Hydrogen charging effects in Pd/Ti/TiO_2/Ti thin films deposited on Si(111) studied by ion beam analysis methods

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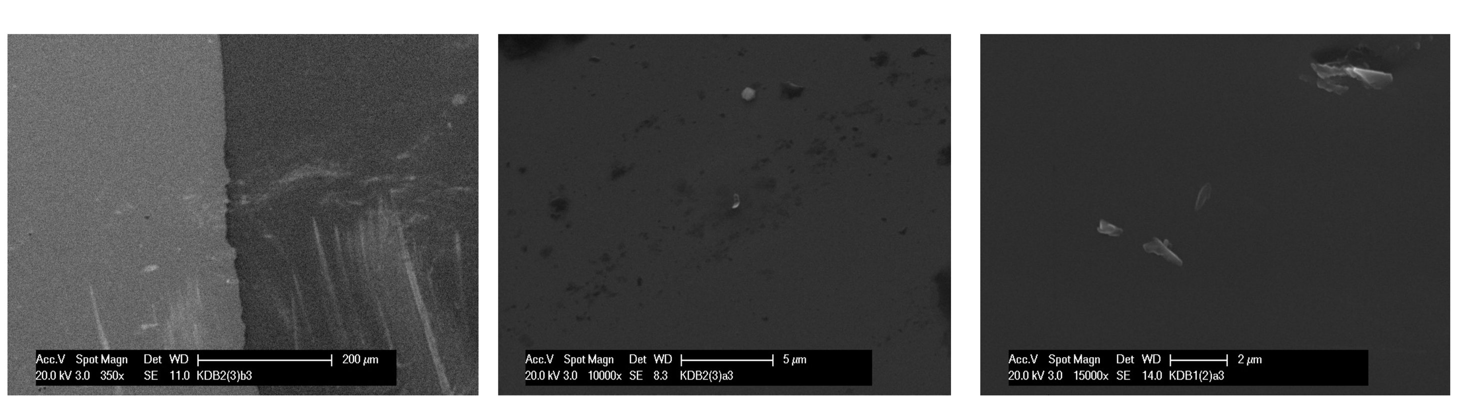
Motivation

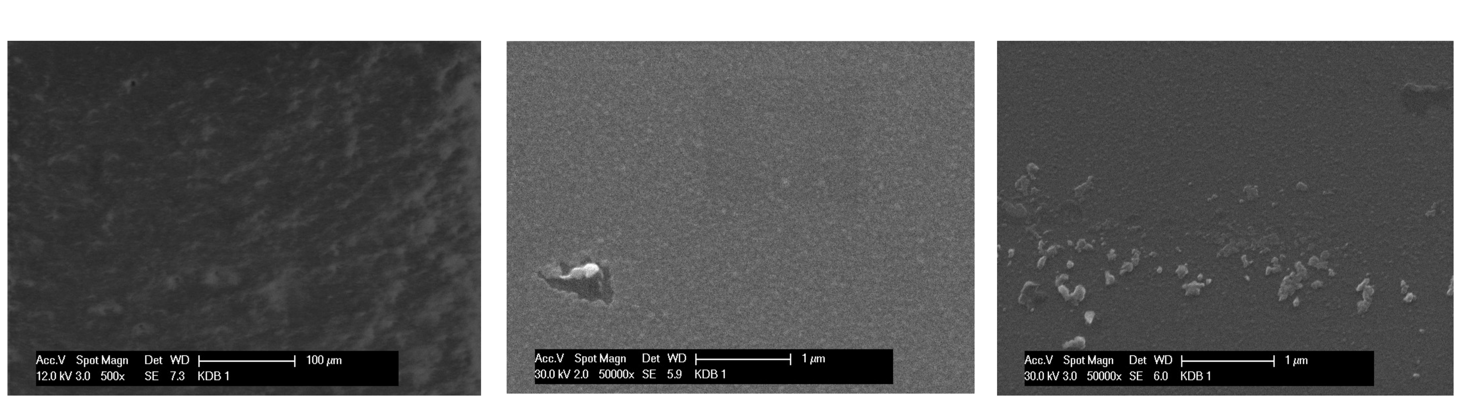
Titanium hydride films have many potential applications, e.g. neutron super mirrors, hydrogen storage layers, standards for hydrogen quantitative analysis, etc. Neutron super mirrors are multilayers of nickel and titanium employed for the transport of cold neutron beams. Saturation of these systems with hydrogen improves their reflectivity, because hydrogen increases the difference between the two indices of refraction and allows one to diminish the number of layers needed. In addition, titanium deutride films can be employed as a neutron source in ion beam technology. Titanium and its alloys have many industrial applications thanks to their excellent corrosion resistance and high specific strength. However, hydrogen absorption induces cracking of titanium layers. Titanium dioxide top layers acts as a protective layer (against corrosion), but also as a barrier to hydrogen absorption into the metal.

