Superparamagnetic nanoparticles for Faraday rotation

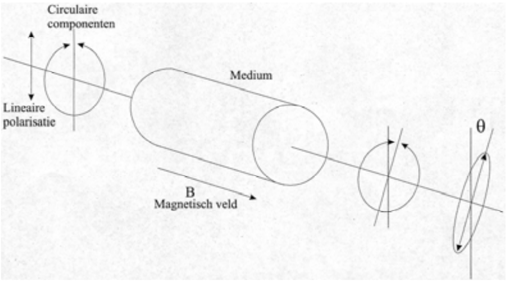
By Jelle Wouters

Molecular and nanomaterials

Faraday rotation

- Magneto-optical effect
- The polarization plane of light rotates in the presence of a longitudinal magnetic field.
- The strength of the effect is linear with:
  - The magnitude of the magnetic field
  - The distance light travels through the sample
  - The Verdet constant: a material constant, also dependent on wavelength
    - In general: Verdet constant larger around absorption band

Faraday rotation



- Circular components have different speed in medium
- Phase difference between components after pass through medium
- Rotation of polarization plane

Applications

- Faraday rotation is a non-reciprocal effect
- Optical isolator:
  - Combination of a polarizer with an efficient Faraday material can strongly diminish unwanted feedback
- Magneto-meter:
  - Faraday rotation has linear dependence on magnetic field so could be used as a magnetic sensor

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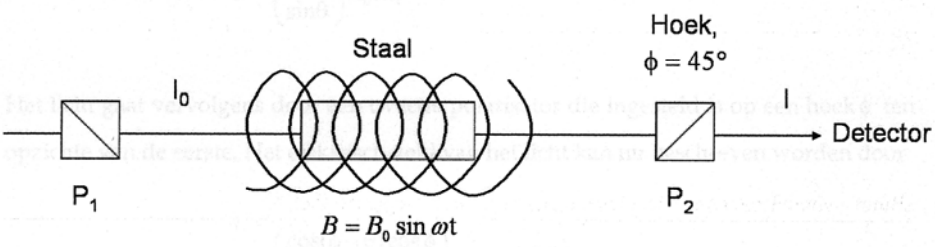
How to measure

- Polarized light
- AC magnetic field
- Polarizer

- Photodiode detects small difference in intensity
- Lock in amplifier measures modulation on the signal coming from the fotodiode



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How to measure

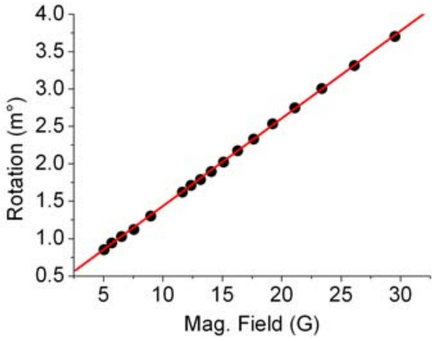
$$\Theta = V*L*B$$

Θ: Rotation angle

V: Verdet constant

L: Thickness of sample

B: Magnetic field strength



- Rotation angle versus field strength
- Slope = V*L/10000
- Known thickness of sample (AFM)
- Calculation of Verdet constant

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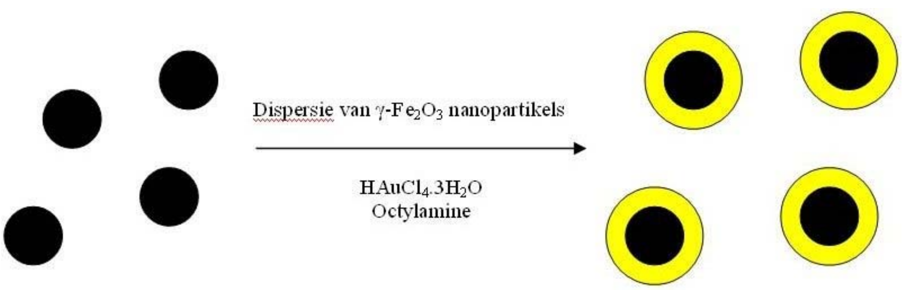
Nanoparticles

- γ-Fe2O3 super paramagnetic core (9 nm – 40 nm) with high monodispersity
- Gold shell (0.5 nm – 5 nm)
- Wet chemical synthesis
- Different surface functionalization of nanoparticles is possible



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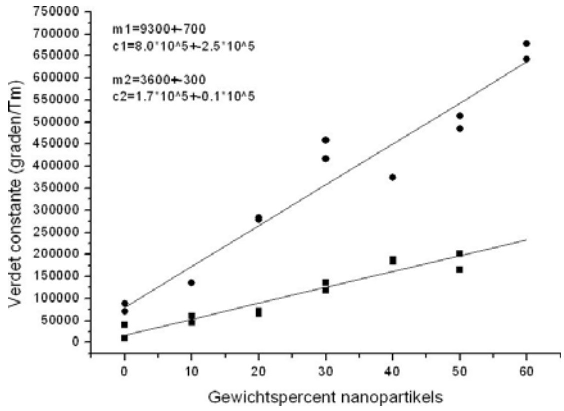
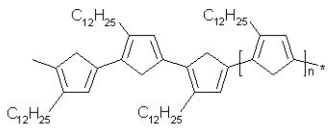
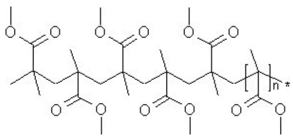
Results



Polythiophene



Polymethyl methacrylate



Conclusions so far (1/2)

- The hybrid films are more then the sum of their constituents.
  - The nanoparticles augment the Faraday effect much more in polythiophene, which has a high Verdet constant in itself, then in PMMA
  - Verdet constant of polydodecylthiophene +9300 per % nanoparticles
  - Verdet constant of PMMA only +3600 per % nanoparticles

Conclusions so far (2/2)

- Verdet constant of 650000°/Tm for hybrid (40-60) polythiophene-NP film @ 830nm
- Absorbance <0.1 for 500nm film @ 830nm

- Commercial materials
  - Tb doped glass: 4000°/Tm @ 632nm
  - Terbium yttrium garnet: 7700°/Tm @ 632nm
  - Yttrium iron garnet: 92000°/Tm @ 632nm

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Current work

- Study of nanoparticles attached directly to glass
- No matrix effects
- No solution effects
- Control of aggregation of the nanoparticles on the glass via depositing parameters

- Possible aggregation effects

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Current work

- Surface functionalization of nanoparticles and possible effects on Faraday response
- Goldshell thickness, exact influence
- Optimizing of synthesis, different batches have different Verdet constants for same weight.

Future work

- Study of more general magnetic properties of the nanoparticles
- Study of the crystal structure of the nanoparticles
- Possible connection between general properties and Verdet constant

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