Nanocomposites based on (CaO-SiO2) and (2CaO-SiO2) on Silicon surface obtained by cavitation processing

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INTRODUCTION

Micro and nanostructurization of semiconductor surfaces is used for a modification of surface properties such as

- topography,
- roughness,
- light reflectivity,
- chemical activity,
- biocompability.

These features have a potential use in electronics and medicine as well as in special miniaturized devices.

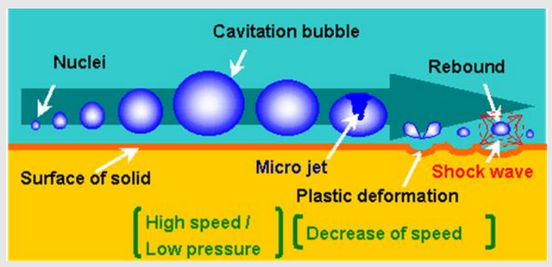
A wide range of topological features can be developed upon bombardment with ions as well as under irradiation with laser pulses.

AIM of PRESENT WORK :

Structurization of the silicon surface by the cavitations' impact for its photovoltaic application and biofunctionalization.

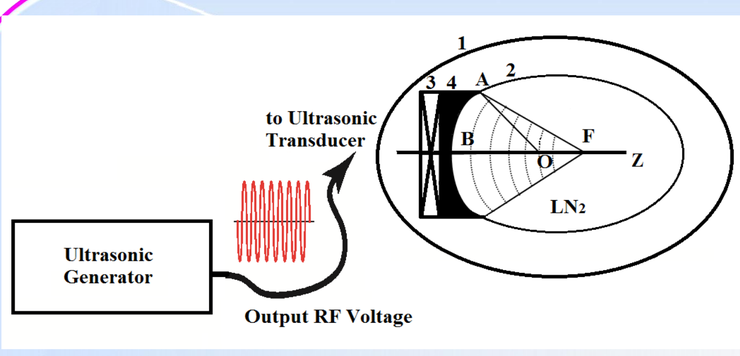
EXPERIMENT

- CAVITATION AGENCIES ;
  - temperature (5000°C)
  - pressure (1000 atm)
  - high heating/cooling rate (above 10^{10}K/s)
  - plasma generation
- CAVITATION TREATMENT CONDITIONS ;1-6 MHz, 15 W/cm² with Zn / Mg as a catalytic agent



- CHARACTERIZATION
  - AFM, SEM , ellipsometry
  - Surface photovoltage spectroscopy
  - XRD, HRXRD, Raman, FTIR

Silicon properties evolution with cavitation treatment

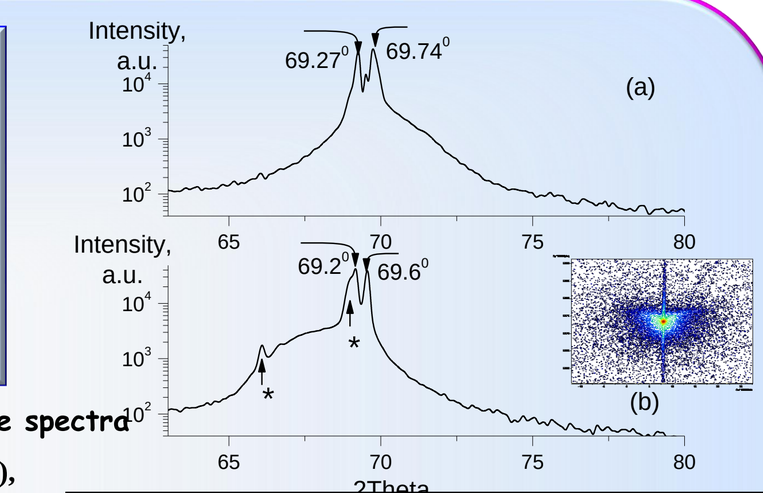


A schematic image of the ultrasonic cell (top view): stainless steel tank (1) with internal copper cell (2) equipped with an acoustic system – a piezoelectric transducer (3) and copper lens (4); AO = R_{cu} is a curvature radius, AF = F is a focal distance, ∠AOB = β, ∠AFB = γ.

