



Magnetic properties of MOCVD-prepared ZnO and ZnO:Co thin films

Anna Semisalova

Laboratory of magnetic measurements and researches of magnetic materials (MMRLab)

- Head – Prof. Dr. Nikolai Perov
- 2 PostDocs
- 1 PhD student
- 9 students



Research activities

Magnetic nanoparticles

Biomedicine, ecology

Magnetorheological materials

Multiferroic composite structures

DMS

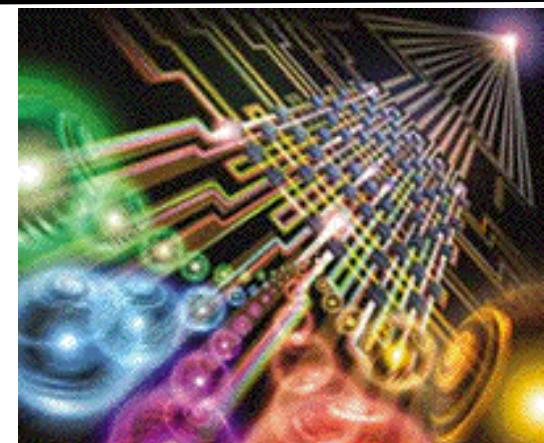
GaN:Cr

Si:Mn

InMnAs

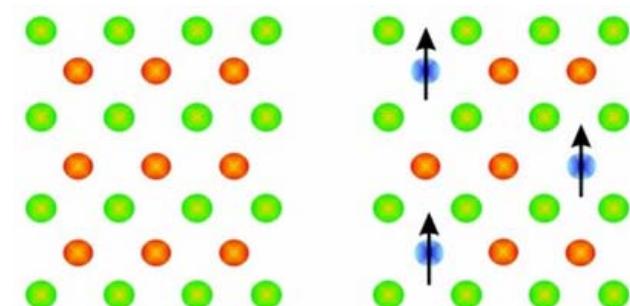
TiO₂:(Co, V)

ZnO, ZnO:Co



$H=0$

$H>0$



ZnO:Co, ZnO MOCVD

Method of the synthesis

MOCVD

Metal precursors

Zn(acac)₂, Co(acac)₂

Substrates:

(1-102) Al₂O₃ (r-sapphire),

(0001) Al₂O₃ (c-sapphire),

(111) MgAl₂O₄

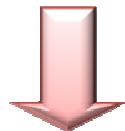
Samples:

Faculty of Chemistry,
Lomonosov MSU

Variations of the method:

Flow O₂, 500-600 °C

Flow H₂O (vapour), 300-500 °C

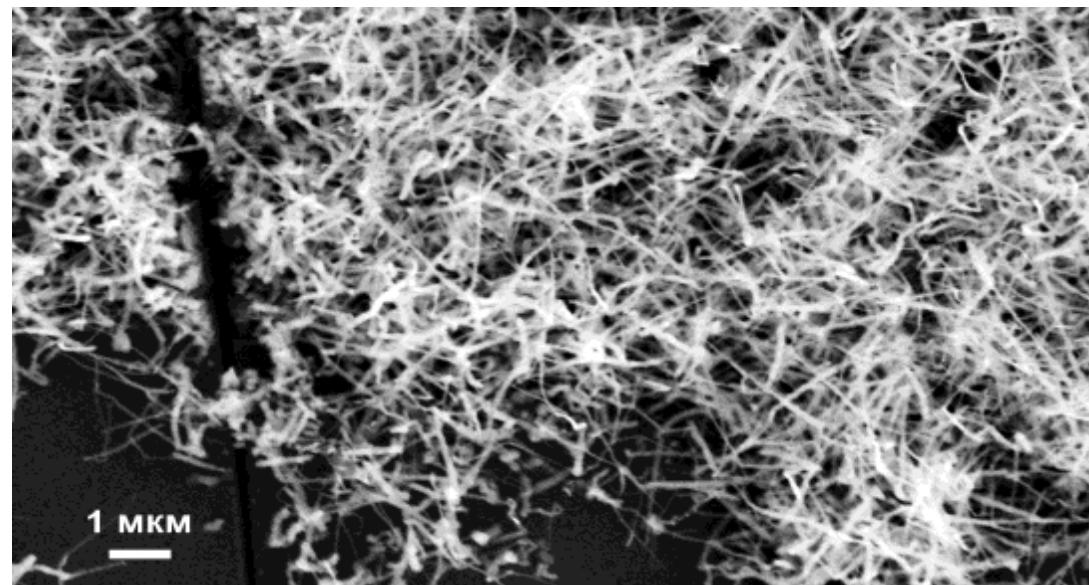


Structure and morphology of
the surface depend on the
conditions of the deposition

