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The Piezoelectric Droplet Generator –A Versatile Tool for Dispensing Applications and Calibration of Particle Sizing Instruments

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Abstract

In many technical and scientific applications it is essential to generate droplets of high uniformity and constant size. In this paper the piezoelectric droplet generator will be introduced. The main working principles and the setup of the droplet generator will be described and measuring results will be presented.

The piezoelectric droplet generator formes droplets of high uniformity and quality in a wide diameter range. The droplet generator is also characterized by an excellent long time stability and low fabrication and maintenance costs.

Introduction

In numerous applications of pharmacy, biotechnology or particle sizing it is imperative to generate small droplets of high uniformity, constant size and form [1]. To form droplets of this feature, two kinds of droplet generators, continuous jets and piezoelectrical generators -also called “droplet on demand generators”- have been developed. Variations in droplet size or deformed droplets result in wrong dosage or in measuring error (caused by wrong calibration) [2].

Using a continuous jet the liquid is pressed through a nozzle with high pressure. The stream disintegrates into series of droplets [3]. The droplet diameter can be varied in a wide range. The disadvantages using a continuous jet are the poor reproducibility and the low variety of the droplet rate. Furthermore, a great volume of liquid is required to generate the droplets. To avoid these disadvantages we developed a piezoelectric droplet generator, which is suitable for several applications.

Droplet on demand generators were first used in applications including ink-jet printing [4], [5]. The development of droplet on demand generators is summarized in [6]. New fields of application of piezoelectric droplet generators are described in [7] (biotechnology), [8], [9] (particle sizing) and [10].

The droplets are formed at the orifice of a glass capillary embedded in a piezoelectric tube, which is contracted by an applied voltage puls. Small droplets (diameter <100µm) with a droplet rate from single shot up to kHz can be formed. Other advantages are the high uniformity and reproducibility of the droplets, so that a precise dosage of the dispersed liquid or an exact calibration of particle sizing instruments is possible. Furthermore, only a small volume of liquid is necessary to generate the droplets.

In this paper the great variety, the good (long-time) stability and the reproducibility of piezoelectric droplet generation will be demonstrated by some experimental results.

Setup and working principles

The piezoelectric droplet generator used in this study consists of a glas capillary embedded in a piezoceramic tube, fixed in a holding device. The piezoceramic tube are connected to an electronic signal generator. The capillary is linked up with the liquid-reservoir by a tube.

The orifice diameter of the capillary is responsible for the size of the generated droplets. The user can determine the droplet diameter by varying the nozzle of the capillary. Droplets in a diameter range between 10µm to 100µm can be generated. The face of the outlet of the capillary should be of good quality, because it is crucial for a stabile operation.

Applying a voltage puls to the piezoceramic tube, the tube and the capillary are contracted and the droplet is ejected. Amplitude, duration and type of the pulse have to be tuned to the dispensed liquid and the used capillary for stabile operation. The frequency of the pulse determines the droplet rate and can be set from single shot to 6kHz, so single droplets, accumulation of droplets and chain of droplets can be generated .

The droplet generator is suitable for different kind of liquids: water, alcohol, ink, emulsions and suspensions. If necessary, the reservoir can be heated to disperse liquids with higher viscosity. Using a “multiple piezoelectric droplet generator”, consisting of ten capillaries instead of one, different liquids can be dispensed or droplets with a defined size distribution can be generated.

Experimental Results

The piezoelectric droplet generator is characterized by its high stability and reproducibility. Fig. 1 shows experimental results of 21µm, 53µm 86µm water droplets obtained by phase-Doppler-anemometry (PDA) measurements. The standard deviation amount to 0.4µm for the 53µm and to 0.8µm for the 21µm and 86µm droplets. Droplet volume of 5pl can be obtained. The data are based on 10,000 measured droplets. The long-time stability was controlled for a duration longer then 100 hours.

In Fig. 2 photos of water droplets (left side) and of water-glycerol droplets (right side) with a glycerol concentration of 84wt.-% glycerol are presented. Pictures a) and b) show the generation of the droplets on the nozzle. On account of the higher viscosity of the water-glycerol solution the droplets form a tail near the nozzle.

In pictures c) and d) the stabile droplet is illustrated. The piezoelectric droplet generator is suitable for liquids with a viscosity up to 150mPas. The stability was checked for several hours of continuous operation.

Also other kind of liquids suspensions and emulsions were successful dispersed by the piezoelectric droplet generator (not shown here).

