

# Flexible Magnetic Field Sensors

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Europa fördert Sachsen.

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Europäischer Fonds für  
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Diese Maßnahme wird mitfinanziert  
durch Steuermittel auf der Grundlage des  
vom Sächsischen Landtag beschlossenen  
Haushaltes.



# Applications of magnetism and magnetic materials

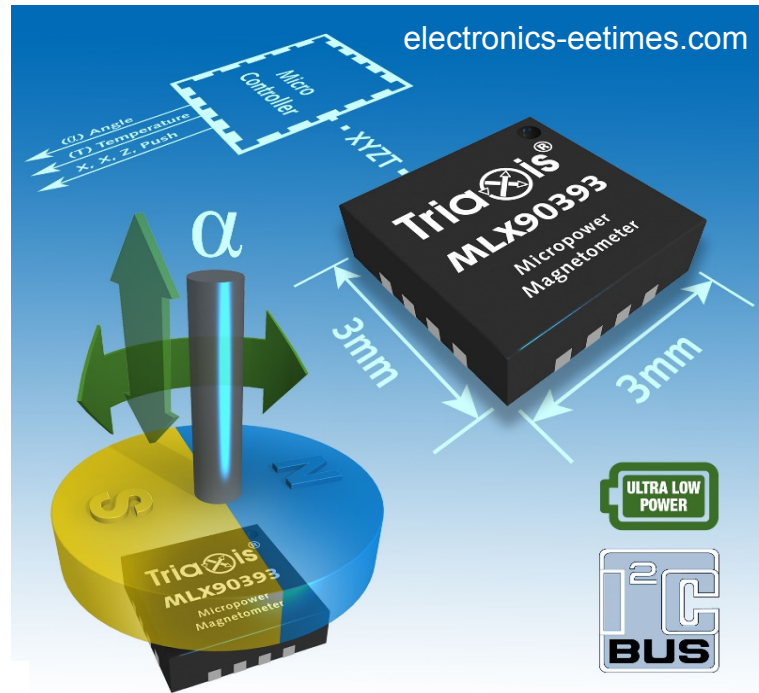


walkinginsunlight.com

Magnetic field sensors are used to monitor any type of motion



de.wikipedia.org



sierracomponent.com



www.reed-rex.com

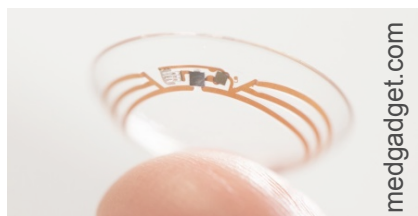
- Displacement
- Proximity sensing
- Rotation
- Vibration



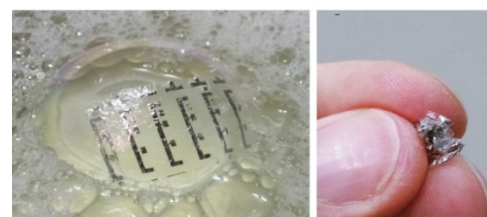
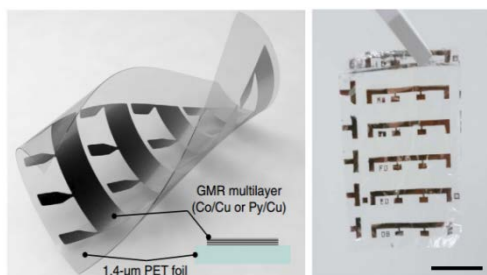
tophdings.com

# Family of flexible electronics

## Healthcare electronics

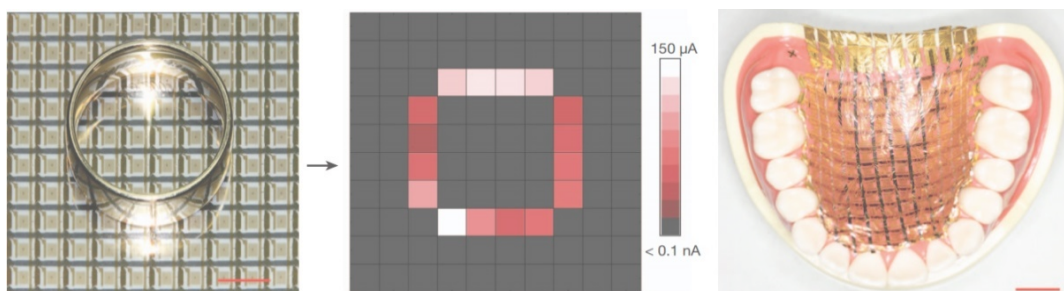


## Magnetoelectronics



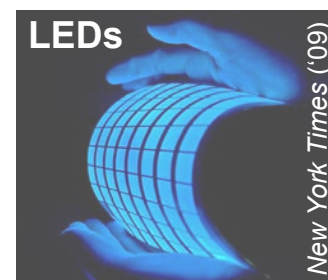
M. Melzer, DM et al., Nat. Commun. 6, 7080, 2015

