Master Course Physics

Specialization branches:
Solid State Physics
Nano Electronics

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Solid = many particles: the whole is more than its parts

experimental solid state physics

Solid = many particles: the whole is more than its parts
Applications superconductivity

Nuclear resonance tomography

Chemical analysis: NMR

- cable for power plants
- crack detection in airplane wings
- THz detectors
**Integer quantum Hall Effect (disorder driven)**

- Accurate measurement of \( h/e^2 \) (precision: \( 10^{-10} \))
- Quantum phase transition at filling factors \( n+1/2 \)

\[ \rho_{xy} = \frac{h}{ie^2} \]

\( n = 2.8 \times 10^{15} \text{ m}^{-2} \)

\( \mu = 3.4 \text{ m}^2/\text{Vs} \)

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1985
Application: quantum Hall effect

PTB, NIST, …

Topological insulator

Conduction band
Surface states
Fermi level
Valence band
Momentum

Ω

KG?

2016
physics and applications

high energy physics
particle high way used by a few physicists

solid state physics
1st transistor 1945 (patent: 1925)

1989: world wide web
data highway for everyone

AMD-processor with 1 Billion transistors (2008)
Future of information processing

smaller and more transistors

Moore's Law - 2005

2035: 1 transistor = 1 atom

more and more energy

2016:
2.5 % of electrical power Germany for data center
10 % of electrical power worldwide for IT
new concepts

employ contrast amorphous/crystalline

neurons coupled to Si transistors

Jeopardy 2011

50 W  2.000.000 W  50 W
Graphene: two-dimensional crystals

Theoretical prediction I:
2D-crystals do not exist (1967)

Theoretical prediction II:
If so, they harbour relativistic electrons (1958)

production (Novoselov, Geim 2004)

Answer to TP I:
Graphene is rippled

2010
Graphene: two-dimensional crystals

application: flexible touch screens

Wafer scale preparation (2009 Samsung)

- graphene is transparent: transmitting 98% of light
- graphene is good conductor: touch signals can be processed easily
- graphene is extremely tensile: 10% stretching possible

process: 1) Deposit C₂H₄ on hot Cu
2) etch Cu away

1st Touchscreen with graphene (2010)
Other 2D materials: staples by stamping

Other 2D materials (insulators, semiconductors, metals, supercond.)
Fe, P, CrI, Ge\textsubscript{2}Cr\textsubscript{2}Te\textsubscript{6} (Si, Ge)
BN, GaSe, TiC
MoS\textsubscript{2}, MoSe\textsubscript{2}, WSe\textsubscript{2}, NbSe\textsubscript{2}
CuN\textsubscript{3}, Bi\textsubscript{2}Sr\textsubscript{2}CaCu\textsubscript{2}O\textsubscript{8+x}

NanoLett. 14, 3270 (2014)
Nature Nanotechnol. 9, 676 (2014)
exp. solid state physics

more basics

offered by:

physics

differences:

solid state physics II
(2. semester V4Ü2)
Intro to 4 subjects by
4 professors of physics
Optical properties of solids
Mesoscopics
Correlated materials
Interactions and topology

lectures:

7 days of experiments mostly in
II. Institute of physics:
AFM, QHE, SQUID
PL, Ultra sound, HF technique,
mass spectroscopy, pseudo MOSFET
1 lab experiment

laboratory course:

nano electronics

more applications

physics /electrical eng. + FZJ

new materials + devices in
information technology
(announced in german: Campus)
(1.+2. semester 2 × V2Ü1)
Prof. Waser (electr. eng.)
DRAM, FETs
scaling, memories
LED, LCD,…

experiments also at Faculty Electr. Eng./FZJ
7 days of experiments:
physics: AFM, QHE, PL
electr. eng.: clean room, non-volatile memories
FZJ: spin transport, Bioelectronics
oxide layers, TEM,…
Registration for physics master lab courses

For the term SS 2020 you can register for either the lab course nano-electronics or solid-state physics.

More information/registration can be found on the webpage of the 2\textsuperscript{nd} Physics Institute A:

http://institut2a.physik.rwth-aachen.de
\rightarrow Teaching
\rightarrow Solid state physics / Nano electronics

Registration is open from 1.1.2020 until 17.01.2020

Important for the nano electronics course!
Experiments take place in SS20 at RWTH, but also in the week from Mon 23.03.2020 – Mon 30.03.2020 (during this period at Research Center Jülich)
Please make sure you have no examinations during this week!