

Wettability Difference Induced Out-of-plane Unidirectional Droplet Transport for Efficient Fog Harvesting

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ABSTRACT

Securing freshwater resources is a global issue for ensuring sustainable development. Fog harvesting is attracting great attention as a method to collect water without any energy input. Previous reports that were inspired by insects and plants have given insights such as the effectiveness of in-plane wettability and structural differences for droplet transport and it might enhance artificial water harvesting efficiency. However, further efforts to transfer droplets while maintaining performance are needed because droplet motion owing to these effects are limited on the in-plane direction. In the present study, we report droplet transport between three-dimensional copper wire structures with nanostructured hydrophobic and superhydrophilic features. This mechanism enhanced the fog harvesting capability by more than 20% compared with the cumulative value of individual wires. In addition, the relationship between droplet height and spacing of wires affected the performance. Our results show the importance of out-of-plane directional droplet transport from the wire surface assisted by differences in wire wettability, which minimizes limiting factors of fog harvesting including clogging and droplet shedding. Furthermore, the proposed arrangement reduces the overall system width compared with that of a two-dimensional arrangement while maintaining the amount of harvested water. These results provide a promising approach to designing large-scale and highly efficient fog harvesters.

Keywords: fog harvesting, wettability difference, unidirectional droplet transport, projected area, vertical copper wires

1. INTRODUCTION

Water is one of the most important resources for human life but more than 2 billion people live under environments with high water stress. [1] Furthermore, demand for water is increasing owing to the growth of population, agricultural land use, and industry. [2, 3] To overcome these issues and achieve sustainable development requires alternative water resources from rivers, lakes, and groundwater. In the past few decades, various research efforts such as desalination [4] and reverse osmosis [5] have provided techniques to use seawater and wastewater; however, availability of these water sources and additional energy that must be supplied is limited. Other approaches such as atmospheric water harvesting can generate water resources in the absence of a water supply by collecting water by adsorption of moisture in the air. [6] However, this process still requires an additional energy input for desorption. As an alternative approach to tackling both problems, fog harvesting has drawn great interest because it works in the absence of any energy input though the performance depends on the season and location. [2, 7, 8]

On this basis, many types of fog harvester have been investigated. In particular, bioinspired materials have been developed on the basis of natural structures present in insects and plants. [9-13] For example, a hydrophobic-hydrophilic combination surface inspired by the Namib desert beetle [9] has been reported based on patterning of various wettabilities [14-17] to enhance its performance. These surfaces attract water at a hydrophilic part and also repel water at a hydrophobic part. Systems based on these approaches have shown better performance than surfaces with uniform wettability. A spindle-knotted fiber inspired by spider silk [10] provides another possibility for fog harvesting

1 because the gradient of Laplace pressure drives attached droplets. [18-21] In addition, this mechanism
2 is expected to have a synergic effect with the gradient of wettability. [22] Thus, conical spines such
3 as cactus thorns [23, 24] and plant thorns [25] with a hydrophobic tip and hydrophilic root are
4 promising materials because droplets are expected to transfer from the tip to the root side. It has been
5 reported that both these mechanisms can contribute to the droplet motion and enhance water
6 collection. [26-30]

7 Although a greater knowledge of those mechanisms will be helpful for designing efficient
8 artificial fog harvesters, harvesters should also be scalable to enable collection of sufficient amounts
9 of water. However, the scale of these mechanisms is small because of the requirement for an adequate
10 Laplace pressure difference or wettability gradient to drive a droplet. In addition, large-scale fog
11 harvesters, such as meshes or multiwire systems have a characteristic problem, clogging. [31-33]
12 This effect changes the local fog stream and aerodynamic force, which leads to low efficiency or in
13 the worst case, the harvester might be damaged or broken. Thus, appropriate droplet removal method
14 is required to realize a high harvesting capability.

