สำนักงานวิทยทรัพยากร จุฬาลงกรณ์มหาวิทยาลัย

CHAPTER III
EXPERIMENTAL

3.1 Experimental Set up

The experimental unit used in this study consisted of three main parts: a light source, droplet generator, and image capture unit as shown in Figure 3.1.

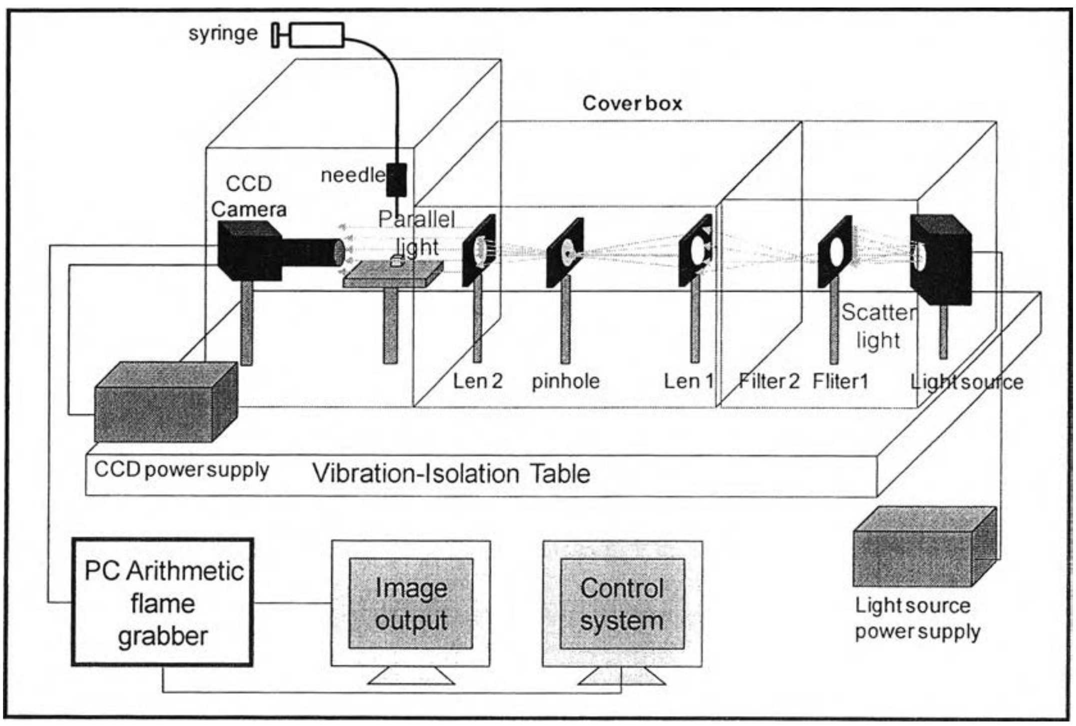

Figure 3.1 Experimental set-up in this study

3.1.1 Light source unit; The light source unit was composed of a light generator and series of lens. The light was generated by an 100W (ORIEL) an electric bulk passing through a series of lens. It firstly passed through 1% filter which allowed only one percent of light pass through filter. After that, the filtrated light passed through the 1st convective lens in order to focus light into one spot. The pinhole was set up behind the 1st convective lens to spot light into one spot. After the light passed through the pinhole, it parallelized by the 2nd convective lens which was set up oppositely with the 1st convective lens. The parallel light with circular shape was confirmed by measuring the light area at three different distances.

In order to obtain parallel light, a laser beam was used and set in the straight line toward the CCD camera. The perfect parallel light was found to be produced as confirmed by the same light area at any distance position. The light source unit set up is shown in Figure 3.2.

