Condensation and solid phase reactions of Fe in Mg silicate systems

S. Wetzel[1]   A. Tamanai[1]   H.-P. Gail[2]   A. Pucci[1]

[1]Kirchhoff Institut für Physik, Universität Heidelberg

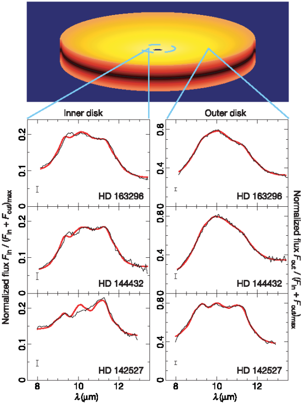
[2]Institut für theoretische Astrophysik, Universität Heidelberg

09. November 2011

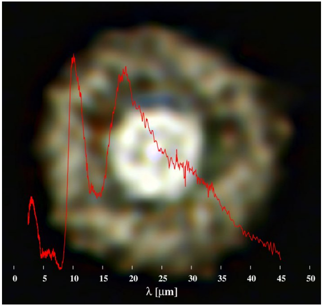

Heidelberg University - Kirchhoff Institute for Physics

Outline

Introduction



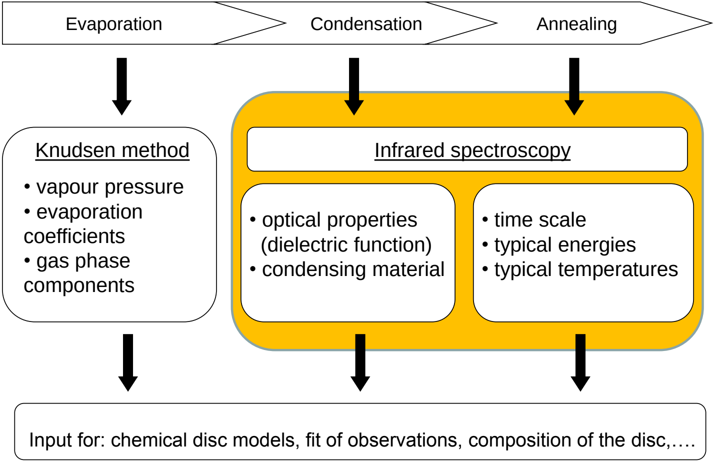
R. van Boekel *et. al.*, Nature, 2004



IRAS 17163-3907 "Fried Egg Nebula", This is a post-Red Supergiant star. The emission spectrum was obtaines at VLT (ESO) in Chile (provided by H.-P. Gail)

- Silicates are among the most abundant minerals $\Rightarrow$ 10μm feature
- Crystallinity, material composition, shape, formation conditions

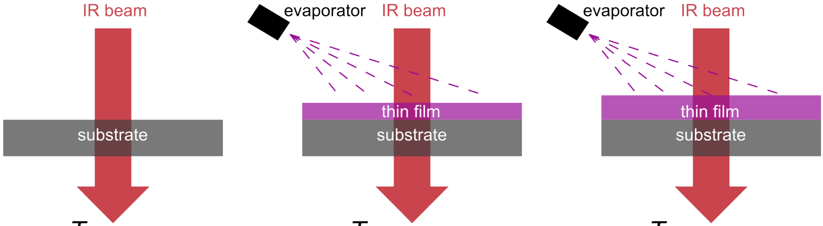
What we can study in our lab



Measurement technique and Experimental setup

In situ IR spectroscopy

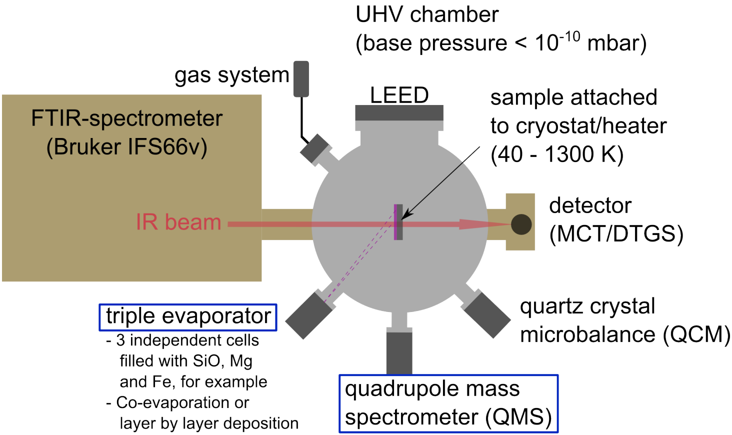
IR spectroscopy during film growth:



$T_{\text{substrate}}$ $T_{\text{substrate+film}}$ $T_{\text{substrate+film}}$

$$T_{\text{rel}} = \frac{T_{\text{substrate+film}}}{T_{\text{substrate}}} \rightarrow \text{absorbance} = -\log\left(T_{\text{rel}}\right)$$