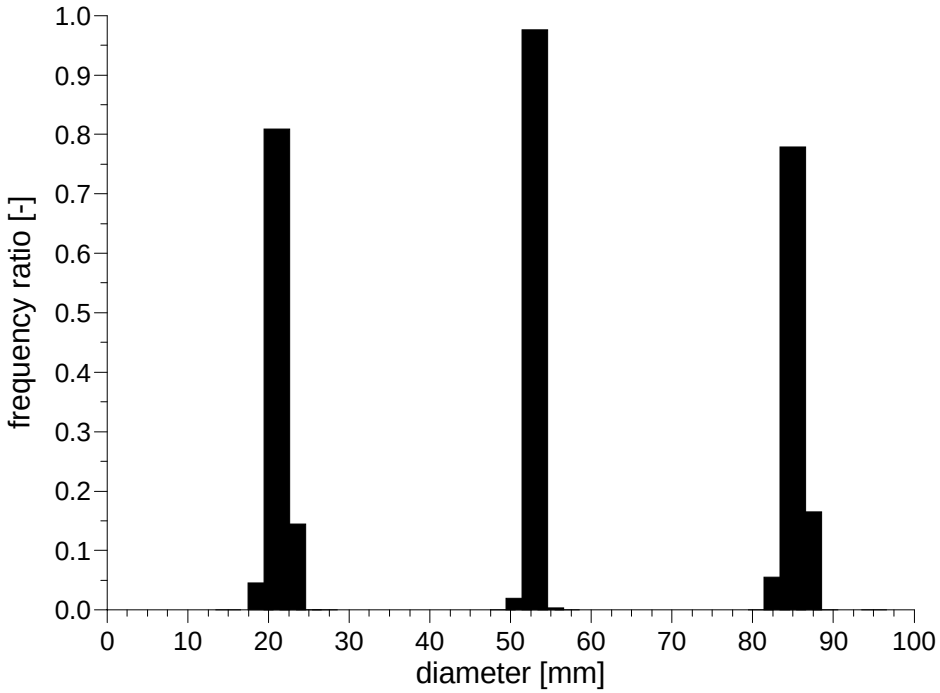

Figure 1: Distribution of droplet diameter for 21µm, 53µm and 86µm water droplets

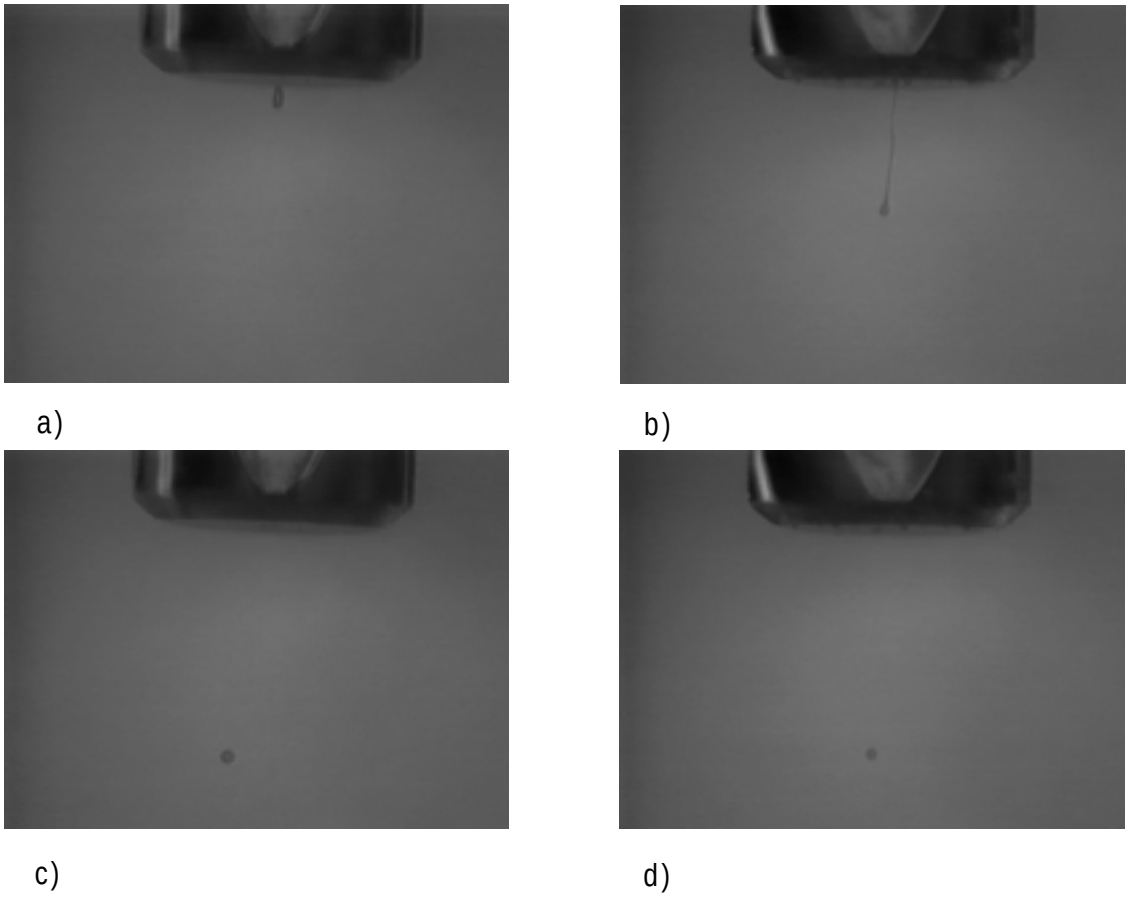

Figure 2: Photos of 44µm water and water-glycerol (84 wt-% glycerol) droplets a), b) droplet generation c), d) stabile droplet

Conclusion

In this paper the piezoelectric droplet generator was introduced and its properties were shown by experimental results. Droplets of high uniformity and quality in a diameter range between 10µm and 100µm can be generated. A droplet rate up to 6kHz can be selected by the user. The droplet generator is suitable for different kind of liquids like water, alcohol, ink, emulsions and suspensions. The piezoelectric droplet generator is also characterized by an excellent long time stability (over 100 hours), simple maintenance and low fabrication and maintenance costs.

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