ZnO:Co – weak ferromagnetism, no clear dependence on Co content, films thickness, conditions of the synthesis

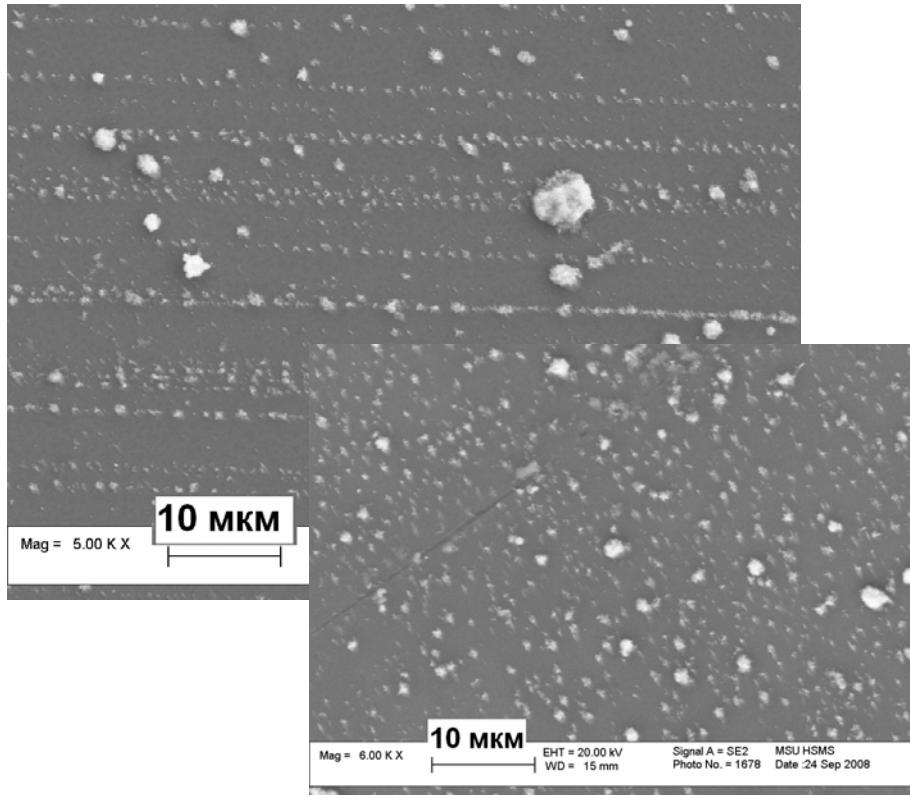
Magnetic properties of ZnO:Co films depend on the structure and morphology of the surface

