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The investigations of nanoclusters and micron-sized periodic structures created at the surface of the crystal and amorphous silica by resonant CO_2 laser irradiation

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Abstract. The creation of nanoclasters and micrometer sized periodical structures at the surface of silica (crystal quartz and fused quartz) by action of pulsed CO_2 laser radiation (pulse energy of 1 J, pulse time of 70 ns) have been investigated. The laser action on the surface of samples lead to appearance of two kind of structures – periodical micron-sized structures with the period length close to wave length of CO_2 laser irradiation and nanoclusters with size close to 50-100 nanometers. This creation connects with the intensive ablation of matter at the maxima of standing waves which are a results of the interference of falling and surfaces waves. This connects with the resonant absorption of infrared laser radiation by silicate minerals.

The appearance of nanoclasters and micrometer sized periodical structures at the surface of silica (crystal quartz and fused quartz) by action of pulsed CO_2 laser radiation (pulse energy of 1 J, pulse time of 70 ns) have been investigated. The samples was irradiated by CO_2 laser in two regimes – single-mode (fluency of 40 J/cm^2) and multi-mode (fluency of 48 J/cm^2) and with two laser frequency – 975 cm^{-1} and 1076 cm^{-1}.

The images of laser spots by means of the high resolution optical microscop and atomic force microscop have been made. It has been observed that by laser action on the surface of samples two kind of structures have appeared – periodical micron-sized structures with the period length close to wave length of CO_2 laser irradiation and nanoclusters with size close to 50-100 nanometers. It has been observed that the relief depth of the periodic structures depends on laser pulses number.The maximal highness of nanoclusters at the resonant frequency of laser (1076 cm^{-1}) has been observed.

The infrared (IR) reflection spectra and luminescence spectra of irradiated surface also have been recorded. The IR reflection spectra for irradiated samples show the enhancement

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of reflectance in the region of laser frequency with the band width of 20 cm^{-1} for crystal quartz. More high enhancements have been found at the frequency of 1076 cm^{-1}. It has been established that the reflectance enhancement has an accumulating character, namely, dependence of this ones on the number of laser pulses incident upon the samples take place. The luminescence spectra of irradiated sample have shown the lines in region of 380 nm for fused quartz and the line with two maximum - at 415nm and 440 nm - for crystal quartz. We believe that these spectra belong to silicon nanocrystals as long as these ones are similar to the luminescence spectra of silicon nanocrystals produced by other ways. It has been known that such spectra is associated with silicon nanocrystals having size from 2 nm to 10 nm [1, 2]. We suggest that the 50 – 100 nm sized nanoclusters mentioned above represent the aggregations of a silicon 2 – 5 nm sized nanoclusters .

We can made some conclusion:

- The periodical micro-and nano-structures in a crystal and amorphous silica have appeared because of interference of incident waves and surface waves induced by incident waves in resonant absorption media. That structures arise because of the increase of ablation velocity at the maxims of standing waves.
- Cumulative properties of periodical structures formation show us that the mainly ablation processes take place by laser action on silica surface.
- Dependence of relief depth from frequency of laser action shows that microstructure formation connects with the resonant interaction of CO_2 laser radiation with silicates. Intensive ablation in maxims of standing waves connects with the breaking of covalent oxygen – silicon bonds in region of laser action frequency what can be proved by IR spectra of irradiated samples [3].

References

1. V. Svrcek, T. Sasaki, Y. Shimizi, N. Koshisaki, Appl. Phys. Lett. **89**, 213113 (2006)
2. S. Yang, W. Cai, H. Zeng, Z. Li, J. Appl. Phys. **104**, 023516 (2008)
3. A. Mukhamedgalieva, A. Bondar, Proc. SPIE **2118**, 224 (1994)