Plasma synthesis of Fe-based nanoparticles in low-pressure discharge

P. Zelina, V. Kudrle, O. Jašek, P. Synek
B. David, N. Pizúrová, O. Schneeweiss
R. Hanzlíková, A. Rek

Department of Physical Electronics, Masaryk University Czech Republic
Institute of Physics of Materials, Academy of Sciences of the Czech Republic
Institute of Scientific Instruments, Academy of Sciences of the Czech Republic

F7900 Študentský seminár

November 2$^{\mathrm{nd}}$, 2010

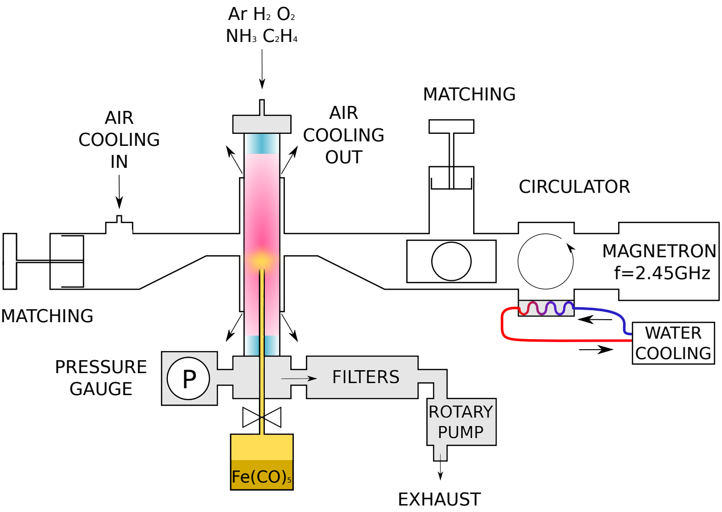
This work was supported under the GA ČR grant GA202/08/0178.

Outline

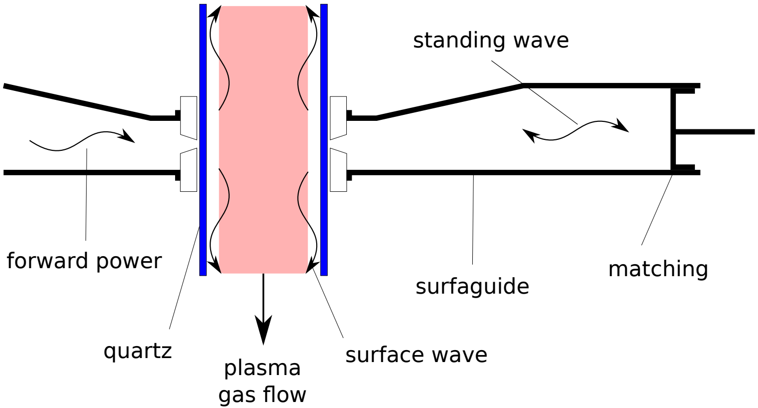
Plasma synthesis

- simple, flexible, controllable and reproducible process
- high power efficiency
- free electrons - temperature up to 10 000 K
- nanoparticles with narrow size distribution

Low-pressure reactor schema



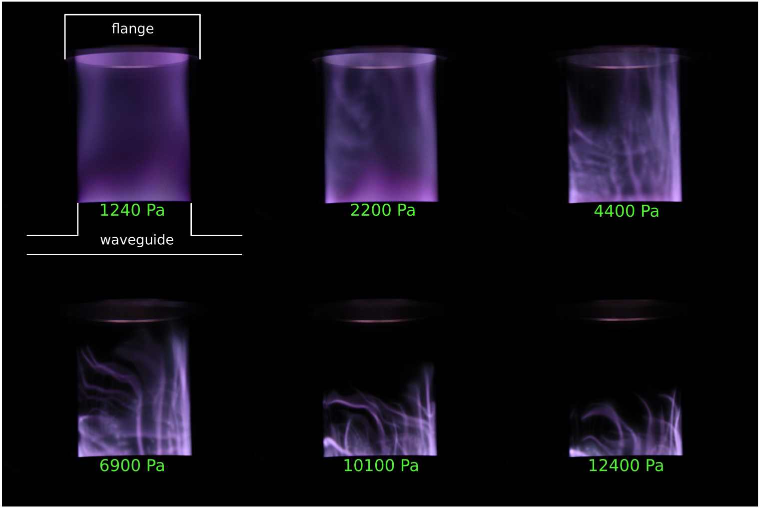
Surfaguide - surface wave launcher



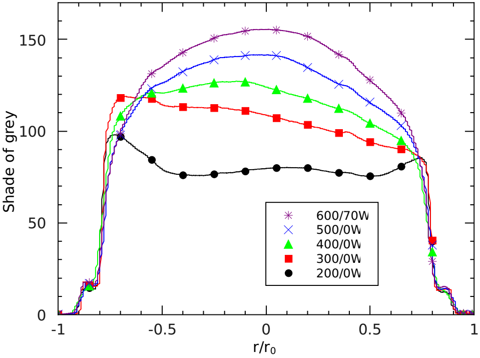
Diagnostics and analytical methods

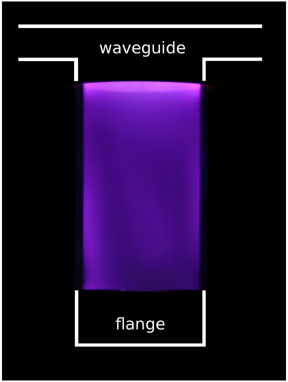
- Digital photography
- OES - Optical emission spectroscopy
- XRD - X-ray diffraction
- TEM - Transmission electron microscope
- HR-TEM - High resolution TEM
- other: Raman and Mössbauer spectroscopy, FTIR, magnetic properties measurement, ...