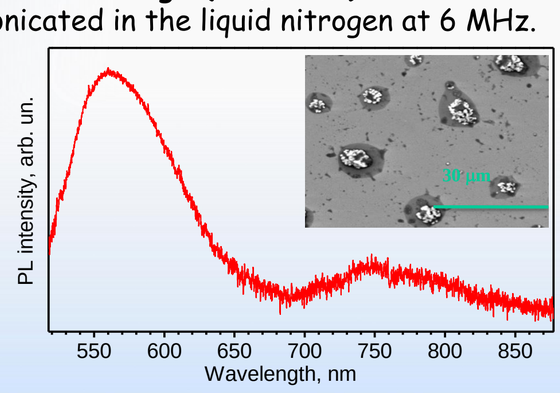
$$F = R_{cu}\left(1+\frac{n^2}{1-n^2}\cos\beta\left(1+\sqrt{1+\frac{1-n^2}{n^2}\cos\beta}\right)\right)$$

$$n = \frac{c_1}{c_2},\ k_I = \frac{4Ff_{US}}{c_1}\sin\gamma$$

- ✓**Ellipsometry data point out to the formation of the complex optical system with two transition layers**
- ✓**XRD results in the coherent-scattering region point out to the compression of the structured layer (residual stress of ~1.55 GPa)**
- ✓**A dendrite-like micron-scale array inside ultrasonically structured region**
- ✓ **Significant rise of the photosensitivity**
- ✓**Luminescence from the microstructured regions**

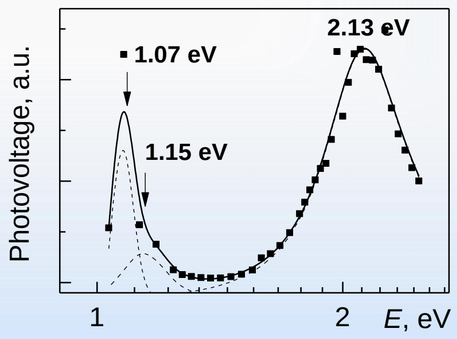


Photoluminescence spectra (488 nm of Ar-Kr laser) **and SEM image** (7kV, x2000) **of Si surface** sonicated in the liquid nitrogen at 6 MHz.



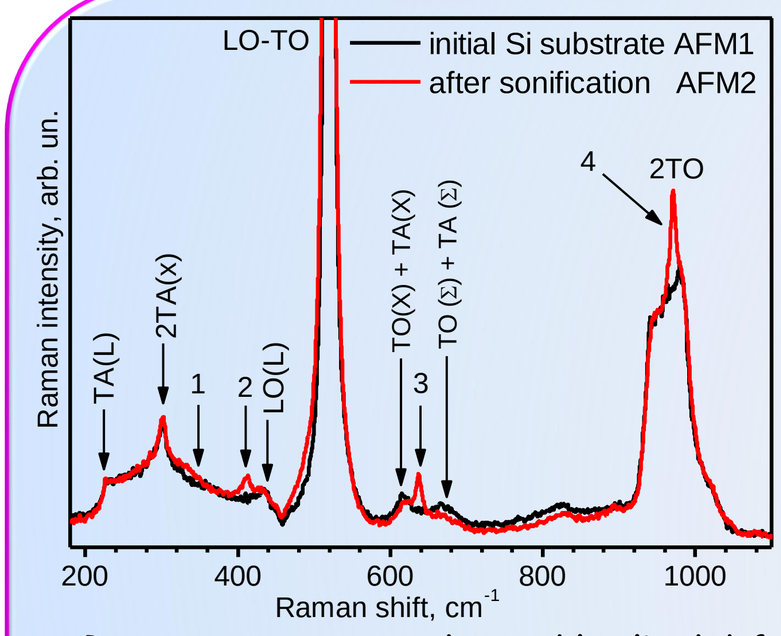
Surface photovoltage spectra

$$V_{PV}(\omega) = J_{PC}(\omega)\cdot Z_{eff}(\omega),$$

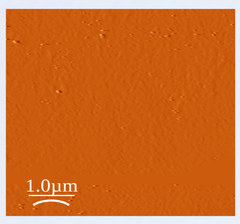


	n	k	d
Substrate Si	3.88	0.29	semiinfinity
First layer	3.12	0.26	500-900 nm
Second layer	1.43-1.48	→ 0	130 nm