Surface

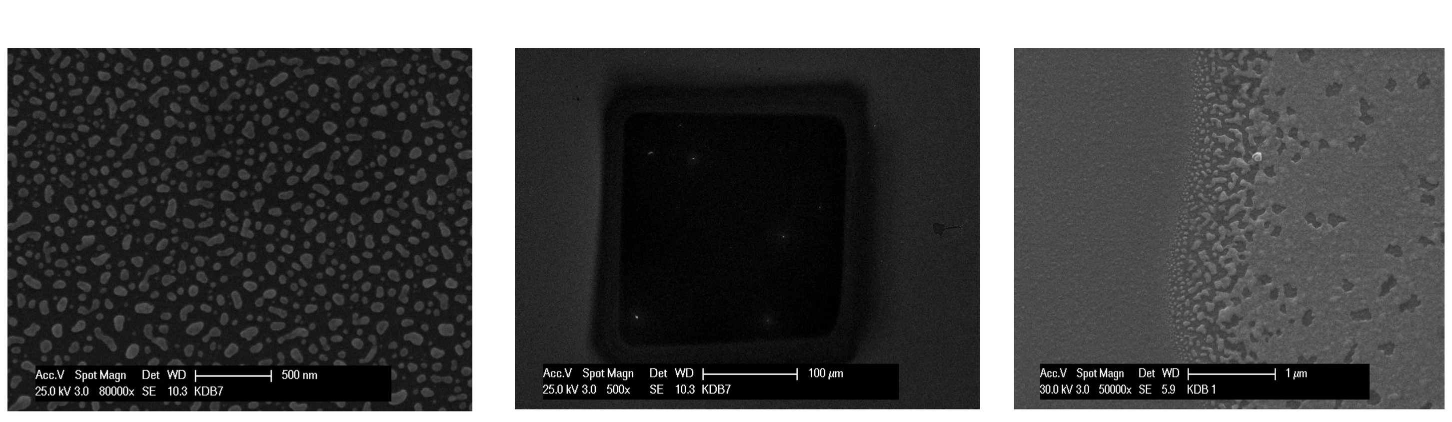
Before hydrogen charging – surface smooth and homogenous



Titanium layer after hydrogen charging – granulation of the surface



Palladium layer – irradiation with heavy ions (Cs) during SIMS measurements – granulation of the surface, annealing during hydrogen charging caused some cracks on the surface.



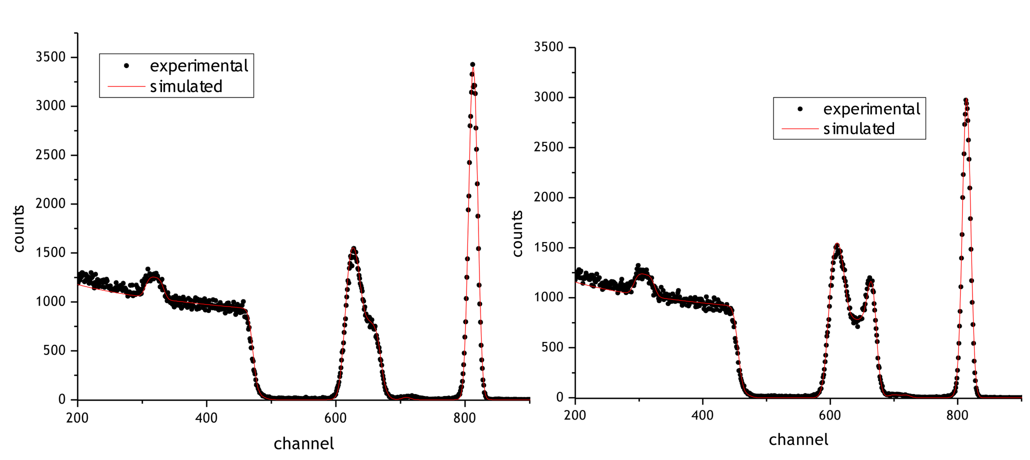
Samples

- Ti/TiO_2/Ti multilayers deposited on Si(111) substrates by magnetron sputtering
- Some of samples partially covered with palladium by MBE