## Tactile piezo - electronics

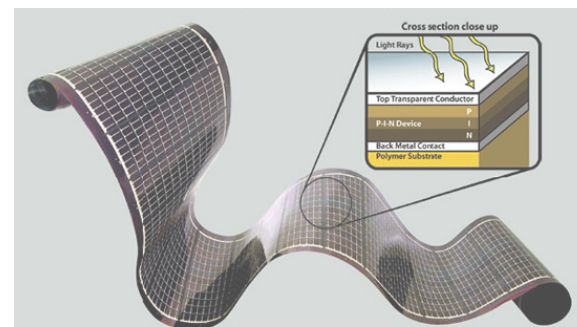


M. Kaltenbrunner et al., Nature 499, 2013

## Consumer electronics



## Solar cells



PowerFilm Solar (2010)

Extended range of applications

Smart skins for...



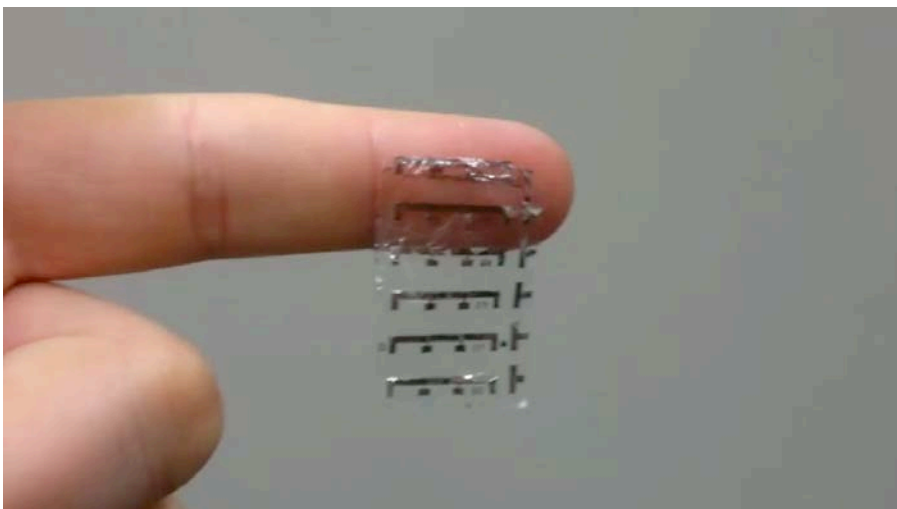
augmented reality



virtual reality

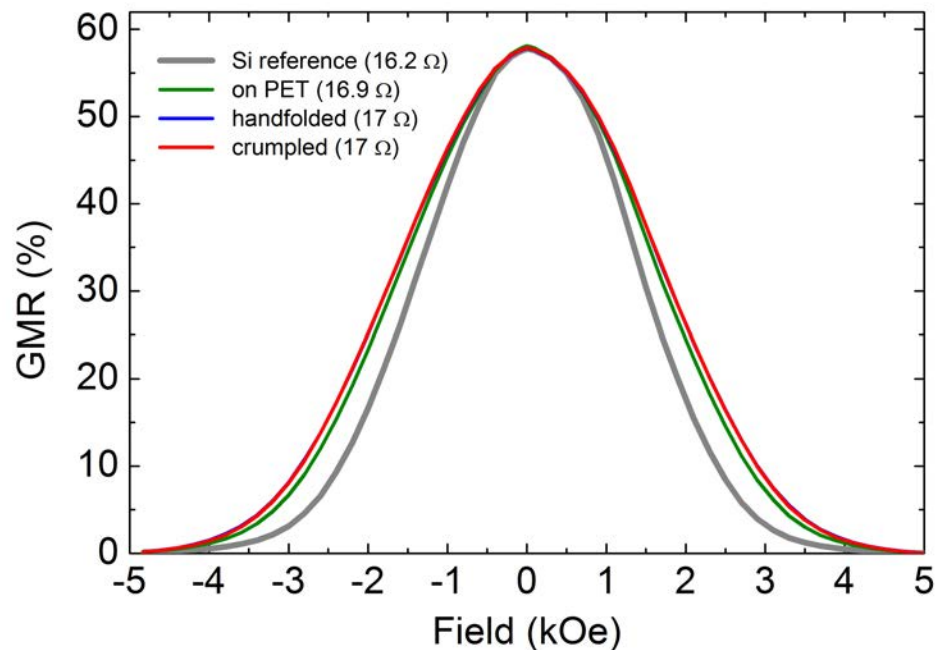


... Nature Electronics (2018) & Science Advances (2018) & Nature Communications (2019) & Advanced Materials (2021)...



