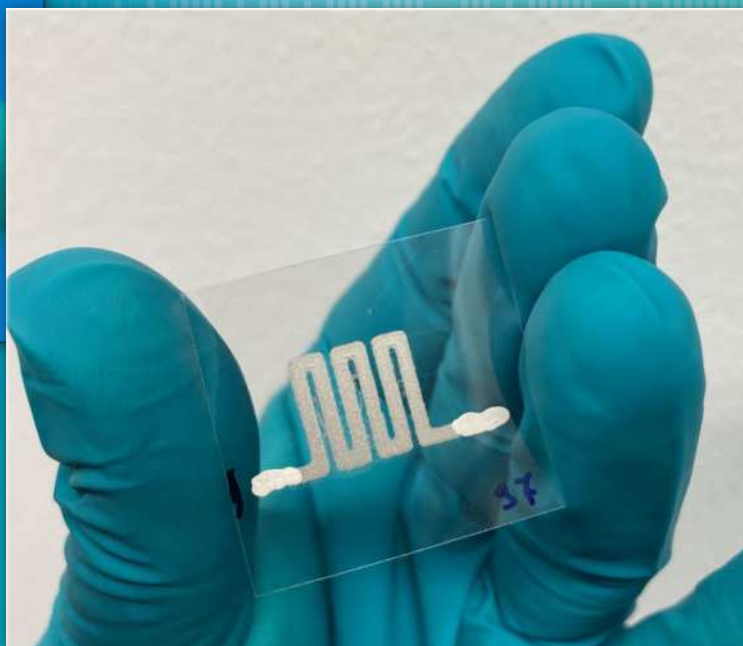
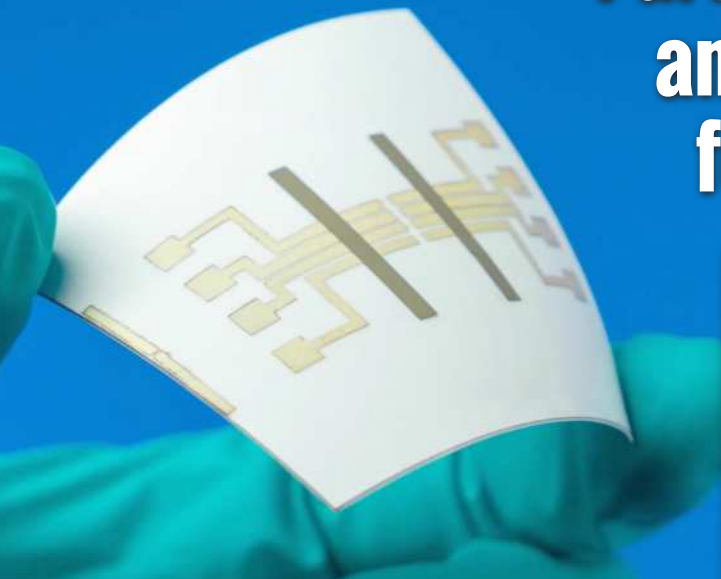


Synthesis of Magnetic Particles for Printable Inks and Pastes by Sputtering for Sensor Applications



**By Morris Ott¹, Thomas Preussner¹, Mykola Vinnichenko², Clemens Voigt², Sindy Mosch²,
Denys Makarov³, Eduardo Sergio Oliveros Mata³, Kerstin Täschner¹, Jörg Neidhardt¹**

¹Fraunhofer Institute for Organic Electronics, Electron Beam and
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Printed magnetoresistive sensors are paving the way for novel applications like contactless flexible electromagnetic switches and touchless human-machine interfaces. The reported sensors, which can be processed with industrial printing methods, are based on non-saturating large magnetoresistance materials like bismuth. However, due to their limited sensitivity in the low field range certain applications like smart textile technologies and safety wearables are still not accessible. To overcome these limitations, a scalable technological approach, called MAG4INK, will be presented for the preparation of printed flexible anisotropic magnetoresistive (AMR) sensors with a sensitivity in the low field range.