15 Recently, meshes and surface structures that have hydrophobic/hydrophilic cooperative
16 Janus systems have been proposed. [34-37] These collect fog droplets through a hydrophobic
17 harvester and the attached large droplets are transferred to a hydrophilic backing. For example, Cao
18 et al. combined hydrophobic mesh and hydrophilic cotton absorbent to construct such a system and
19 they confirmed unidirectional transport of submillimeter-scale droplets. [37] In addition, previous
20 reports have revealed improvements in fog harvesting performance. However, the effects of the

wettability difference on droplet behavior have yet to be verified.

In the present study, we investigate unidirectional droplet motion and fog harvesting performance of a three-dimensional unit composed of three wires with different wettabilities. We found that a large wettability difference contributes to unidirectional droplet transport and the amount of harvested water was increased by more than 20% compared with the cumulative value estimated from the performance of individual wires. However, liquid bridges generated between wires with inadequate wettability differences inhibited fog harvesting. In addition, the dependence of fog harvesting on the arrangement of wires suggests the possibility of optimizing the design for efficient fog harvesting.

2. EXPERIMENTAL METHODS

Materials. Copper wire with diameter of 0.5 mm was used. A copper substrate ($15 \times 15 \times 1$ mm) was also used to evaluate the wettability. Ethanol, hydrochloric acid (HCl), sodium hydroxide (NaOH), ammonium persulfate ((NH₄)₂S₂O₈), and sodium hydrogen carbonate (NaHCO₃) were purchased by Fujifilm Wako Pure Chemical Co.. Teflon AF 1600X was acquired from Mitsui-DuPont Fluorochemical Co. and used as the hydrophobic coating material. FC-770 purchased from Hayashi Pure Chemical Ind. Ltd. was used as a solvent. 6-Mercapto-1-hexanol obtained from Sigma-Aldrich was used as a hydrophilic coating material.

Sample preparation. To investigate the fog harvesting performance, five types of samples with different wettabilities were prepared. All samples were fabricated from copper wire with a length

of 65 mm. All wires were first ultrasonically washed in ethanol for 15 min to clean the surface and rinsed with purified water from a water purification system (CPW-102, Advantec Co., Japan). The following procedures were applied to each sample.

Type 1. The wire was immersed in aqueous 6 M HCl for 20 s to remove the native oxide layer. The wire was then immersed in an aqueous solution of 2.5 M NaOH mixed with 0.1 M $(\text{NH}_4)_2\text{S}_2\text{O}_8$ for 20 min at 4 °C to form surface nanostructures, followed by dipping into an ethanol solution of 6-mercapto-1-hexanol at a concentration of 10 mM for 5 min. The wire was then rinsed with ethanol and purified water, followed by drying with a compressed air stream.

Type 2. An ultrasonically cleaned wire was soaked in an ethanol solution of 6-mercapto-1-hexanol at a concentration of 10 mM for 5 min and then rinsed and dried as for the sample type 1.

Type 3. The wire was immersed in FC-770 solution with 0.5 wt% Teflon AF 1600X for 30 s. The treated wire was then baked at 90 °C for 60 min to reveal the hydrophobic properties.

Type 4. The native oxide layer on the wire surface was removed by 6 M of HCl aqueous solution followed by immersion in aqueous solution of 2.5 M NaOH and 0.1 M $(\text{NH}_4)_2\text{S}_2\text{O}_8$ for 20 min at 4 °C. The treated wire was then baked at 180 °C for 2 h to convert the $\text{Cu}(\text{OH})_2$ into CuO. Finally, the wire was coated with Teflon according to the procedure described above.

Type 5. After the removal of the native oxide layer, the wire was immersed in aqueous solution of 0.1 M NaHCO_3 and 0.02 M $(\text{NH}_4)_2\text{S}_2\text{O}_8$ for 24 h at 24 °C to fabricate the surface nanostructure. Then the wire was rinsed with purified water, followed by the hydrophobic coating, described above.

The same procedures were applied to the copper substrate samples to fabricate each of the surfaces, which were then used to evaluate the surface wettabilities.

Sample characterization. Chemically treated nanostructures were characterized by scanning electron microscope (SEM, JEOL7001F, JEOL Co.) imaging. The accelerating voltage was set at 10 kV.