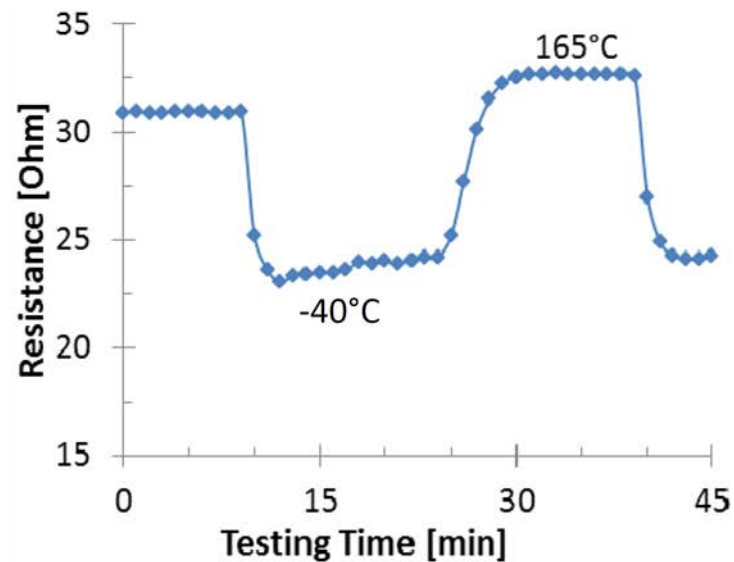
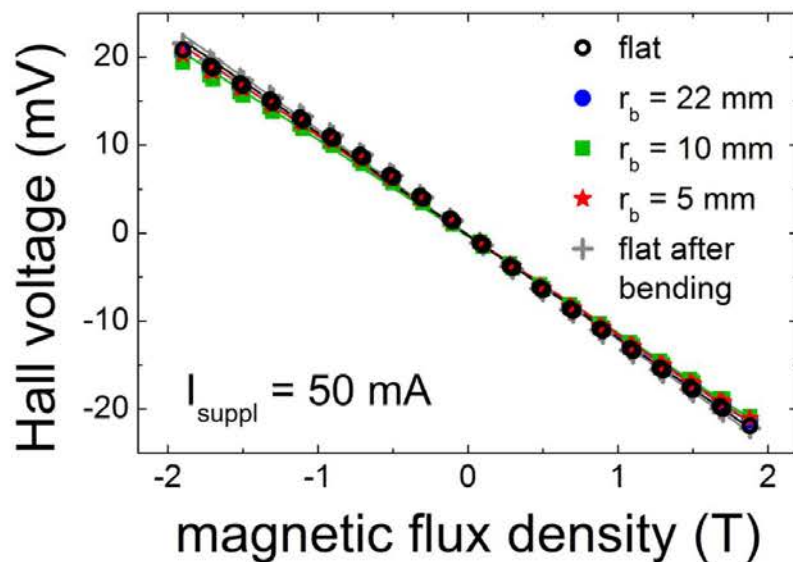
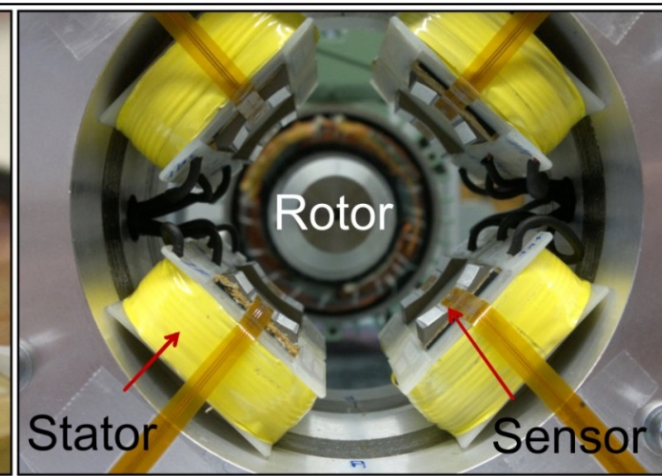
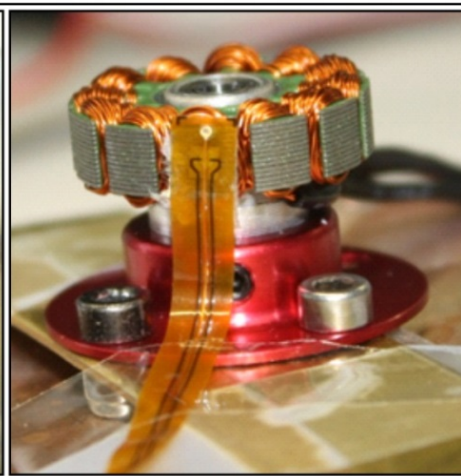
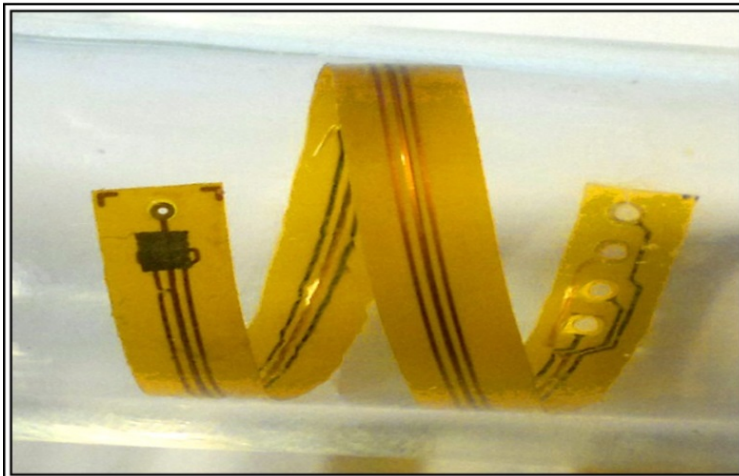
Michael Melzer, DM et al., *Nature Commun.* **6**, 6080 (2015)