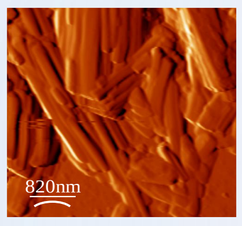
First layer is SiN_x conceivably
Second layer is SiO_2



AFM1



AFM2



$Ca[CH_2OH(CHOH)_4COO]_2$

$\downarrow O_2$

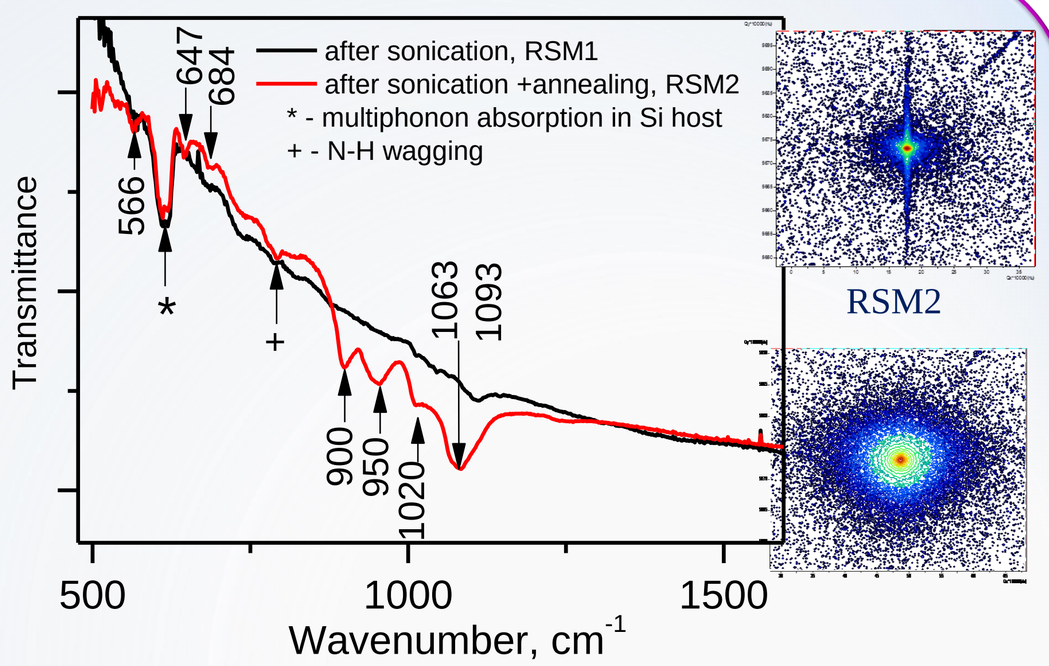
$CaO,\ C,\ CO_2\ ,\ H_2O$

$Si+O_2+CaO \xrightarrow{t°C} CaSiO_3$

$Si+O_2+2CaO \xrightarrow{t°C} Ca_2SiO_4$

$t = 1000\text{-}1200\ °C$

RSM1



μ-Raman spectra measured around localized defects after MHz sonication (15 W/cm², 30 min) and annealing: 1 - 336 cm^{-1}, 2 - 412 cm^{-1}, 3 - 642 cm^{-1}, 4 - 971 cm^{-1}. Spectrum of the untreated silicon is depicted as black. On the right of the μ-Raman spectra, the AFM images of the respective regions are depicted.

FTIR spectra point out to sonochemical synthesis of calcium silicate on Si substrate
Depicted vibration modes associated with β-$CaSiO_3$
According to M. HANDKE //APPLIED SPECTROSCOPY Volume 40, Number 6, 1986

- High-intensity sonication of silicon samples in the LN_2 was shown to induce functionalization of Si surface with calcium silicate,
- It leads to the formation of a complex optical system with two transition layers with thickness from 0.6 μm to 1 μm.
- Significant value rise and expansion of the spectral range of photosensitivity takes place also after cavitation treatment.