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Combining nanoindentation with complementary techniques for mechanical and structural characterization of ultra uow-k (ULK) thin films

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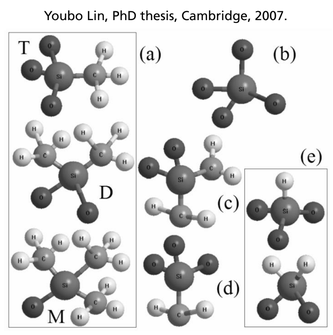
1. MOTIVATION

Nano-porous dielectrics (ULKs) used as insulating materials between on-chip interconnects are an important component in metallization stacks of leading-edge microelectronic products to reduce electrical signal delay and power loss. The main drawbacks of these porous dielectrics are their weak mechanical properties. The main part of this study are the experimental techniques used for mechanical and structural analysis of the organosilicate glasses (OSGs). Mechanical characterization is done using nanoindentation (NI) and is complemented by atomic force acoustic microscopy (AFAM) as well as surface acoustic wave (SAW) measurements.

2. MATERIALS

Studied are new types of porous organosilicate glasses (OSGs) exhibiting a highly ordered pore arrangement. The OSGs were produced by SBA materials using a sol gel spin on process and different amounts of porogens.

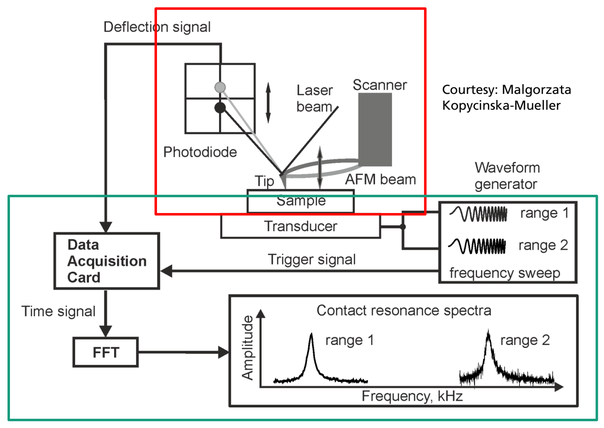


OSG sample building blocks

Sample list

Sample	film thickness t/nm	Porosity p/%	dielectric constant k
1	517	54	1,8
2	510	42	2,1
3	533	30	2,3
4	527	25	2,5
5	489	17	2,7
6	441	0	3,1

3. EXPERIMENTAL TECHNIQUES AND RESULTS



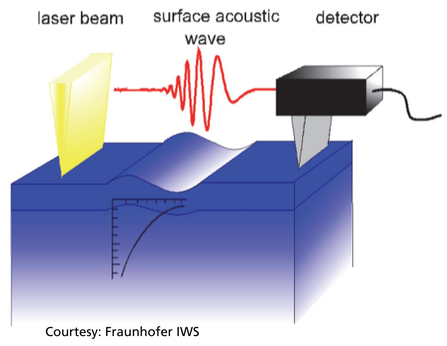
Atomic Force Acoustic Microscopy (AFAM)

- AFM in contact mode coupled with a frequency generator
- See also: Kopycinska-Mueller et al., Nanotechnology 24, 2013

Image courtesy: Hysitron

High resolution nanoindentation using the Hysitron Xprobe

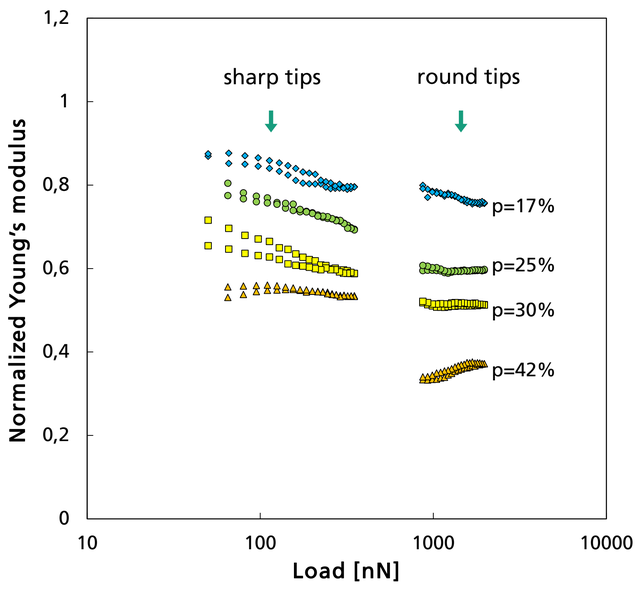
- xProbe: high resolution MEMS nano-indentation transducer
- Basic principles of nanoindentation: Oliver, Pharr, J. Mater. Res. 7, 1992