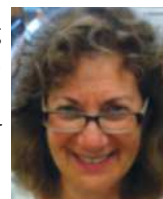
The combination of high quality PVD layers, utilizing the superior process control for the synthesis of ultrapure magneto resistive material with an adjustable morphology and structure, and advanced printing technologies is the core of the MAG4INK technology. Therefore, 100 nm thin magnetic films were coated on a sacrificial layer, released by a lift off process and processed via ultrasound milling to powder. By using this powder to formulate printable inks and pastes for printing in combination with innovative high-power diode laser array post-processing, it is currently possible to realize sensors with a magnetoresistive

effect of about 0.5 % in magnetic fields of ± 6 mT, with the goal of shifting the sensitivity into sub mT range.

The utilization of high rate tubular cathodes and high throughput in-line PVD equipment ensures yields of several grams of powder per day. The approaches for solving the challenges of manufacturing of iron (Fe) and permalloy (NiFe) thin films as well as the source technology for stable magnetic sputtering will be shown. The synthesis-structure-property relations of the resulting films will be presented.

Note from Managing Editor: We are delighted to share with the readers of the Bulletin some of the interesting Powerpoint Presentations from past TechCons. We hope you find them as interesting as we do.

Sue Taube/Managing Editor



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<https://www.svc.org>

DOI: <https://doi.org/10.14332/svc23.proc.0056>

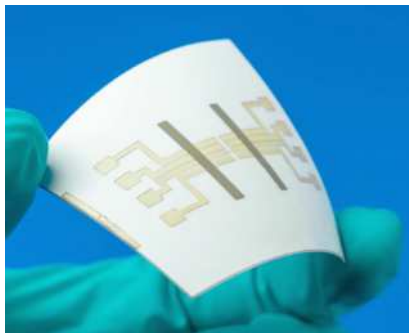


Synthesis of magnetic particles for printable inks and pastes by sputtering for sensor applications

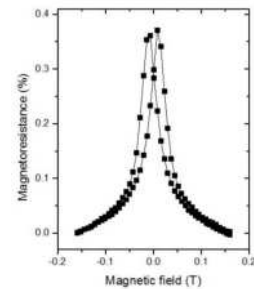
Morris Ott, Thomas Preussner, Mykola Vinnichenko, Clemens Voigt, Sindy Mosch, Denys Makarov, Eduardo Sergio Oliveros Mata, Kerstin Täschner, Jörg Neidhardt

11th May 2023 session thin film sensors SVC

Anisotropic Magnetoresistance as a sensor application



changing the direction of an external magnetic field, applied on an AMR sensor, leads to a change in sensors resistance



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Processing Chain for magnetic particles for an AMR sensor application



substrate preparation



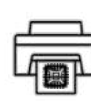
coating



powder production



production of inks & pastes



printing

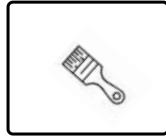


post print treatment

page 4



Processing Chain for magnetic particles for an AMR sensor application



substrate preparation

cleaning of the float glass
1200 x 600 mm²
+
coating with organic sacrificial layer