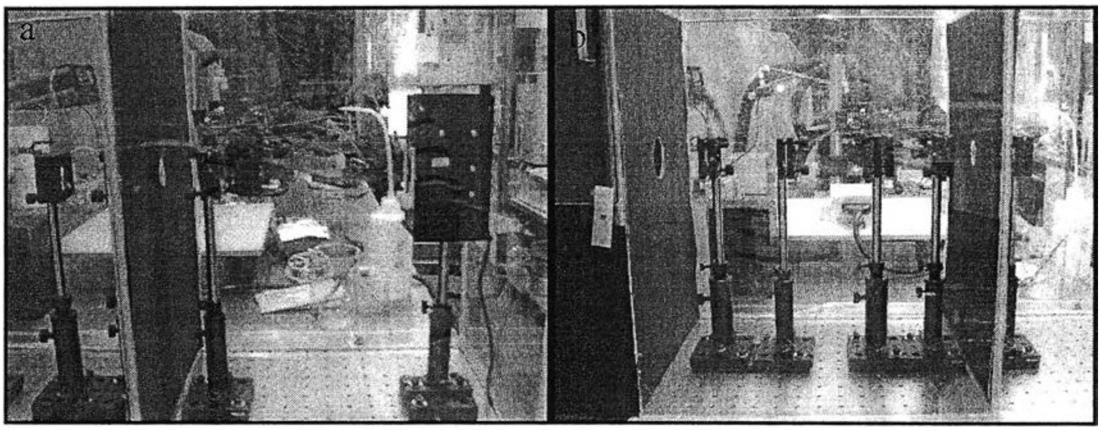

Figure 3.2 Set up of a) Light source b) series of lens and filter

3.1.2 Droplet generator unit; It consisted of a holding arm, plastic tube, needle, solid surface, and straight syringe. The syringe was held by the holding arm. This holding arm could be adjusted the needle position both in horizontal and vertical direction to as shown in Figure 3.3. The water was produced by pumping water through a plastic tube connected to the syringe using a micro pump (Hamiton, model). A water droplet was carefully generated at the tip of the needle. Three sizes of water droplets were generated by using different needle gauges (Needle: guage#31 I.D. 0.13 mm, guage#25 I.D. 0.26 mm, and duage#23 I.D. 0.31 mm).

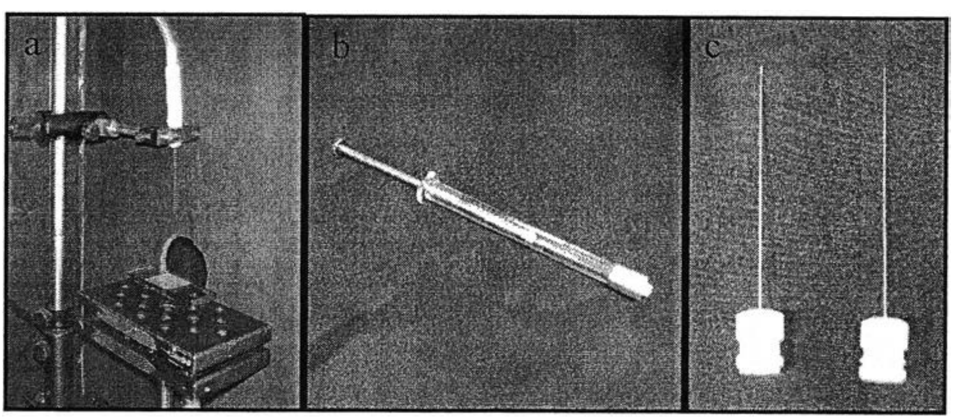

Figure 3.3 a) A droplet generator unit, b) syringe, and c) needles

3.1.3 Image capture unit; It consisted of a high-speed solid state CCD camera, with CCD camera linear power supply, PC arithmetic frame grabber, and two output monitors; one was used to control PC arithmetic frame grabber and another one was used to display experimental results, as shown in Figure 3.4. the High-speed solid state CCD camera as shown in Figure 3.5 had 64×64 pixel both in vertical and horizontal directions. It was set at 256 gray levels with a maximum speed of 2900 images per sec.

