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# A MODIFIED YOUNG-LAPLACE EQUATION FOR THE BUBBLE ELECTROSPINNING CONSIDERING THE EFFECT OF HUMIDITY

by

**Fu-Juan LIU\* and Hao DOU**

National Engineering Laboratory for Modern Silk, College of Textile and Engineering,  
Soochow University, Suzhou, China

Short paper

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*Polymer bubbles can be used for green mass-production of environmental friendly nanofibers with less energy consumption than any other classical methods. A modified Young-Laplace equation is derived considering the effect of humidity. The paper concludes that the humidity is an effective parameter in controlling the spinning process.*

Key words: bubble electrospinning, humidity, nanofibers, surface tension

## Introduction

The electrospinnability of classical electrospinning [1-3] mainly depends on solution properties, e. g. the viscosity, which affects nanofiber morphology, size and its mechanical characters. Nevertheless, that of bubble-electrospinning [4-6] lies geometrically on sizes of produced bubbles, which avoid using a very high voltage, so the bubble electrospinning is the best candidate in the green production of nanofibers in the present time. To reveal this, we begin with the Young-Laplace equation, which describes the surface tension  $\sigma$  of a bubble [7, 8]:

$$\sigma = \frac{1}{4} r (P_i - P_o) \quad (1)$$

where  $r$  is the radius of a bubble and  $P_i$  and  $P_o$  are the air pressures inside and outside the bubble, respectively.

It is interesting to note that the tension depends upon its size and pressure difference, the later can be suitably adjusted using moist air and temperature according to the state equation.

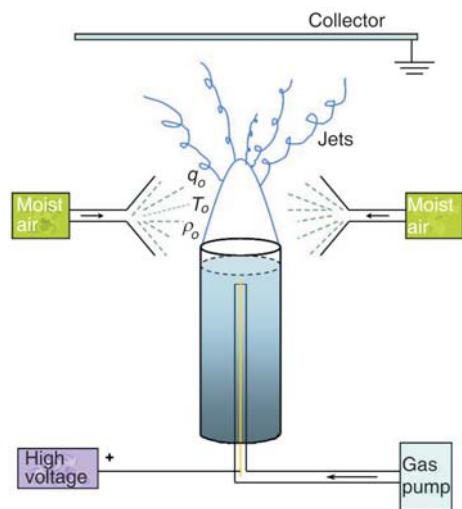
## Effect of humidity on the surface tension of a bubble

According to the state equation of moist air [9], the gases inside and outside of the bubble satisfy, the following relationships  $P_i/\rho_i = R_d(1 + 0.61 q_i)T_i$  and  $P_o/\rho_o = R_d(1 + 0.61 q_o)T_o$ , where  $R_d$  is the dry air constant,  $T$  – the temperature,  $\rho$  – the density,  $q$  – the specific humidity, defined as  $q = m_v/(m_d + m_v)$ , where  $m_v$  and  $m_d$  are the mass of water vapor and dry air, respectively. The subscripts i and o mean the inner and outer of the bubble, respectively (fig. 1).

By a simple derivation, we obtain a modified Young-Laplace equation, which is:

$$\sigma = \frac{1}{4} r R_d [(1 + 0.61 q_i) T_i \rho_i - (1 + 0.61 q_o) T_o \rho_o] \quad (2)$$

\* Corresponding author; e-mail: liufujuan@suda.edu.cn



**Figure 1.** The set-up of bubble electrospinning

Equation (2) implies obviously that the surface tension is proportional to inner moist, while it is inverse to the outer moist. In order to reduce the surface tension, gas pump generates dry air inside the bubble, meanwhile, humidification is done around the bubble (fig. 1). However, too high humidity is not conducive to the spinning based on real experiment. Therefore, a suitable choice of  $q_i$  and  $q_o$  can reach a minimum of the surface tension, which is very necessary and beneficial to the spinning process by losing much less energy for overcoming the surface tension. This property can be used for green fabrication of nanofibers.

### Conclusions

As a result, surface tension reduces significantly by adjusting humidity inside and outside of the bubble, which is beneficial to energy saving and the green fabrication of ultrafine fibers.

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