Undoped ZnO films demonstrate ferromagnetism

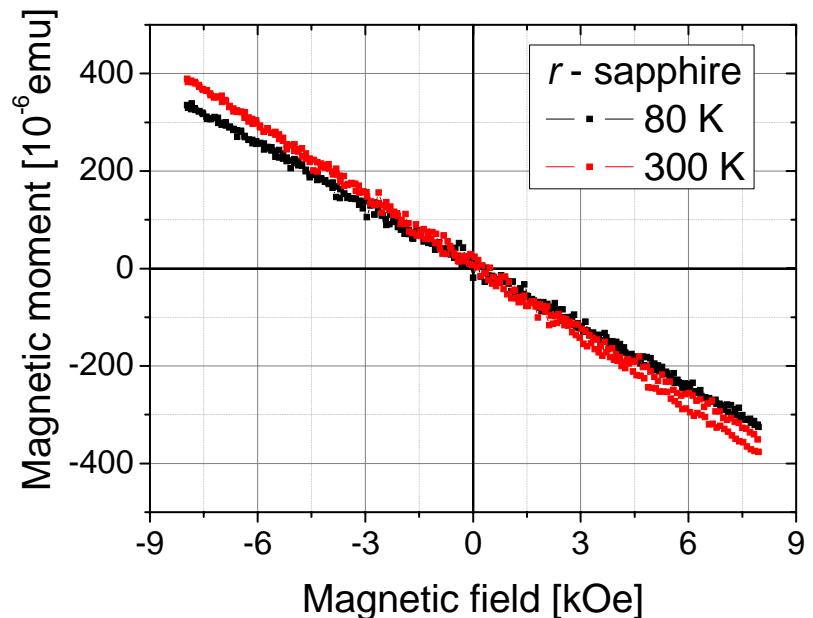


Magnetic properties of the undoped films

Epitaxial, well-crystalline,
dense films



Substrates - r-, c-sapphire

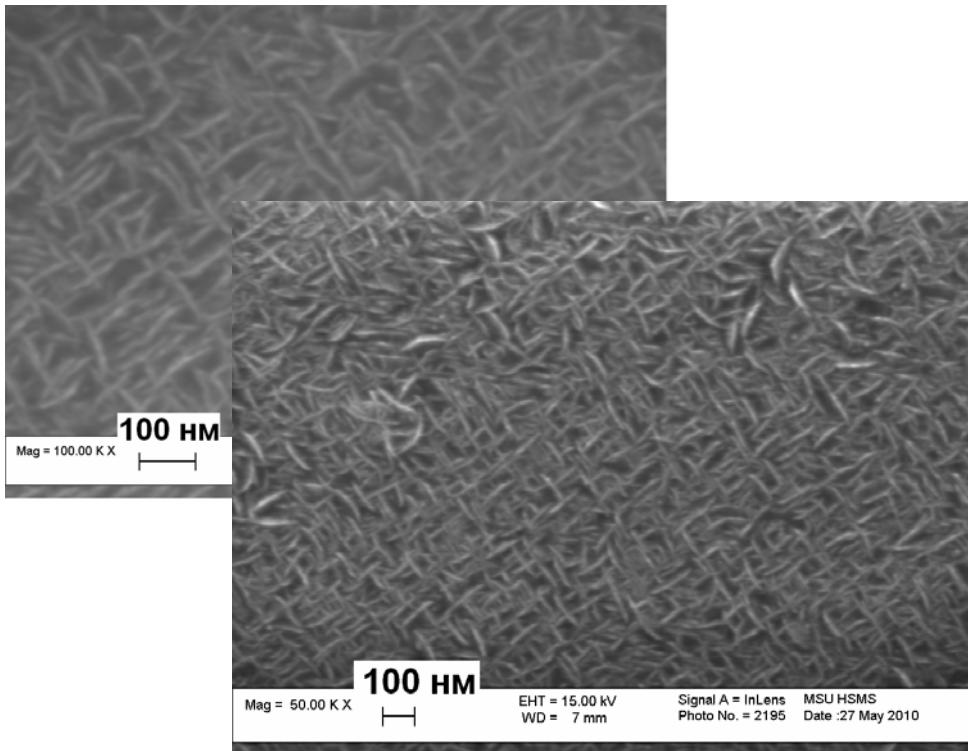


Flow O₂, 600 °C

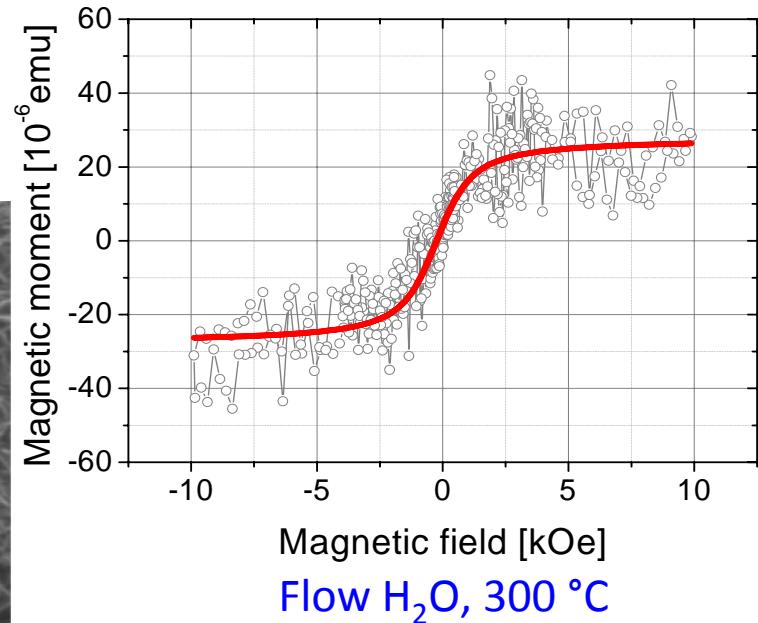