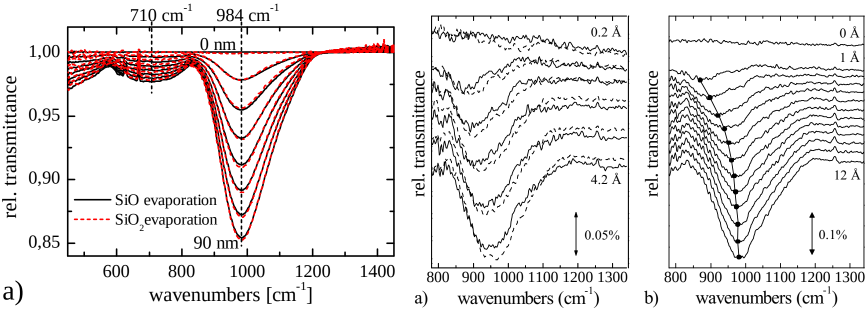
Experimental setup



Triple evaporator for preparation of different types of thin films:

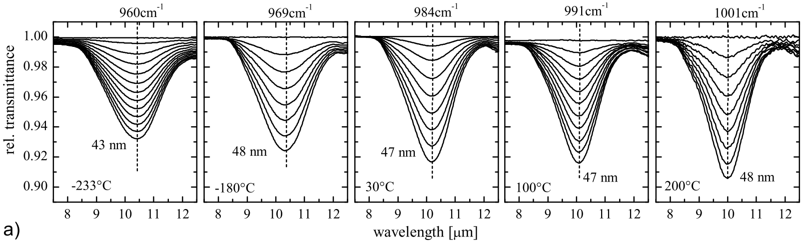
Results

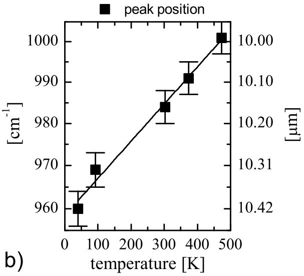
Studies on SiO and SiO_2 evaporation



- Klevenz *et al.* Appl. Spectrosc., 64(3) (2010) (left)
- Klevenz *et al.* Phys. Status Solidi B, 247(9), (2010) (right)

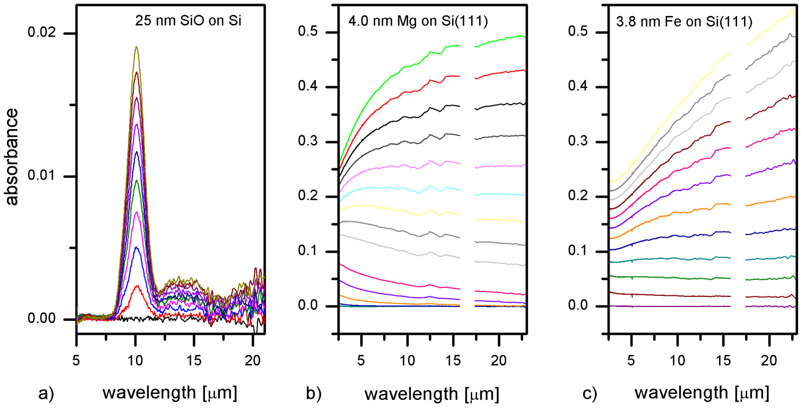
Varying substrate temperature: SiO on Si(111)





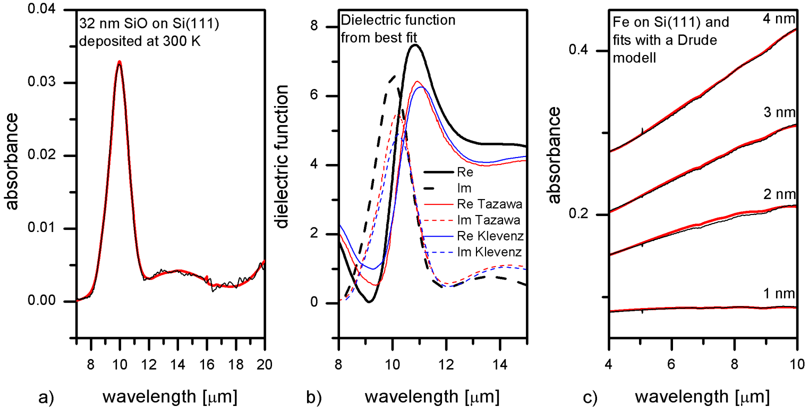
- Disproportionation proccesses
- Already at room temperature?
- Influence for very low temperatures unclear

Single layers of Fe, Mg, and SiO



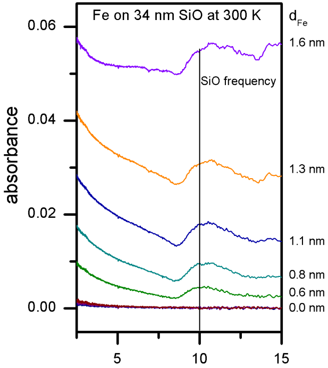
- 10μm feature of the SiO stretching vibration (left)
- Island growth, percolation and Drude-like behaviour of metal