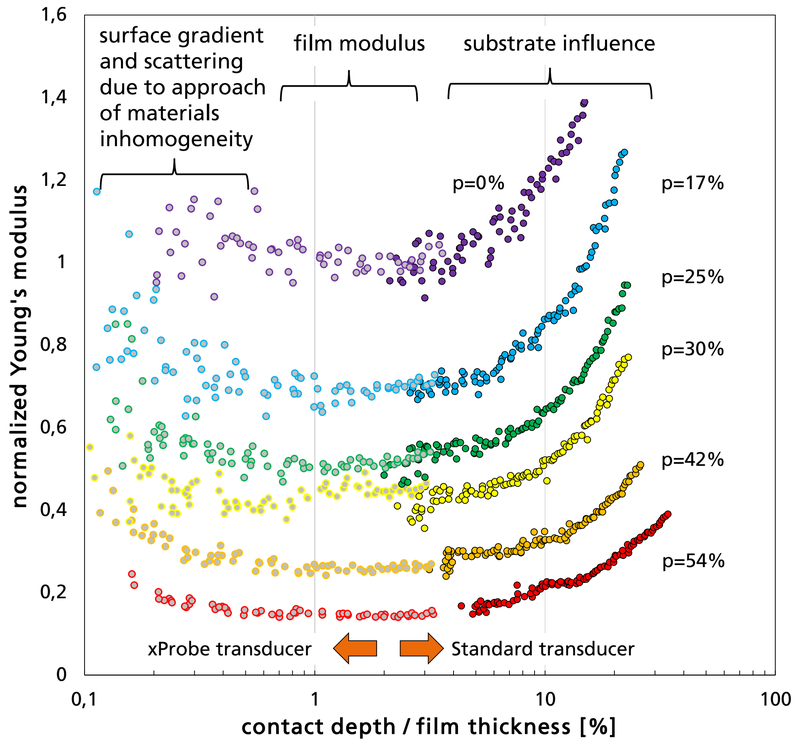


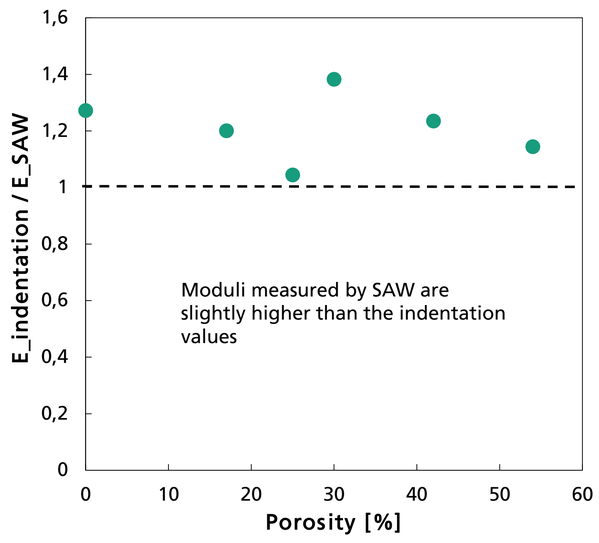
Courtesy: Fraunhofer IWS

Surface Acoustic Waves (SAW)

- Measuring speed of sound by laser induced lateral elastic waves







4. CONLCUSIONS

- ✓ Using AFAM, very shallow surface gradients become visible.
- ✓ Using the high resolution Hysitron xProbe in addition to the standard transducer enables the measurement of substrate influence free moduli of thin films.
- ✓ Using the xProbe, even the surface gradient in the modulus, seen using AFAM, becomes accessible using nanoindentation
- ✓ The visible surface gradient could be due to the measurement of the material's backbone rather than its global compliance at low indentation depths
- ✓ SAW measurements give slightly higher moduli compared to indentation, maybe due to anisotropy of the material