Experiments and investigation techniques:

- Surface examined by HRSEM and AES
- Structure investigated by RBS
- Hydrogen charging and hydrogen profiles obtained by SIMS and NRA (N-15 method)

Structure

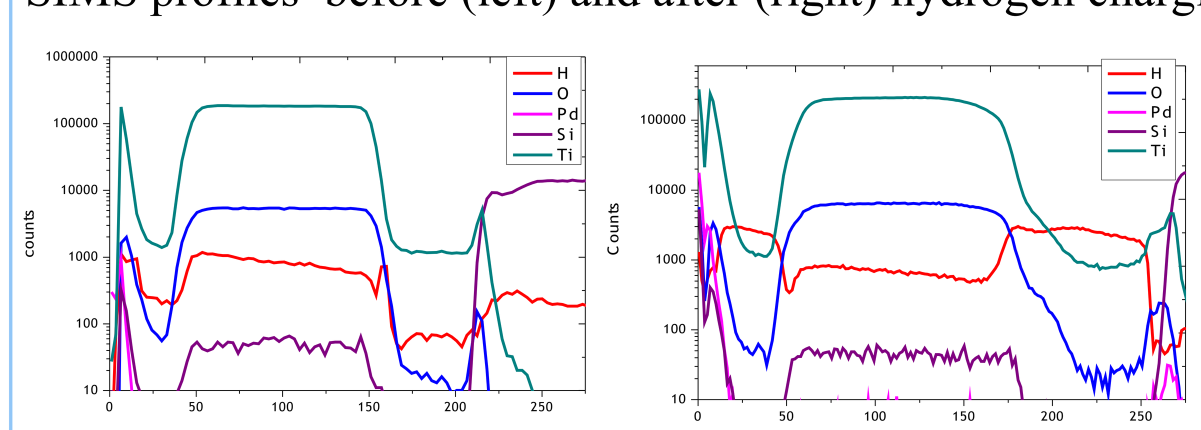


Prior to other experiments samples were studied by RBS. For samples with top titanium layer partially covered by palladium, no interdiffusion was observed and the thicknesses of the layers were in good agreement with the estimated values

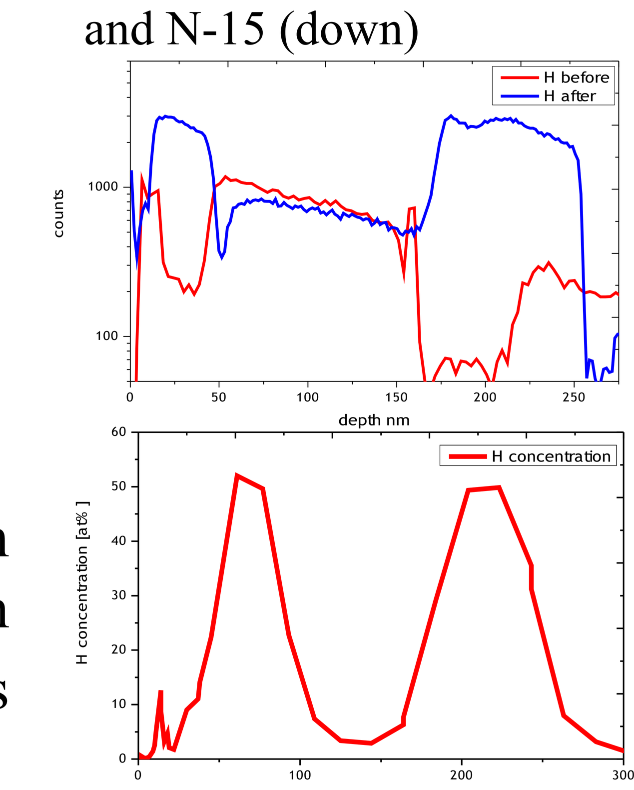
Hydrogen profiles

Pd(20nm)/Ti(50nm)/TiO_2(100nm)/Ti(100nm)/Si(111)