Modelling of Spectra - SiO and Fe

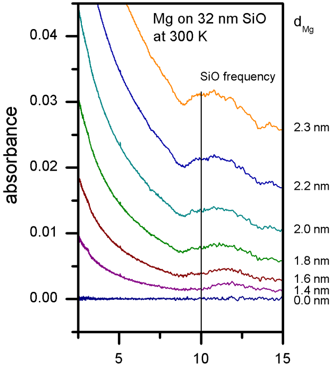


- Brendel dielectric function for Si-O vibration (Klevenz et al. 2010)
- Drude-model for metal films (beyond percolation)

Multilayers - Fe, Mg on SiO



a)

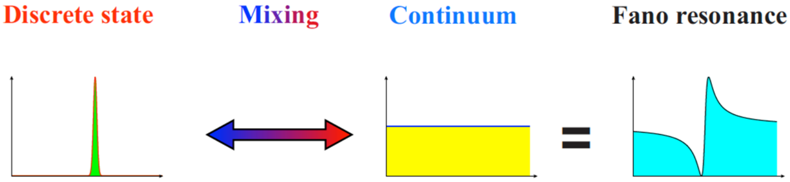


b)

- Additional feature around 10μm from Fano-type interaction of plasmonic excitation of the metal film with SiO phononic excitation: lineshape is asymmetric, intensity depends on film morphology

Fano-type interaction

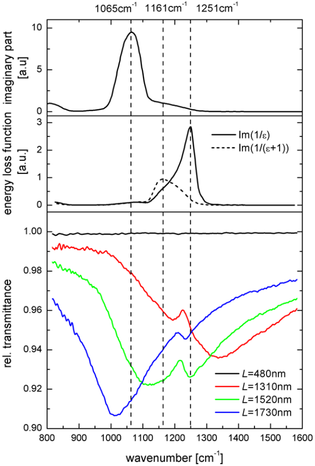
Scattering cross section (after U. Fano) $\sigma = \frac{(\epsilon+q)}{\epsilon^2+1}$



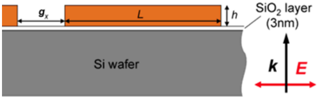
$$\frac{q^2-1}{\epsilon^2+1} \quad + \quad \frac{2q\epsilon}{\epsilon^2+1} \quad + \quad 1 \quad = \quad \frac{(\epsilon+q)^2}{\epsilon^2+1}$$

- Phenomelogical asymmetry parameter q
- From A. E. Miroshnichenko et al. Reviews of Modern Physics 82, 2257 (2010)

Plasmonic interaction with surface polaritons

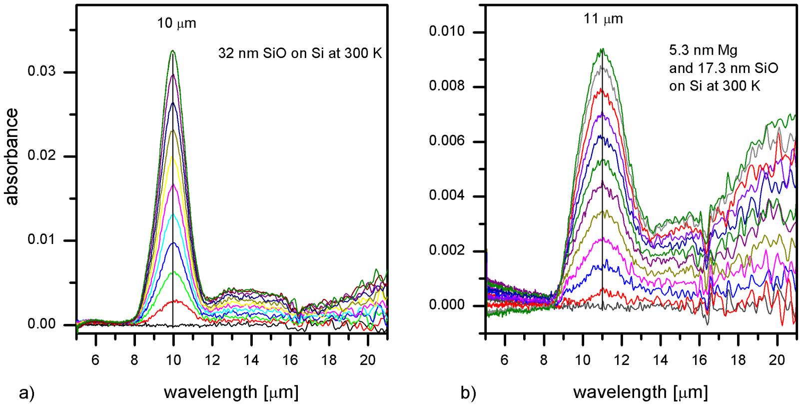


F. Neubrech *et. al.*, J, Phys. Chem C, 114, 7299 (2010)



- Enhanced Fano-type signal in surface polariton region of Si-O stretching vibration of SiO_2.
- Position different to finding with Fe islands
- Detailed analysis in progress

Coevaporation - Mg and SiO



- Redshift of the Si-O stretching vibration (from 10μm to 11μm) and broadening are confirmed. Metal itself seems to be "invisible".

Summary & Outlook

Summary

⇒ *In situ* IR spectroscopy during film growth under UHV conditions

- Optical properties from transmittance measurements
- Influence of substrate temperature and interface effects
- Triple evaporator: Single layer, Multilayer & Coevaporation experiments possible
- Single layer: Mg, Fe and SiO show IR spectra in accordance to literature data
- Mulltilayer: Fano-type interaction of metal island films with Si-O stretching vibration, at higher coverages conducting layers are formed
- Coevaporation: Significant redshift of the resonance and a broadening has been observed

Outlook

- Detailed data analysis in progress
- Continue Multilayer & Coevaporation experiments for Fe and SiO with special attention to the influence of Fe on the 10μm feature.
- Surface analysis by means of SEM & EDX in cooperation with partners
- Annealing experiments with layers produced by subsequent or simultaneous evaporation of Fe, SiO, Mg (MgO)
- Annealing experiments with amorphous silicate layers with varying Fe content produced by cooperation partners
- Implementation of results into theoretical models by H.-P. Gail

Acknowledgement

Thank you for your attention.

Financial support by

- Prof. Tetsuo Yamamoto - Hokkaido University
- SPP1385 - The first 10 Million years of the Solar system
- Reserach Group FOR759 - Planet formation