Sensors on 1- $\mu\text{m}$ -thin polymeric foils (PET, PI...)



# Flexible and ultrathin Hall effect sensors

## Ultra-thin flexible Hall sensor    Electrical motor    Magnetic bearing system



D. Ernst, DM et al., *IEEE Proceedings of the 37<sup>th</sup> International Spring Seminar on Electronics Technology*, pp. 125-129 (2014)

I. J. Mönch, DM et al., *IEEE Trans. Magn.* **51**, 4004004 (2015)

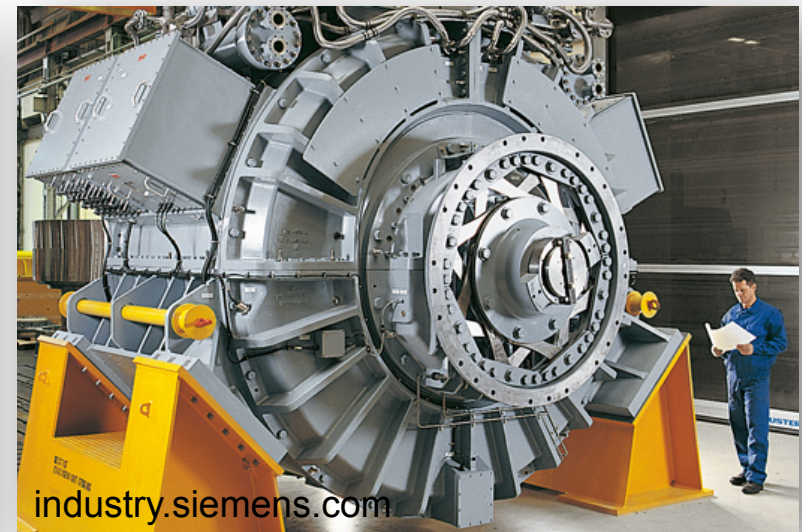
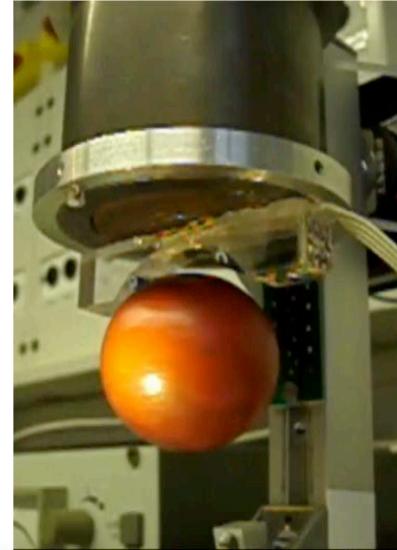
# Monitoring eMotors