The static contact angle of each surface was measured by the sessile droplet method. Purified water droplets with a volume of 3.5 μL were gently deposited on the surface and the droplet shape was imaged by a digital camera (D5300, Nikon, Japan) to characterize the contact angle. The advancing and receding contact angles (θ_a and θ_r) were characterized during increasing and decreasing the water volume. The values of static and dynamic contact angles were acquired at least five different positions on the surface.

Fog harvesting experiment. In the present study, we first examined the performance of individual wires. Figure 1(a) shows the experimental setup. A fog stream with 255.3 ± 8.0 g/h of water contents at 1.5 m/s of wind speed was supplied to the sample. The sample was set 20 mm behind the fog outlet, which had a size of 25×25 mm. Water droplets shed from the sample were collected in a container below the sample. After the experiments, liquid attached to the wire was collected in a container and the mass of harvested water was measured immediately.

On the basis of the results for individual wires, we conducted three-wire experiments. Figure 1(b) shows the arrangement of wires in the constructed unit from the front side. Both ends of each wire were fixed to a frame with a size of $70 \text{ mm} \times 62 \text{ mm}$ of height and width with 10 mm thickness and placed 20 mm behind the fog outlet. Because the opening section of the frame ($60 \text{ mm} \times 60 \text{ mm}$) was much larger than the size of fog stream, water droplets in the fog collided with only the wires and the frame did not make any contribution. Figure 1(c) shows the detailed arrangement of wires. The intervals between side wires and depth are defined as w and h , respectively. The downstream direction was defined as positive in terms of depth. Harvested water was collected in a thin pan and the mass was measured after the experiment. All fog harvesting experiments were conducted at $20.5 \pm 1.0 \text{ }^\circ\text{C}$ and $52 \pm 10\%$ relative humidity. In addition, the measurements of each sample were conducted three times and the duration of each test was 30 min .

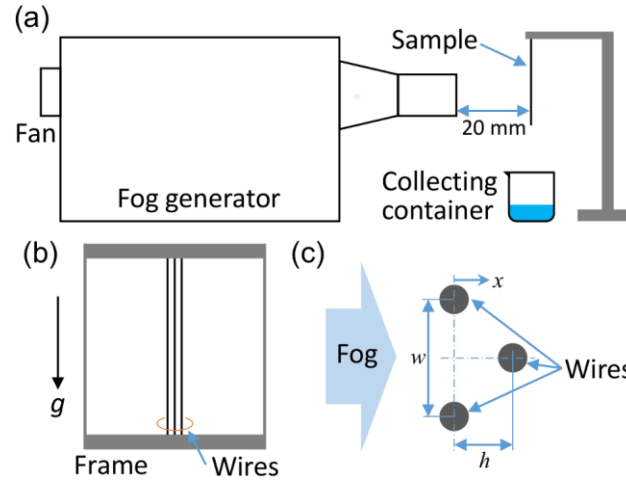


Fig. 1 (a) Experimental setup for fog harvesting. (b) Front view and (c) top view of multiwire unit.

Details of the droplet shedding mechanism were observed by the digital camera. The camera was installed at a slight angle from the wire to avoid the fog stream. To evaluate the projected area of

the wire and attached liquid (droplet and film), we conducted extra experiments to capture images from the downstream side. However, because the fog disturbed the image capturing process, the fog flow was stopped every minute after 20 min and the system was imaged. Captured images were imported to in-house software to analyze the projected area. Briefly, a binarization process was performed on the image (Fig. 2) and the number of pixels of wire and droplet areas were counted.

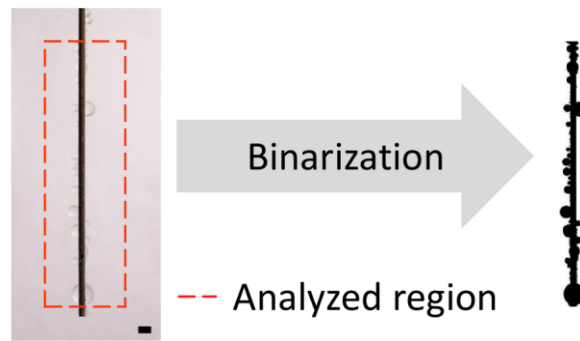


Fig. 2 Procedure for projected area evaluation. Figures from before and after droplet attachment were captured and evaluated. Scale bar shows 1 mm.