Discharge at different pressures



Surface wave - flat intensity profiles

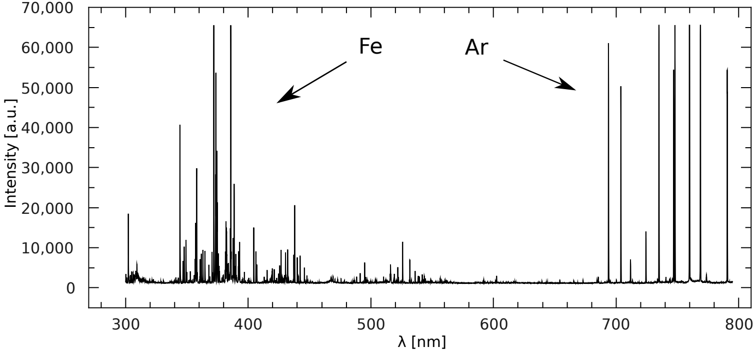




absolute intensity profiles $\longrightarrow$ Abel integral

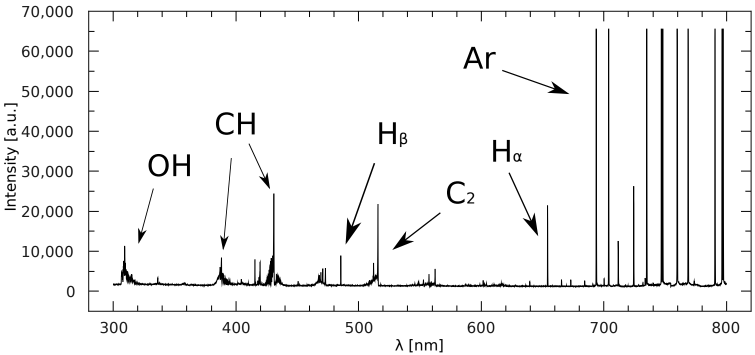
Optical emission spectroscopy

- deposition conditions: P=500/0 W, Ar 200 sccm + $\mathrm{Fe(CO)_5}$, 1300 Pa



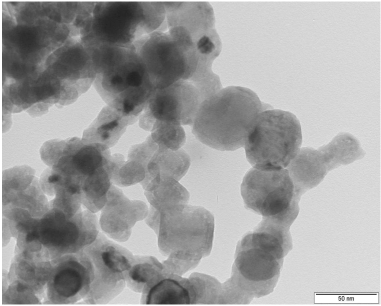
Optical emission spectroscopy

- discharge conditions: P=500/0 W, Ar 200 sccm + C_2H_4 25 sccm, 800 Pa

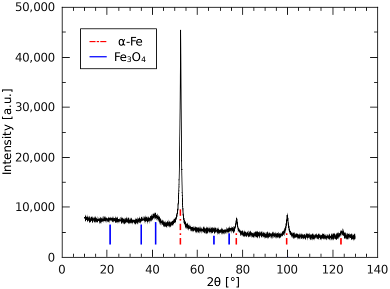


Discharge after synthesis

TEM and XRD



TEM LP#16A - scalebar is 50 nm



XRD LP#16A - α-Fe (14 nm, 76% wt.)

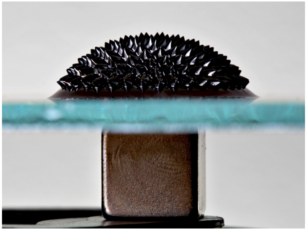
Properties of the product

- production rate: 10 g/hod
- particles of nanometer size: 9–14 nm
- high surface/volume ratio - up to hundreds m^2/g
- nanopowder samples contain: α-Fe, α- and γ-Fe_2O_3, Fe_3O_4
- samples also exhibit macroscopic magnetic properties

Practical applications

Application:	We can produce:
catalysis	α-Fe (15 nm, 93% wt.)
biotechnology and medicine:	
MRI contrast agent,	
transport of cancer drugs	γ-Fe_2O_3 (13 nm, 99% wt.)

Other applications: ferrofluids, magnetic storage devices, superparamagnetism



Conclusions

Accomplished:

- plasmachemical synthesis of ultrafine nanopowder
- sufficient production rate
- composition of iron and/or iron oxides
- phase controlled product

Todo:

- narrow size distribution
- size controlled synthesis
- test potential applications
- prepare other phases (β-Fe_2O_3, ϵ-Fe_2O_3) and nitrides, carbides, Fe-Co nanoparticles ...