No ferromagnetic
signal

Magnetic properties of the undoped films

Polycrystalline films
with nanosized "plate-like"
morphology



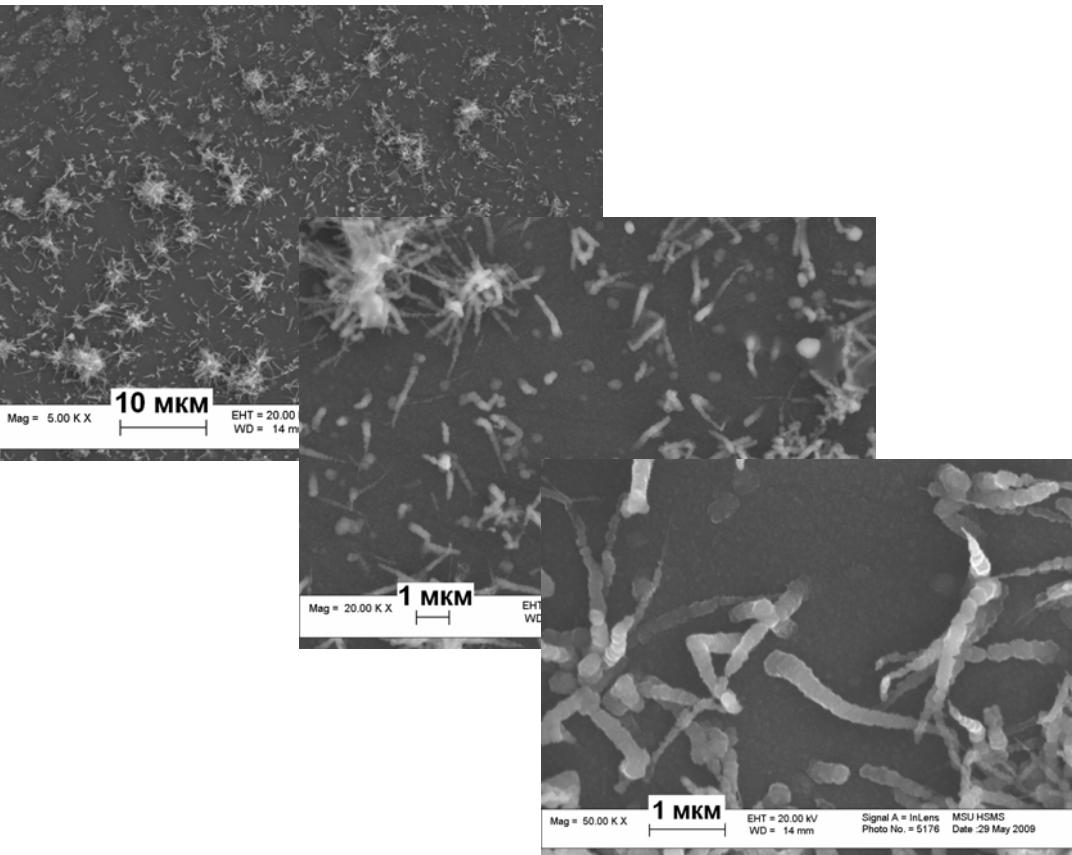
Substrates - r-, c-sapphire



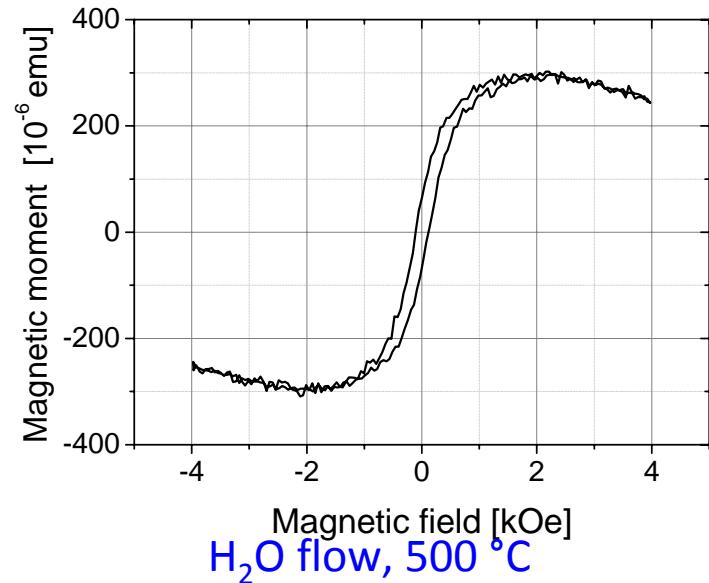
Weak ferromagnetic moment
 20×10^{-6} emu