page 5



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Substrate preparation



Ultrasonic wet cleaning
using detergent



max. 600 x 1200 mm²



30 µm ... 6 mm



Water conductivity



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Fraunhofer
FEP

Processing Chain



coating



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Fraunhofer
FEP

Pilot coating equipment at FEP



10 process stations

- DC and PMS
- PVD and PECVD
- Planar and cylindrical

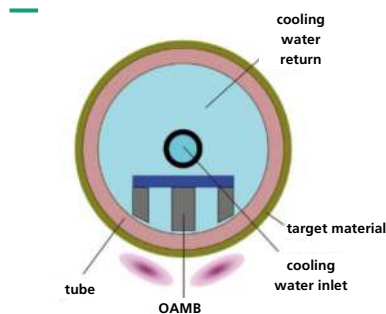
max. 600 x 1200 mm²

Room temperature
Pre- and Postannealing
FLA

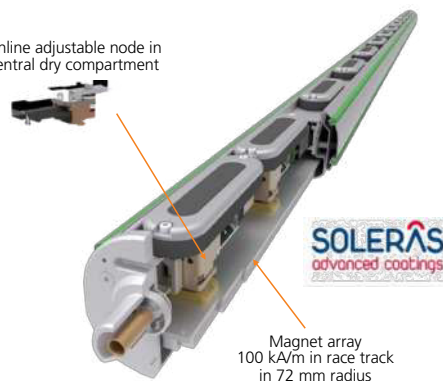
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Iron sputtering with an In-situ adjustable magnetbar



Online adjustable node in central dry compartment



e-REFLEX In-situ adjustable magnetbar

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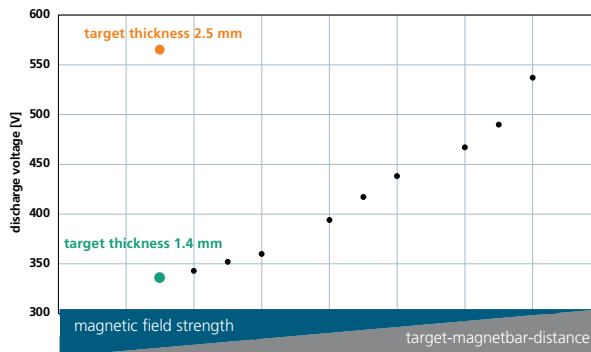


Iron sputtering with an In-situ adjustable magnetbar



$$R_{dyn} = 22 \dots 28 \frac{\text{nm} \cdot \text{m}}{\text{min}} \quad (P = 4 \frac{\text{kW}}{\text{m}})$$

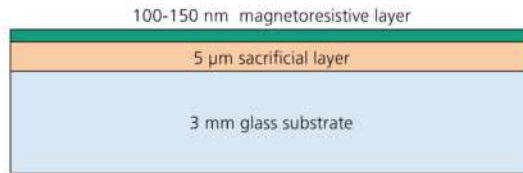
Targeted control of the discharge voltage and particle energy by adjusting the magnetic field



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Deposition of a magnetoresistive layer



AMR material	Ta-Fe-Ta
	$R_{\text{spec.}}$ [$\mu\Omega\text{cm}$]
bulk	10...15
coating	20...24

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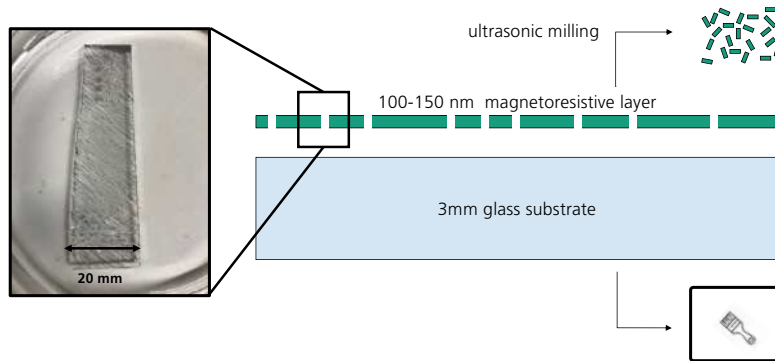
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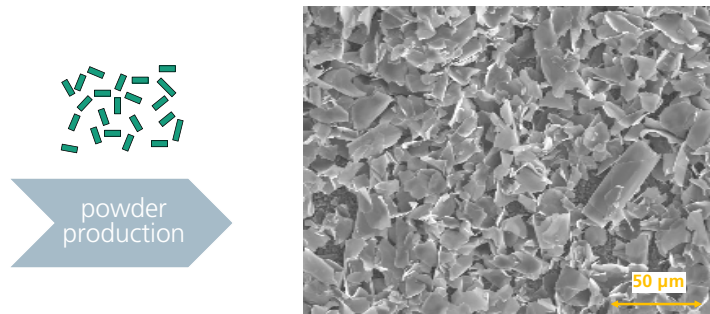
lift off process: removing the sacrificial layer