I. Mönch, DM et al., *IEEE Trans. Magn.* (2015)

Integrated magnetic field sensor offers:

- 3D magnetic field profile of eMotor
- Optimization of the eMotor performance
- Angle positioning in rotary motors
- Feedback system for the eMotor

Electromobility (eCar / eBike)



buildaroo.com

industry.siemens.com

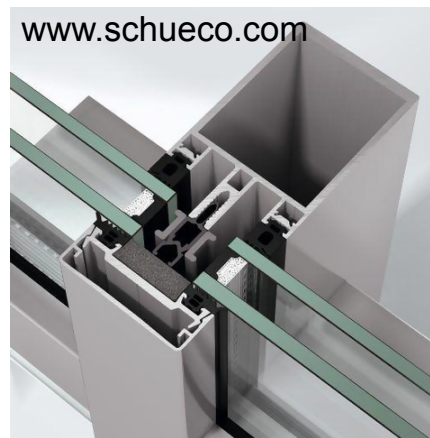
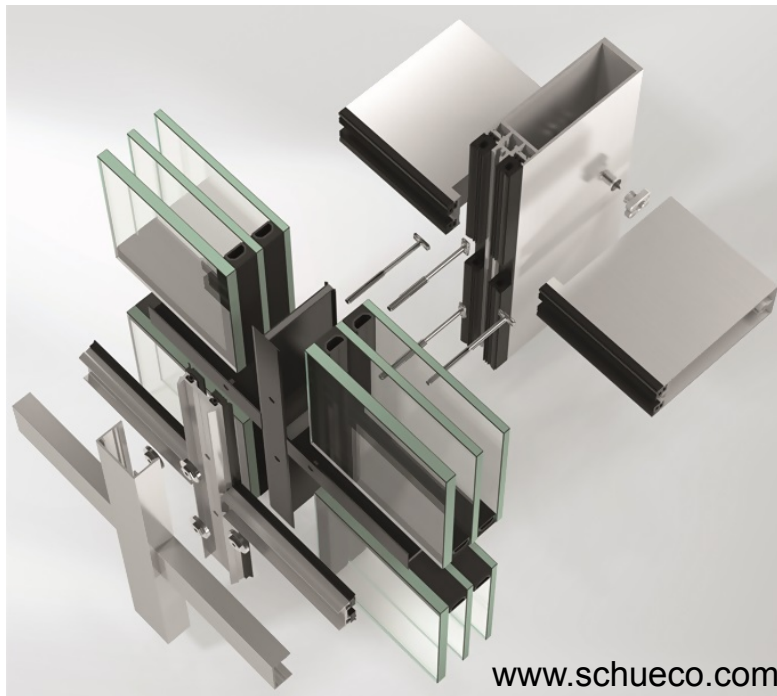


Member of the Helmholtz Association

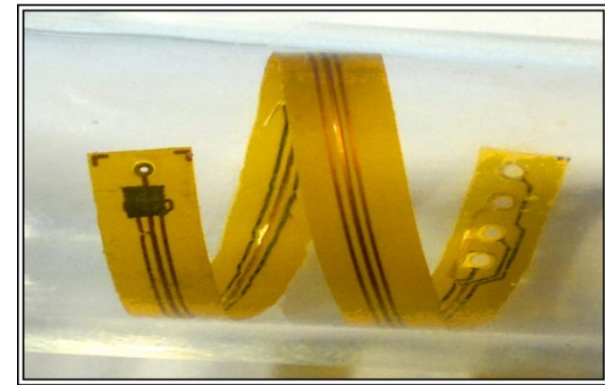
# Flexible sensors



- ✓ Magnetic field sensors to monitor the firm attachment of panels: lower maintenance costs
- ✓ Contactless switches: Enhanced safety compared to REED switches



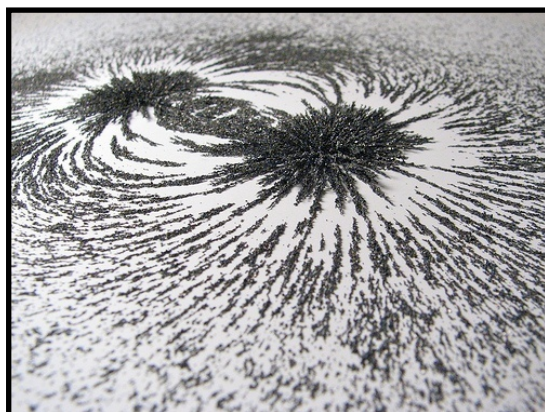
## Ultra-thin flexible Hall sensor



Use of flexible magnetic field sensors and flexible magnets to detect the distance between panels