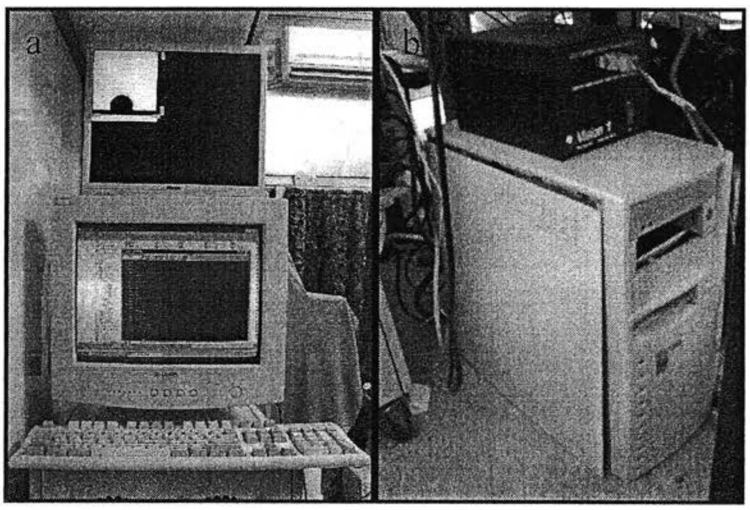

Figure 3.4 a) Monitors and b) Computer and CCD camera power supply

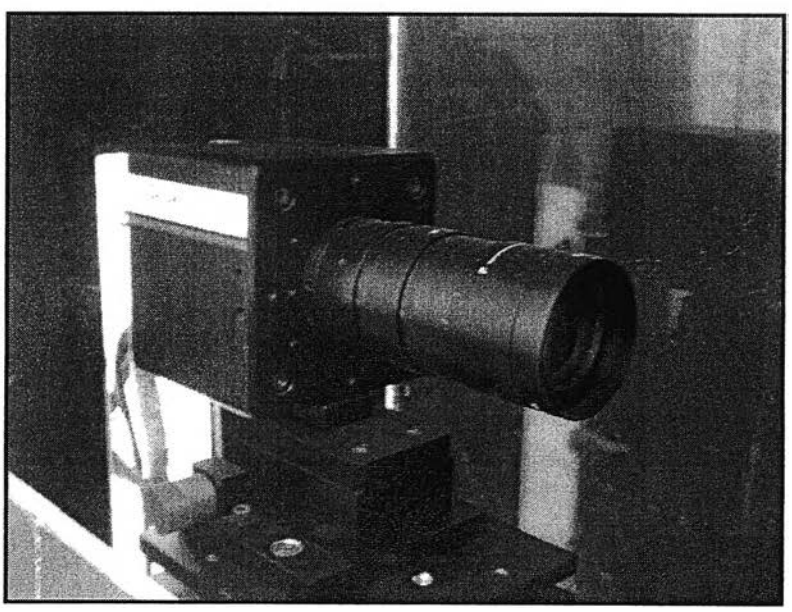

Figure 3.5 High-speed solid state CCD cameras

3.1.3 Support unit; It composed of a vibration-isolation table which was used to eliminate any external vibration such as foot step and a cover box which was wrapped with black paper to eliminate wind and light effects because this system was very sensitive to wind and light. Wind could affect droplet position and Light could affect gray level calculation. The photos of the cover box and vibration-isolation table are shown in Figure 3.6. During the experiment the system temperature was controlled constantly at 25 °C.

