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TEMPERATURE DEPENDENCE OF MULTIBUBBLE SONOLUMINESCENCE AT DIFFERENT ULTRASOUND INTENSITIES

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Depending on insonation conditions, the sonoluminescence intensity generated by multibubble cavitation field increases, exhibits a maximum or decreases with increasing the temperature (temp.). The differences in the temp. dependencies are explained by the competing effect i) the increase of the number of cavitation events (collapses) per unit time and ii) the decrease of the efficiency of collapses due to the bubble interactions, the screening action of cavitation, the surface tension decrease and the vapor pressure increase of the liquid.

Keywords: ultrasound (US), sonoluminescence, cavitation.

The available data on the temp. dependence of the cavitation activity (evaluated, for instance, by the sonoluminescence intensity or by the yield of the sonochemical reactions) are contradictory [1–5].

Thus, in refs. [1] the data obtained are indicative of the increase of the SL intensity with an increase of the temp. In [2,3] the authors report about maximum in the SL output as a function of the temp. and in [4] – about decrease.

The experimental set-up used in this work is described in details elsewhere [6]. A focusing 40 mm diameter piezoceramic transducer with a resonance frequency of 880 kHz is mounted at the bottom. The central region of the chamber is viewed by the photomultiplier whose output is indicated by L.

In Fig. 1 SL intensity is given as a function of the transducer voltage U for different liquid temp. q.

It follows from Fig. 1 that with the temp. the SL voltage threshold increases, i.e. sonoluminescence appears at higher transducer voltages (volt.). However, the maximum of the SL intensity obtained by the variation of the transducer voltage increases by decreasing the temp.. The position of the curves (U) relatively each other changes as well (regions I, II and III in Fig. 1). At low transducer volt. the SL intensity increases with temp. growth (curve 1). At high driving volt. (curve 3) the SL intensity decreases with increasing the temp. At the intermediate intensities (curve 2) L reaches a maximum and then decreases. Fig. 2 shows the temp. dependencies of SL intensity obtained at the volt. U of regions I, II and III in fig. 2.

Here, three sonification regimes exist as judged from the SL temp. dependencies. At low transducer volt. the SL intensity increases with temp. growth (curve 1). At high driving volt. (curve 3) the SL intensity decreases with increasing the temp.. At the intermediate intensities (curve 2) L reaches a maximum and then decreases.

To explain the indicated differences in the temp. dependencies, we call attention to the fact that the decrease of the cavitation activity at high bubble volume concentrations can be induced by the reasons discussed earlier. These, first of all, are the screening action of cavitation and interbubble impact. The increase of the intensity of bubble interactions will increase the probability of the bubbles deformation and their collapse in a nonspherical way.

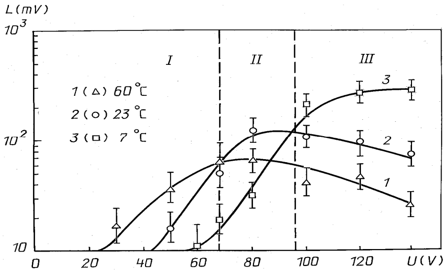

Fig. 1. SL intensity L versus transducer voltage U for different temp.s q: q = 60°C (2), 23°C (3), 7°C (3); f = 880 kHz, pulsed sonification, US pulse duration t = 3 ms, pulse period T = 30 ms; liquid – distilled water

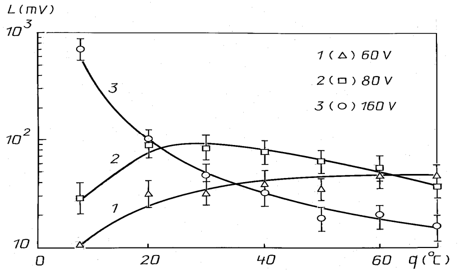

Fig. 2. SL intensity L versus temp. q of distilled water for different driving volt. U: U = 60 Volt (1), 80 Volt (2), 160 Volt (3); f = 880 kHz, t = 3 ms, T = 30 ms**.** SL threshold voltage is 58 Volts at q = 7 for this experimental conditions

The latter decreases, according to, the efficiency of energy concentration by bubbles thus decreasing the SL intensity. The increase of the vapor pressure P_v and the decrease of the surface tension σ of the liquid with temp. promotes decreasing bubbles collapse rate.

Thus, with increasing the liquid temp., the SL intensity experiences the influence of two competing factors associated with the increase of the volume density and the amount of cavitation bubbles. These are the increase of the number of cavitation events (collapses) per unit time, on one hand, and the decrease of the efficiency of concentrating the energy by bubbles upon collapse, on the other hand. The latter is caused by enhancement of the bubble interactions, the increase of the vapor - gas mixture pressure P_v inside them and the decrease of the surface tension σ and enhancement of the screening effect of cavitation.

Regions I, II and III in Fig. 1 correspond to the following conditions which differ, apparently, by a degree of saturation of the cavitation zone by active bubbles.

(I) At low US intensities the number of cavitating bubbles is small and the SL intensity is low. The temp. increase entails the decrease of the cavitation threshold, the increase of the amount of collapsing bubbles and, correspondingly, the increase of the SL intensity despite the possible decrease of a rate of collapses as a consequence of decreasing σ and increasing P_v. In this US intensity range the increase of cavitation events per unit time is the prevailing factor.

(II) The intermediate intensities correspond to the onset of avalanche - like bubble multiplication. With increasing the temp. an amount of bubbles quickly increases and reaches the saturation state. Therefore, SL intensity after achieving maximum decreases.

(III) At high US intensities the cavitation zone is saturated by bubbles already at a low temp. and therefore the increase of bubbles volume density by the increase of the temp. can only decrease the SL intensity (curves 3 in Fig.s 3 and 5). In this US intensity range the dominant factor is the decrease of the efficiency of collapses.

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