# Printable magnetic field sensors

## Magnetic powder



- Sensitivity
- Ambient conditions

## Binder solution



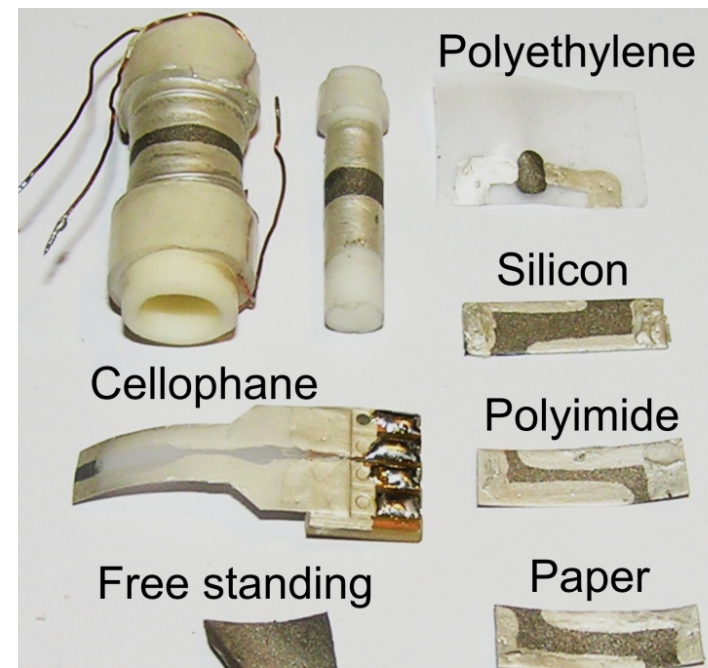
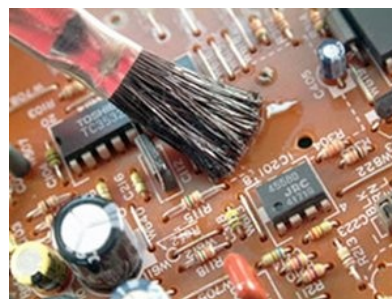
## Inks



## Pastes



## Paints



Patent: DE 10 2011 077 907.8.

Patent: US 13/528,076

Patent application: DE 10 2019 211 970.0

*Adv. Mater.* **24**, 4518 (2012)