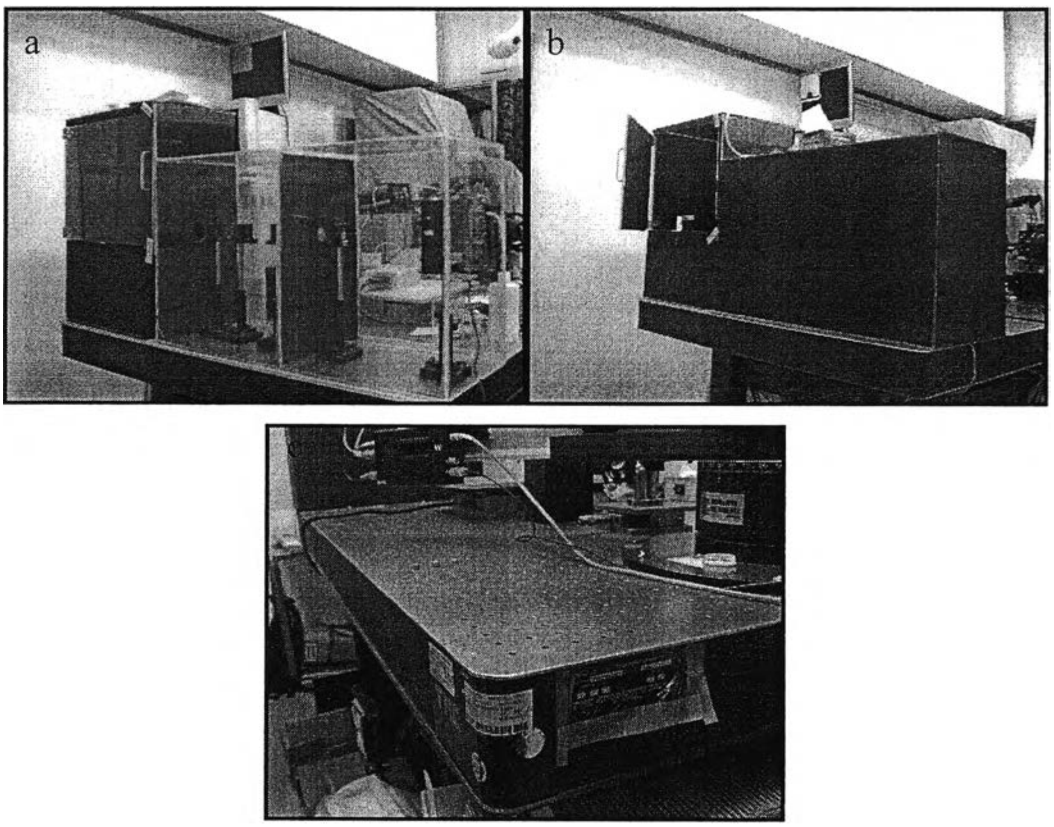

Figure 3.6 a) Cover box before wrapped with black paper b) Cover box after wrapped with black paper and c) Vibration-Isolation table

3.2 Studied Liquid and Solid Substrate

Ultra high purify water used in these studies was produced by using a reverse osmosis and deionization technique (Barnstead, model). This water used was freshly prepared for each experiment.

As shown in Figure 3.7, the super-hydrophobic film of plasma-treated polypropylene film coated on a glass surface was done by 3 sequential steps. The first step was to attach the polypropylene film and glass surface. To attach the polypropylene film onto the glass surface, twin adhesive tape was used. The second step was the plasma treatment with oxygen at 15 sccm and followed by Ar at 5 sccm at 40 mtorr pressure and 50 W power for 3 min. For the third step, the surface was treated by using CF_4 plasma at 10 sccm, at 35 mtorr pressure and 10 W power for 10 min. After the surface treatment, the surface had the contact angle with pure water of 140^o and at 25^oC.

