Experimental and theoretical investigations of sonoluminescence

Sonoluminescence (SL) – a weak emission of a broad wavelength spectrum of light which appears when liquids are irradiated by ultrasound.

Sonoluminescence refers to acoustic cavitation – the ultrasound-driven formation, growth, and collapse of gas and vapor filled microbubbles. Violent collapse of the cavitation bubbles is accompanied by extremely large concentration of energy - up to 12 orders of magnitude. During the collapse the temperature and pressure inside the cavitation bubble increase up to values about 3000 - 5000 K (and more) and 300 – 500 atm, that lead to formation of a great number and a variety of excited state molecular and atomic species in the bubble.

The bubble collapse are also accompanied by white noise, shock waves, erosion of hard materials, rupture of living cells and, also, leads to sonochemical reactions.

In the last years, the cavitation bubble property to concentrate acoustical energy is widely used in sonochemistry, production of materials, ultrasonic cleaning, biology, and medicine. In sonochemistry, cavitation is used to enhance, assist, or induce chemical reactions that would not occur spontaneously. Processes, leading to SL and sonochemical reaction, are widely studying but not yet to be established in many aspects. Spectra investigation of SL is a unique tool for studying processes inside the cavitation bubble.

SL spectra shape is determined mainly by the chemical composition of a liquid and dissolved gas.

SL spectra are actively applied for studying sonochemical reactions . SL spectra can be also used to determine the concentration of ions in liquids.

In 1989 the experimental set up for studying SL spectra was created by our research group. In 1990 for the first time SL spectra of water, saturated with noble gases, have been measured taking into account spectral sensitivity of the detection system. During the subsequent years extensive experimental and theoretical investigations of SL have been carried out by our group. The results obtained are recognized and widely quoted in Russian and foreign scientific editions.

The main results of our investigations are the following:

- Intense emission band in ultraviolet region of SL spectra (between 200 and 300 nm) was discovered and systematically investigated. Discovery of a high-energy component of SL spectra testified that the energy inside the collapsing bubble was essentially higher than it was supposed before.
- A detailed scheme of the physicochemical processes inside the cavitation bubble was proposed for the SL emission spectra observed from water saturated with inert gases.
- Influence of ultrasound frequency and intensity, saturated gas properties, solution temperature, and internal pressure on SL spectra shape and intensity have been investigated and explained.
- For the first time it was experimentally shown, that the differences between single-bubble SL spectra (the regime of single-bubble SL was discovered in 1992 [Gaitan D.F. e.a., JASA, 1992]) and multibubble SL spectra was, probably, caused by a higher temperature inside the bubble in the case of single-bubble SL. The trends in spectra changes, observed in our study, imply that the source of both the regimes is molecular emission.
- Influence of hydrostatic pressure on SL spectra of aqueous alkali and earth metal salts solutions has been studied. It was found that the line emission from exited state metal atoms grows rapidly with the increase of hydrostatic pressure. The discovered effect is due to higher temperature inside the cavitation bubbles and allows to improve the sensitivity of SL as the method for determination the concentration of ions in liquids.

Basic references

1. Didenko Y. T., Gordeychuk T. V., Koretz V. L. The effect of ultrasound power on water sonoluminescence // J. Sound Vibr. 1991. V. 147, N 3. P.409-416.
2. Didenko Y. T., Pugach S. P. Spectra of water sonoluminescence // J. Phys. Chem. 1994. V. 98, N 39. C . 9742-9749.
3. Didenko Y. T., Nastich D. N., Pugach S. P., Polovinka Y. A., Kvocka V. I. The effect of bulk solution temperature on the intensity and spectra of water sonoluminescence // Ultrasonics. 1994. V.32, N 1. P. 71-76.
4. Didenko Y. T., Pugach S. P., Gordeychuk T. V. Spectra of water sonoluminescence: The effect of ultrasound power // Optics and Spectroscopy. 1996. V. 80, N 6. P.821-826.
5. Gordeychuk T. V., Didenko Y. T., Pugach S. P. Sonoluminescence spectra of water in high and low frequency sound fields // Acoustical Physics. 1996. V. 42. N 2. P. 240-241.

6. Didenko Y. T., Gordeychuk T. V. Multibubble sonoluminescence spectra of water, which resemble single-bubble sonoluminescence // Phys. Rev. Lett. 2000. V. 84, N 24. P. 5640-5643.
7. Gordeychuk T. V. The application of sonoluminescence spectra for the determination of chemical composition of liquids // Atmospheric and Oceanic Optics. 2005. Т. 18, N 01-02. С. 188-190.
8. Казачек М.В., Гордейчук Т.В. Оценка пикового давления кавитации по структуре D-линии Na в спектрах сонолюминесценции // Письма в ЖТФ. 2009. Т. 35. Вып.4. С. 87-94.
9. Гордейчук Т.В., Казачек М.В. Экспериментальное наблюдение интенсивного роста сонолюминесценции металлов под влиянием давления и температуры // Оптика и спектроскопия. 2009. Т. 106. № 2. С. 277-280.
10. Gordeychuk T.V., Kazachek M.V. The effect of hydrostatic pressure and temperature on sonoluminescence of metal atoms from aqueous salt solutions // NONLINEAR ACOUSTICS – FUNDAMENTALS AND APPLICATIONS. AIP, 2008. P. 201–204.
11. Гордейчук Т.В. Сонолюминесценция воды // Дальневосточные моря России. М.: Наука, 2007. Кн. 4: Физические методы исследования / отв. ред. Г.И. Долгих. М.: Наука, 2007. 628 с. С. 232-248.

Figure shows a part of experimental installation for measuring sonoluminescence spectra. The ultarsound cell is at the centre