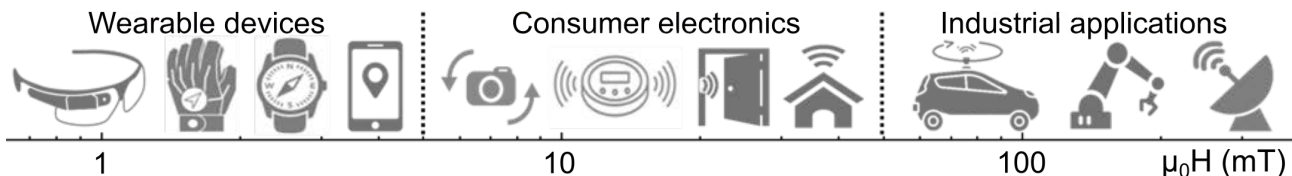
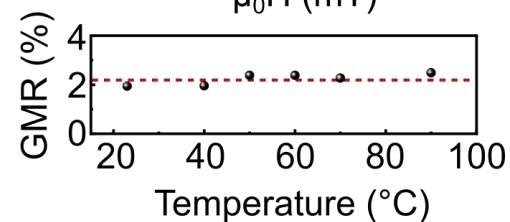
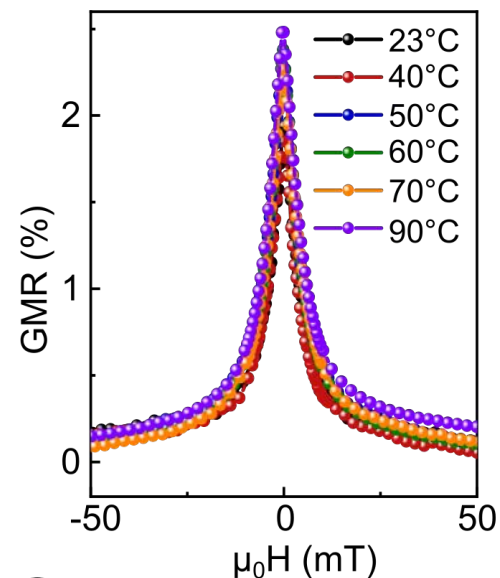
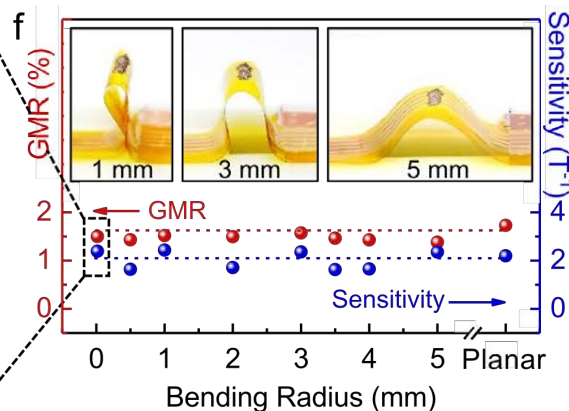
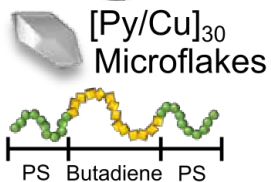
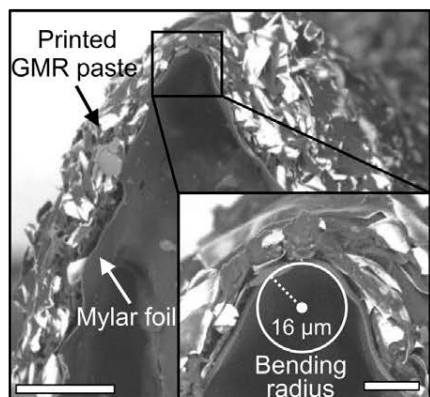
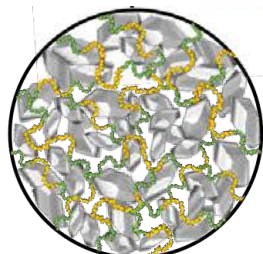
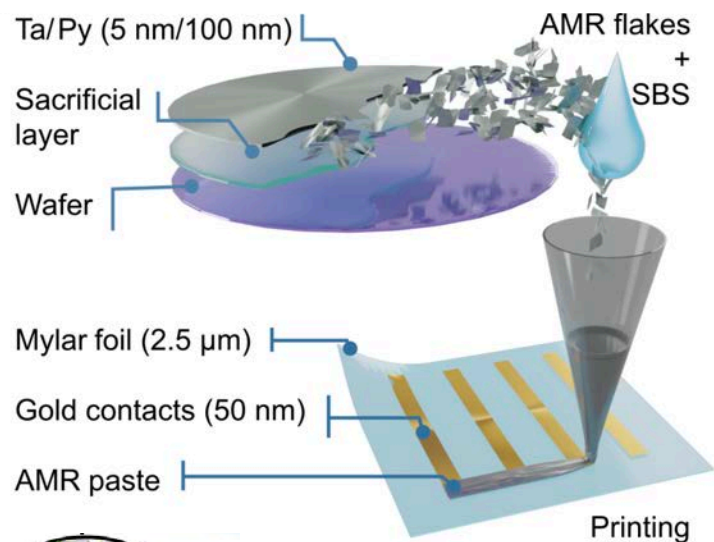
*Adv. Mater.* **27**, 880 (2015)

*Appl. Phys. A* **127**, 280 (2021)

*Adv. Mater.* **33**, 2005521 (2021)



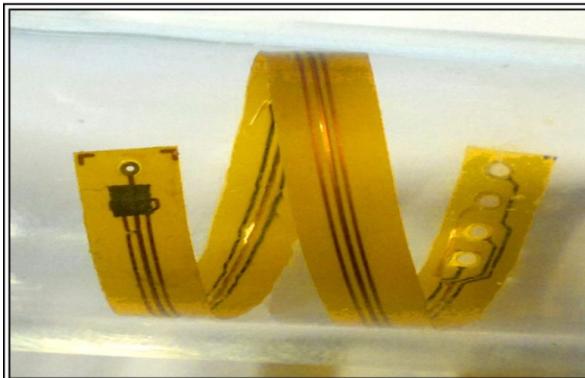
# Printable magnetic field sensors



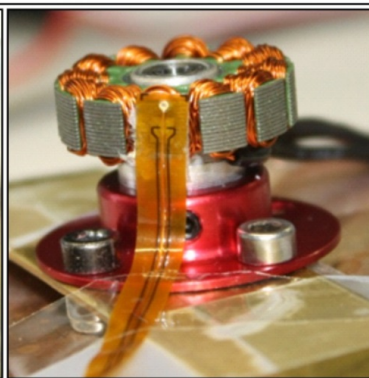
*Adv. Mater.* **33**, 2005521 (2021) & *Appl. Phys. A* **127**, 280 (2021) | Cooperation: FhG-IKTS & FhG-IWS & FhG-FEP  
 Patent: DE 10 2011 077 907.8. & US 13/528,076 & DE 10 2019 211 970.0