SIMS profiles before (left) and after (right) hydrogen charging



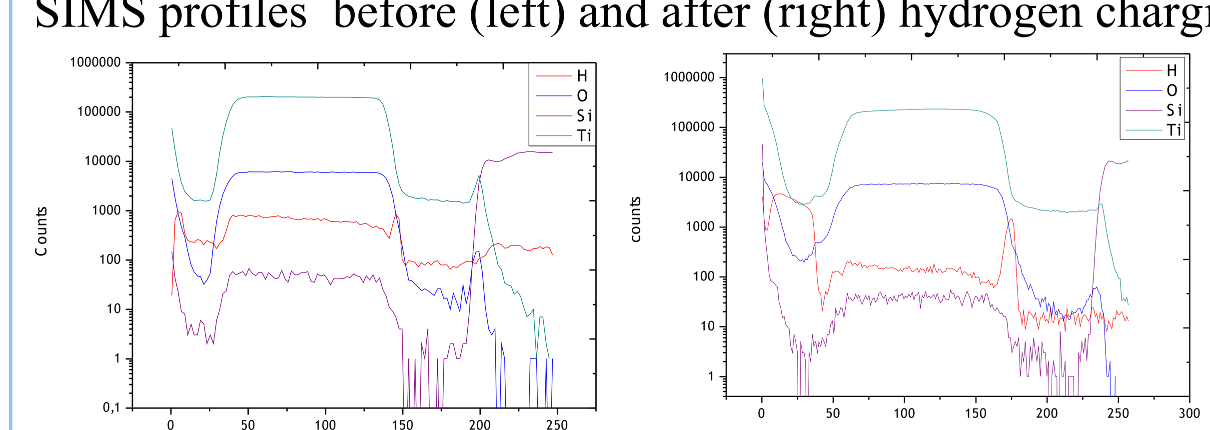
Hydrogen profiles: SIMS (up) and N-15 (down)



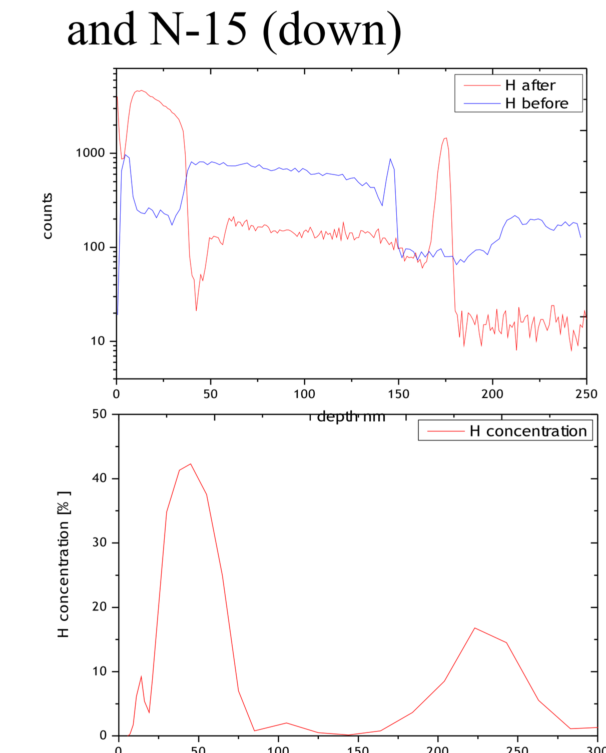
Palladium acts as a catalyst for hydrogen diffusion through TiO_2 layer – after charging hydrogen gathers in titanium layers, in titanium oxide its concentarion is the same as before.

Ti(50nm)/TiO_2(100nm)/Ti(100nm)/Si(111)

SIMS profiles before (left) and after (right) hydrogen charging



Hydrogen profiles: SIMS (up) and N-15 (down)



After charging, hydrogen gathers only in titanium layers, in titanium oxide its concentarion is lower.

Conclusions:

- Hydrogen charging causes a granulation of titanium layer. Palladium layer changed because of annealing (cracks) and irradiation during SIMS measurements (island formation).
- Hydrogen profile obtained by SIMS and N-15 measurements proved a higher hydrogen concentration in samples with partially-covered top layers, than in samples without palladium indicating that palladium acts as a catalyst for hydrogen diffusion through TiO_2 layer.

Acknowledgements

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