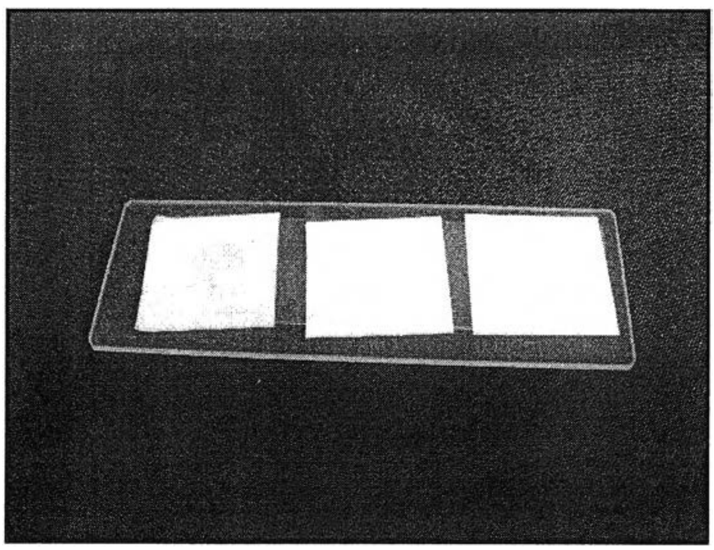

Figure 3.7 Plasma-treated polypropylene film coated on a glass surface

3.3 Experimental Procedure

With the high-speed solid state CCD camera, water droplet images were captured during the water droplet approaching and rebounding on the solid surface. The experimental procedure was divided into 2 sequential steps; data grabber and droplet analysis.

3.3.1 Image Record

First, the needle was position in the focus length of the CCD camera to obtain the sharpest and clearest images. The needle had to be set up at the center of the camera frame in order to obtain the clear water droplet impact phenomena. After the needle position was adjusted at any designed height, water was carefully pumped through the plastic tube to generate a water droplet at the tip of the needle. And finally the water droplet fell by the gravitational force. Three different sizes of needles were used to obtain different mass of the falling water droplet.

As soon as the water droplet left the needle's tip, the CCD camera was turn on with the maximum speed of 2900 images per second to capture images of the water droplet until the water droplet did not rebound. The PC frame grabber was set gray level at 127 out of 0 to 255 which was the default value. The Zero gray level value indicates the blackest color. On the other hands the, 256 level indicates the whitest color. Edge location scanning was separated and stored into 4 data sets. The 1^{st} data set was scanned from left to right, The 2^{nd} data set was scanned from right to left. The 3^{rd} and 4^{th} data set were scanned from top to bottom and bottom to top, respectively. The Four sets of data were combined to obtain one water droplet image.

3.3.2 Image analysis

For the image analysis, the four sets of data were combined using the Microsoft Excel in order to arrange data into correct position. Then, data were analyzed by using the GRAPHER 4.0 program to plot edge location at this step aspect ratio of 0.9852 and real scale of 0.1199 mm/pixel that was obtained from the ball calibration step. Hence it convert pixel to millimeter unit which was easier for the image analysis.

Figure 3.8 shows a typical image of a water droplet taken by the CCD camera and demonstrates how to obtain the edge location of the water droplet. The obtained edge location data was then imported to the 2007 AutoCAD simulation program. In this step, each water droplet was cut into two half in the vertical direction (or y direction), as shown in Figure 3.9. Then both left and right halves were revolved for 180 degree in vertical direction. After combining both half together, the center of mass and droplet volume were obtained. The radius of each water droplet was calculated from the initial stage before water droplet impact onto the solid surface by using $V = 4/3\pi R^3$. At this initial stage, the water droplet was found to be spherical more than those in the other stages.