# Smart magnetic field sensor technologies

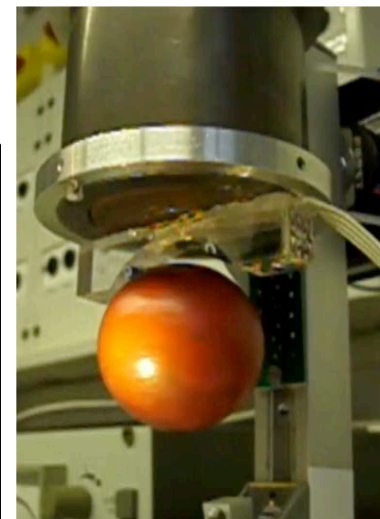
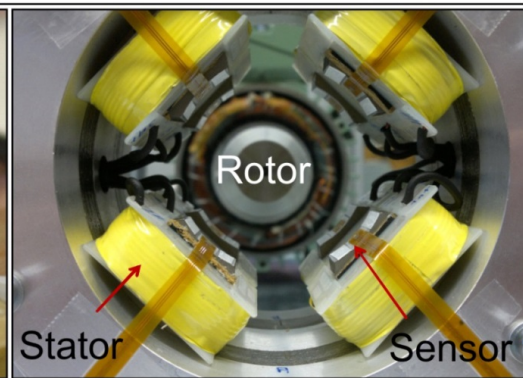
Ultra-thin flexible Hall sensor



Electrical motor



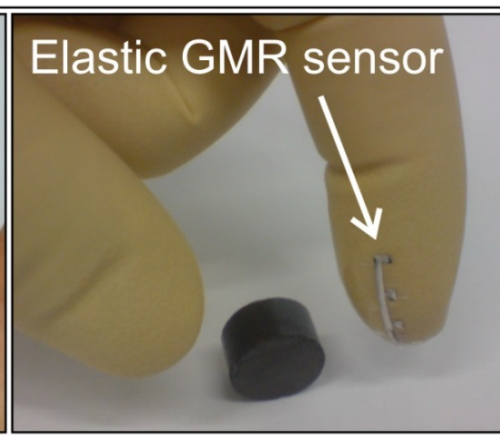
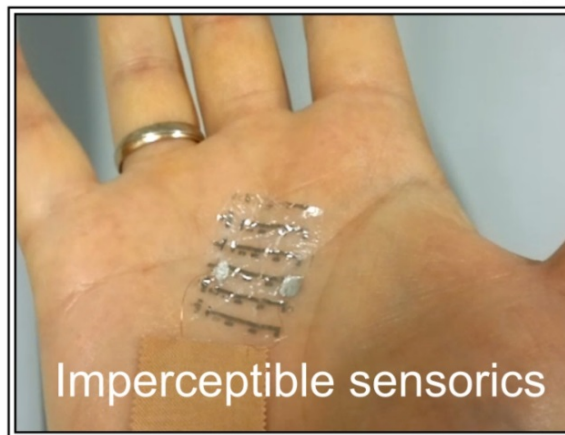
Magnetic bearing system



Printable magnetic sensorics



Stretchable magnetoelectronics



*Adv. Mater.* **33**, 2005521 (2021)  
*Adv. Mater.* **27**, 880 (2015)  
*ChemPhysChem* **14**, 1771 (2013)  
*Adv. Mater.* **24**, 4518 (2012)  
Patent: DE 10 2011 077 907.8

*Nature Commun.* **6**, 6080 (2015)  
*Adv. Mater.* **27**, 1333 (2015)  
*Adv. Mater.* **27**, 1274 (2015)  
*Nano Letters* **11**, 2522 (2011)  
Patent: DE 10 2019 211 970.0

*Adv. Mater. & Adv. Funct. Mater.* (2021)  
*Nature Commun.* **10**, 4405 (2019)  
*Nature Electronics* **1**, 589 (2018)  
*Science Adv.* **4**, eaao2623 (2018)  
Patent: US 13/528,076

Thank you for your attention