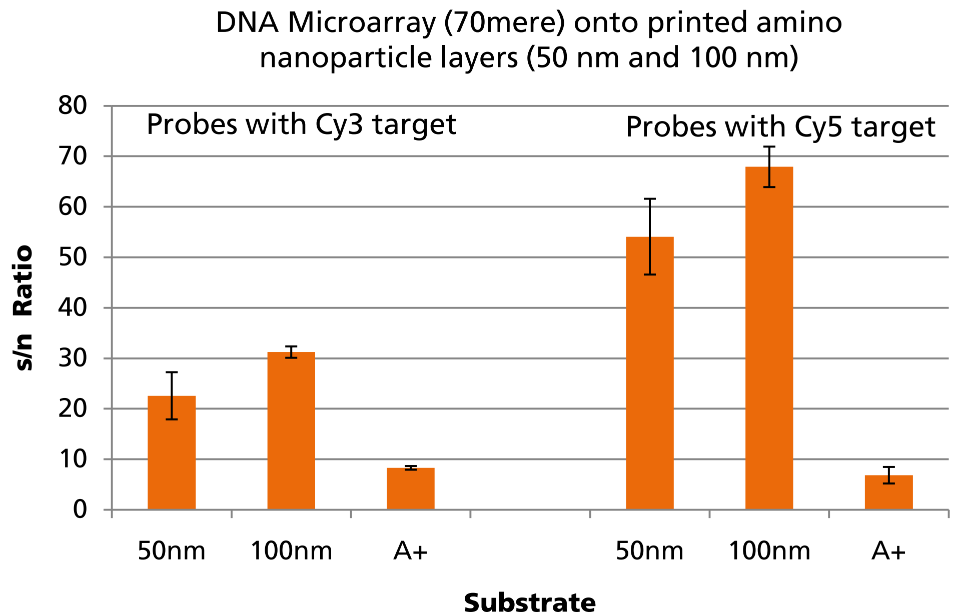
Variation of drop-spacing (= coating thickness)

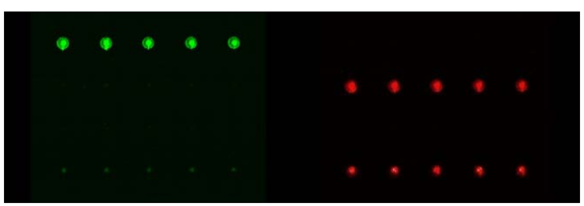


DNA Microarray onto printed particle layers

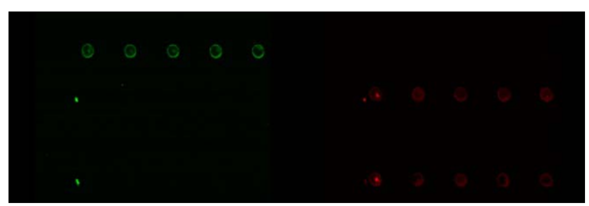
Signal to noise ratio

- Model DNA Microarray with 2 probes, one spotting- and negative control with specific targets at 66°C oN hybridization
- 100 nm und 50 nm nanoparticle layers
- Comparison to Schott Nexterion A+





Slide: 50 nm amino particle



Slide: Schott Nexterion A+

Scan with Axon Genepix 4300A
PMT300, 100% Laserpower

Conclusion

- **Ink formulation**
  - ✓ Inkjet compatible
  - ✓ Bio compatible (SAv)

- **Pattern generation**
  - ✓ Substrate preparation (θ « 25°)
  - ✓ Printing parameters
    (volume/area, sequential ink deposition)

- **Inkjet printing (bio)functional components**
  - ✓ Amino modified nanoparticle suspension
  - ✓ DNA array
  - ✓ Protein solution

Acknowlegdements

Money

BMBF

Fraunhofer Gesellschaft

Collaborations

Dr. Stefan Güttler (Fraunhofer IPA)

Andrzej Grzesiak (Fraunhofer IPA)

Markus Knaupp

Sandra Genov

Tobias Kulschewski

Alexander Baltz

Markus Bucher

(all University of Stuttgart)