Magnetic properties of the undoped films

Polycrystalline films
with nanosized whisker morphology



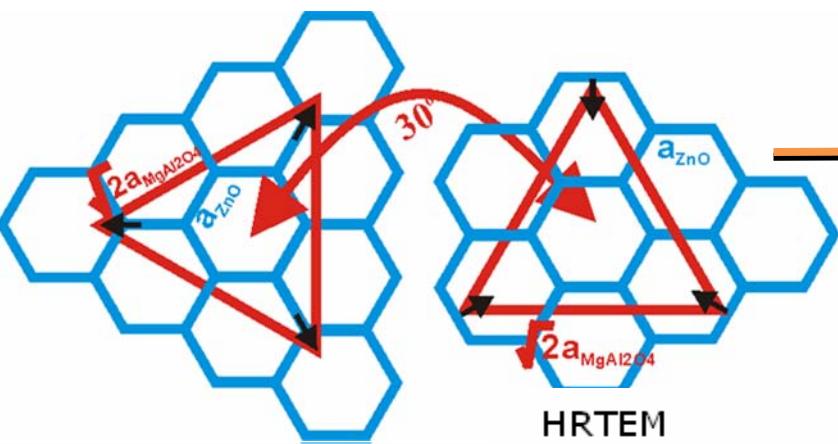
Substrates - r-, c-sapphire



Ferromagnetism at room
temperature
Magnetic moment
 3×10^{-4} emu

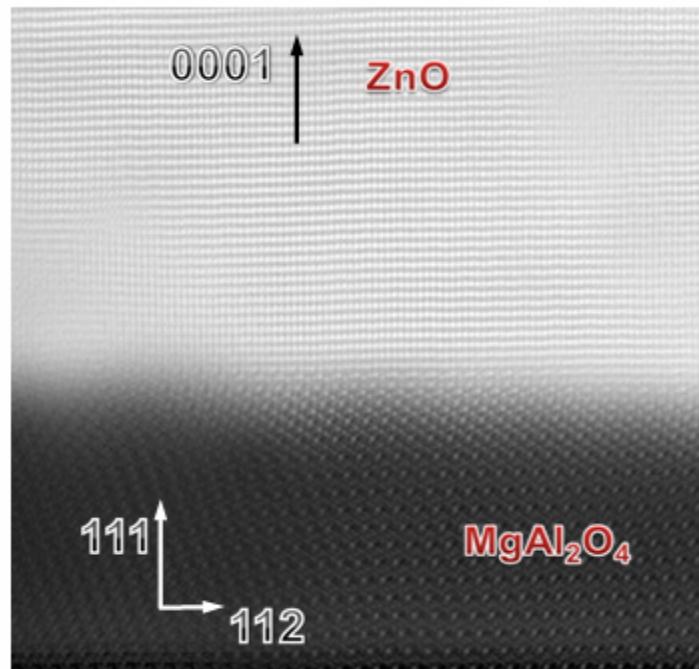
ZnO

Films with variant structure on the substrate (111) MgAl_2O_4

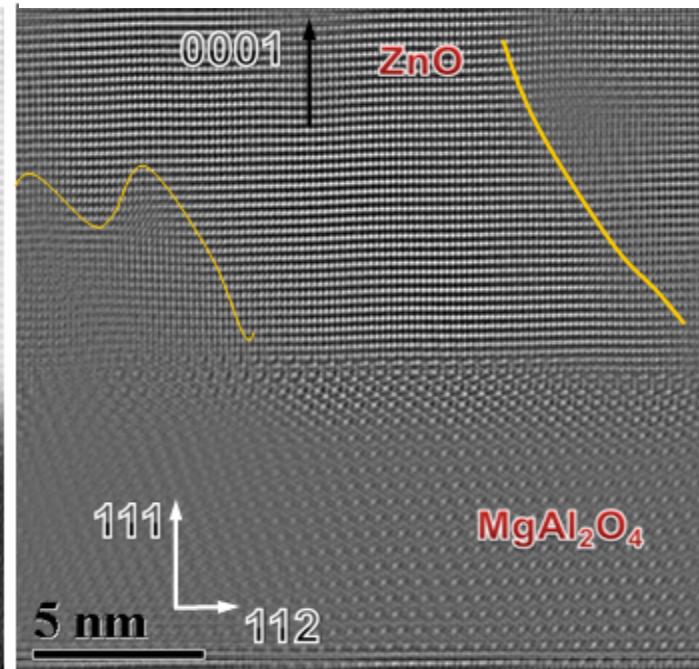


HRTEM

HRTEM images
of ZnO on the
MAO substrate



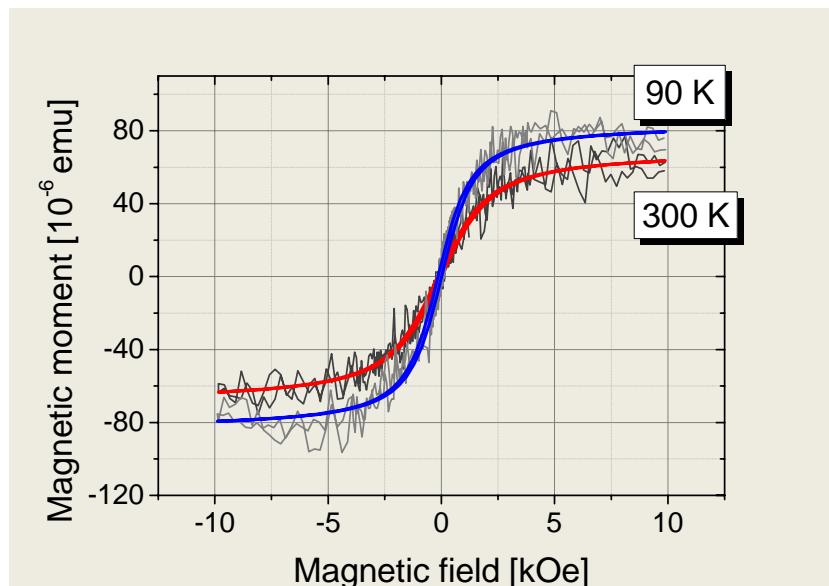
Fourier-filter



ZnO on (111) MgAl₂O₄

Magnetic properties

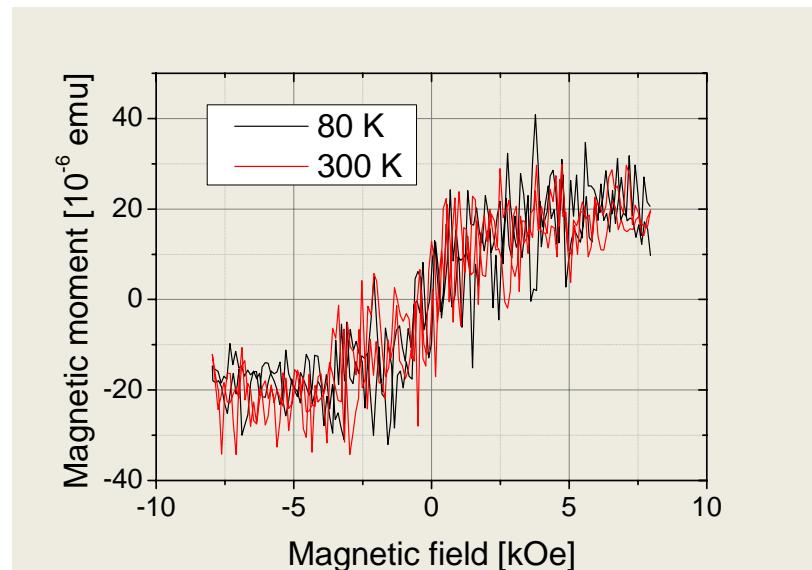
Deposition at 500 °C



50 nm

Magnetic moment - 60×10⁻⁶ emu

Deposition at 600 °C



200 nm

Magnetic moment - 20×10⁻⁶ emu

L.I. Burova, N.S. Perov, A.S. Semisalova, et al. Thin Solid Films, 2012

Conclusions

Crucial role of the morphology and structural nanosized peculiarities of the film surface in the ferromagnetic ordering at room temperature in doped ZnO:Co as well as undoped ZnO films.

The maximal magnetization value was found for undoped ZnO thin films (so called d^0 -magnetism) with highly developed nanostructured surface.

Thank you for you attention!

Description of FM in DMS

Zener model

T. Dietl, H. Ohno (2000)

(Ga,Mn)As, (Ga,Mn)N, ...

Bound magnetic polarons

J.M.D. Coey (2004)

FM in the semiconducting oxides

d⁰ magnetism (2004)

J.M.D. Coey, A. Sundaresan, B.B. Straumal (2009)

ZnO, Si, ...