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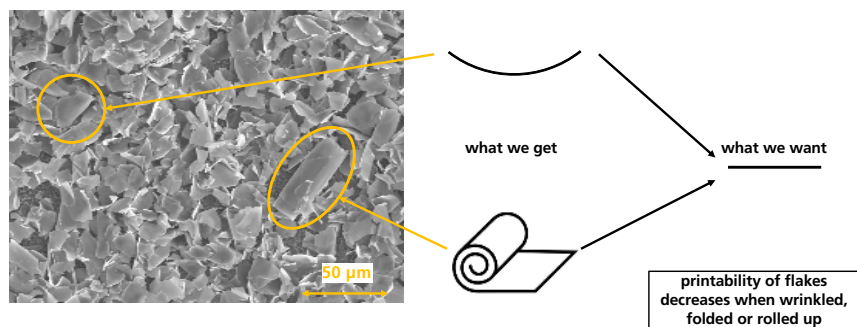
Thin film stress for lifted off particles



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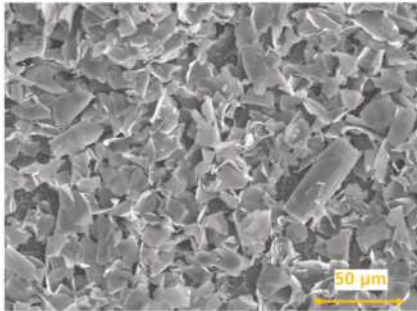
Thin film stress for lifted off flakes



page 14



Tensile film stress for lifted off flakes



No.	Duty cycle [µs]	Pressure [Pa]	Mechanical film stress [MPa]
1	10+3	0.6	+ 965
2	10+10	0.6	+ 949
3	10+10	0.15	+ 597

reducing tensile film stress by lowering depositing pressure

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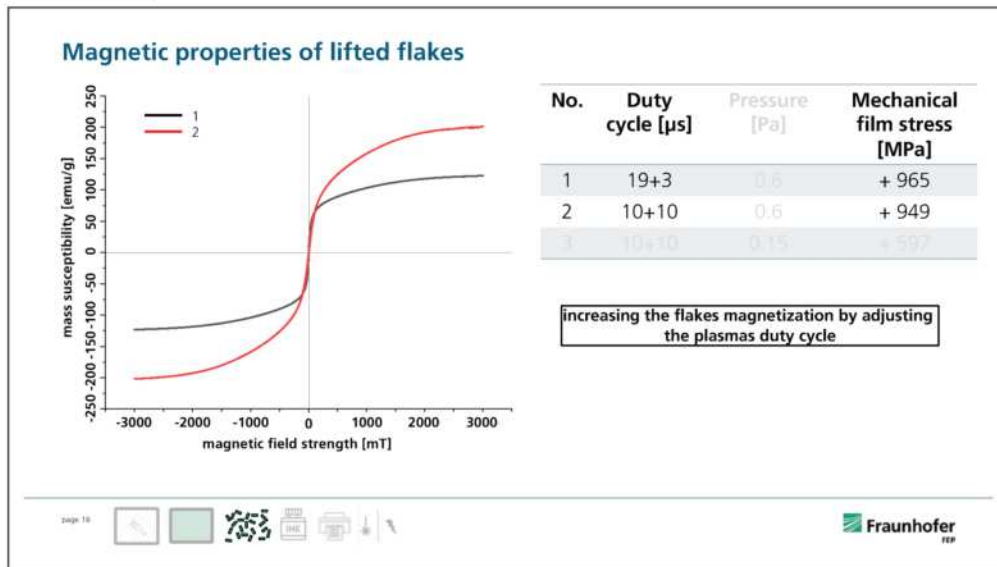
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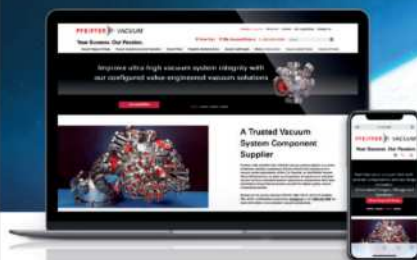
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Powder manufacturing productivity



one Run: 40 minutes with three substrates (400 x 400 mm²)