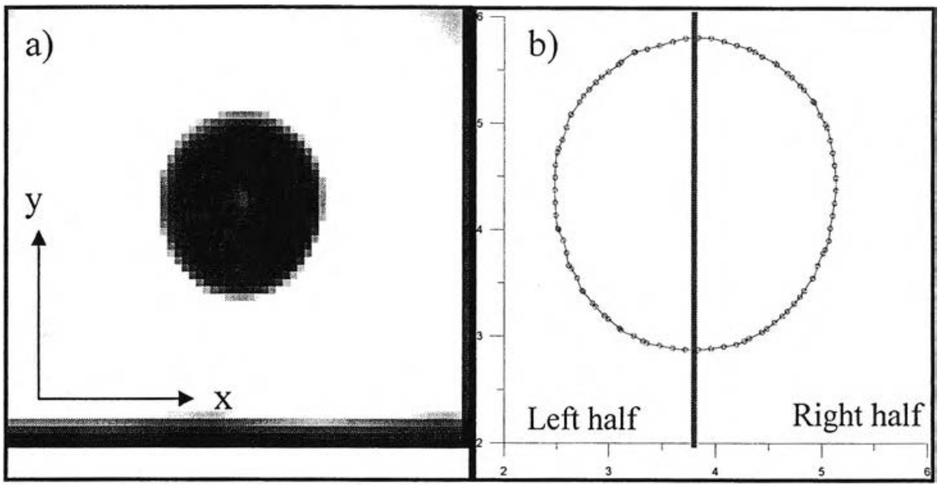

Figure 3.8 a) Image of water droplet taken from the high-speed solid state CCD camera, b) Plot of edge location using the GRAPHER 4.0 program.

Figure 3.9 shows the simulated images of two halves of a water droplet using the 2007 AutoCAD simulation programs and Figure 3.10 shows the simulated image of the whole water droplet.

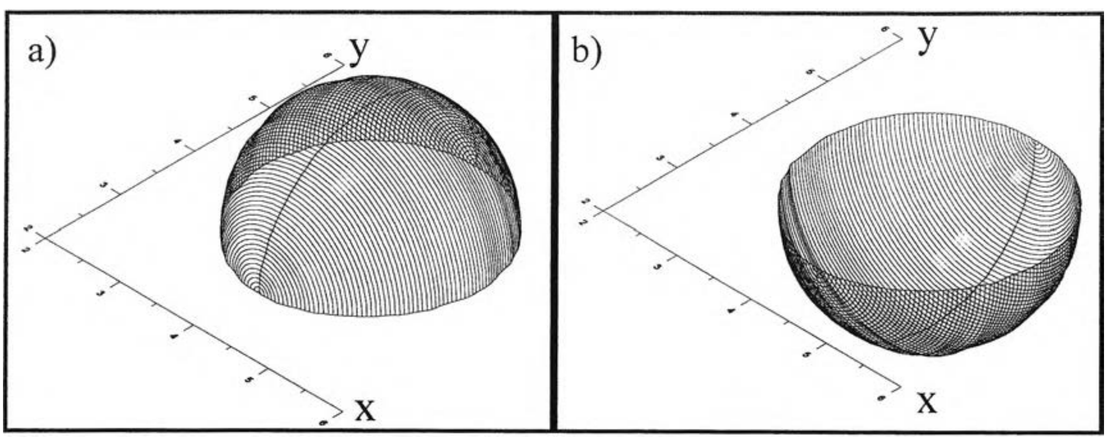

Figure 3.9 Simulated water droplet from 2007 AutoCAD a) Left half, b) right half.

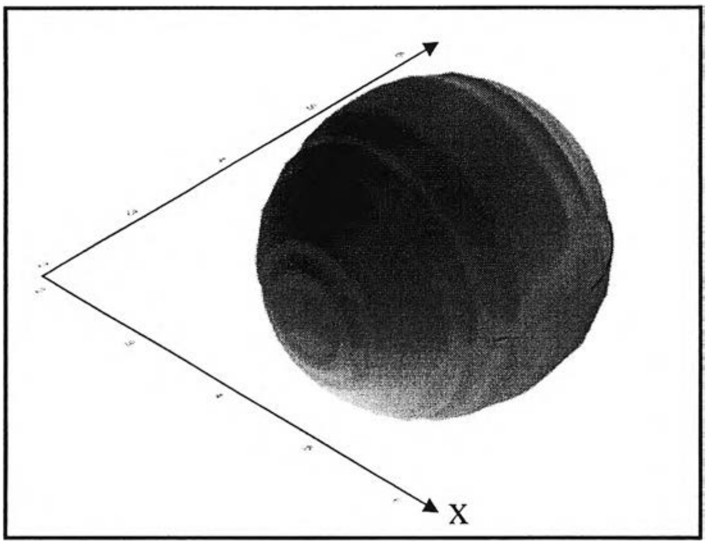

Figure 3.10 Combine of simulated water droplet from 2007 AutoCAD simulation program.