→ 0.4g AMR material

→ **4.7g per day**



23.4g per week

→ **22 weeks** for **500g** AMR material under laboratory conditions

→ enough material for **80 Mio. sensors**

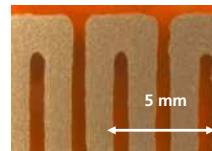
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from powder to sensor



- Choice of binding agent
- Control of ink and paste viscosity
- Particle shape

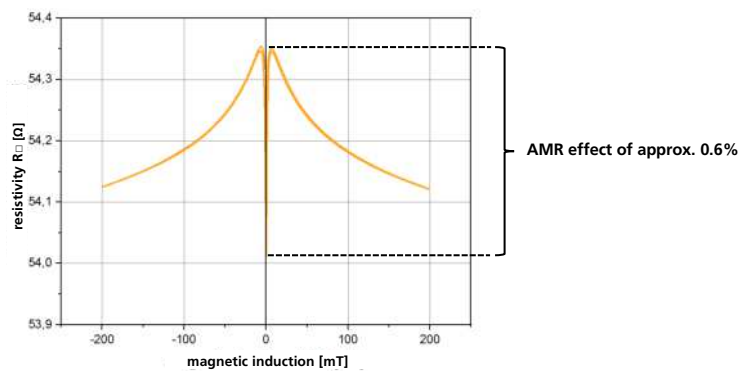


- Choice of printing technology
- Ratio particles/binder after printing
- Thickness and defects of printed structures

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AMR properties for Permalloy (NiFe) as ink material



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Flash Lamp Annealing equipment




arc length: 750 mm

0.9 – 9.5 ms

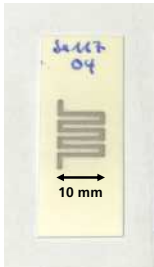
max. 60 J/cm²

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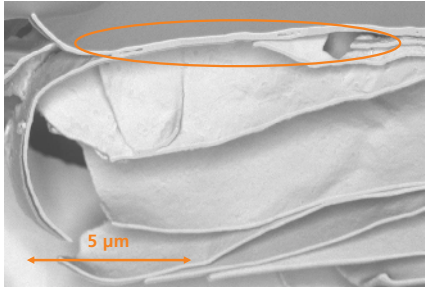

Flash Lamp Annealing of printed AMR sensors

Permalloy based sensor



R _□ [Ω]	
As printed	Post FLA
151	5.7



→ Increased conductivity by factor 30



sintered particles by flash lamp annealing

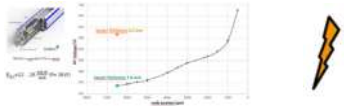
15 J/cm²

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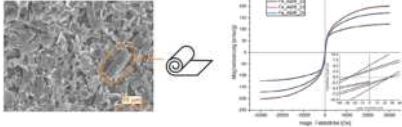



take home notes

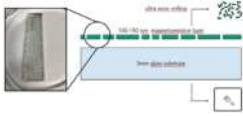
large area inline coating of magnetic materials



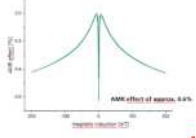
targeted adjustment of layer and particle properties




production of particles of any sputterable material



building an AMR sensor out of sputtered particles



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contact

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Essential results were obtained in the public project „MAG4INK“ with support code 03VP09093, funded by BMBF.



About the Author: Morris Ott



Morris Ott studied material science at the Technical University in Ilmenau, Germany with specialization to thin film technologies. In 2019 he graduated in the topic of large area, rf-sputtered ITO. Since then, he works as process engineer and project manager at the Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology FEP in Dresden. His work is devoted to applied research in fields of thin films, physical vapor deposition, plasma and vacuum technology as well as Flash Lamp Annealing.