3. RESULTS AND DISCUSSION

We evaluated the relationship between fog harvesting performance of individual wires and wettability, and investigated the effects of changing the wire arrangement in the arrays. On this basis, we first evaluated surface structures and wetting properties. Figure 3(a)-(c) show the surface structures of the sample type 3, 4, and 5, respectively. The surface of sample type 2 had a comparable structure to that of the type 3 and the sample type 1 was comparable to that of the type 4 because the same fabrication procedure was used to generate the structures. The sample type 3 had a featureless

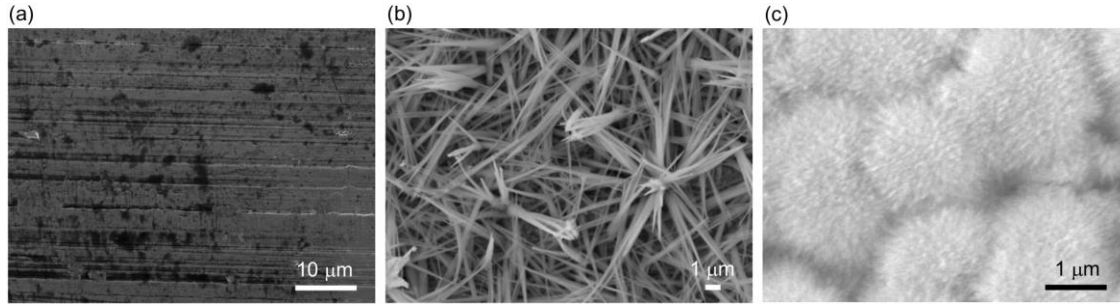


Fig. 3 SEM images of (a) type 3, (b) type 4, and (c) type 5.

1 structure of the pristine copper wire. The surfaces of the sample type 4 and 5 had characteristic
2 structures. The surface of sample type 4 had unoriented needle-like structures whereas the surface of
3 type 5 had micrometer-sized bumps with nanoneedles on their surface [38]. The wetting properties
4 are summarized in Table 1. Type 1 surface had a contact angle less than 10° , which indicates that it
5 is highly wettable because of the surface modified by hydrophilic material and the Wenzel wetting
6 state. [39] The contact angle on the type 2 surface was $57 \pm 2^\circ$. Type 3 surface had a static contact
7 angle of $118 \pm 1^\circ$ and θ_a and θ_r were acquired as $122 \pm 2^\circ$ and $110 \pm 2^\circ$, respectively. A static contact
8 angle of more than 150° was seen on the type 4 surface and it also had a small contact angle hysteresis
9 $\Delta\theta$. These results are attributed to a low solid liquid contact condition, also known as Cassie–Baxter

Table 1 Static, advancing, and receding contact angles (θ , θ_a , and θ_r) and contact angle hysteresis $\Delta\theta$.

Sample	Term	$\theta [^\circ]$	$\theta_a [^\circ]$	$\theta_r [^\circ]$	$\Delta\theta [^\circ]$
Type 1	SHL	<3	-	-	-
Type 2	HL	57 ± 2	63 ± 1	16 ± 3	47 ± 3
Type 3	HB	118 ± 1	122 ± 2	110 ± 2	12 ± 2
Type 4	SHB	156 ± 1	160 ± 1	154 ± 1	6 ± 1
Type 5	P	154 ± 2	161 ± 1	107 ± 3	54 ± 3

wetting state. [40] Although the type 5 surface had comparable hydrophobicity to that of the type 4, much larger $\Delta\theta$ was observed. In addition, droplets were not shed even when the surface was tilted upside down owing to contact line pinning and a so-called petal effect. [41, 42] The samples are named as denoted in Table 1.

The effect of wettabilities on the fog harvesting performance was evaluated and Fig. 4(a) shows the amount of fog collected from each wire. As shown in the figure, the HB wire harvested 45% more water than did the SHL or SHB wires and 25% more than did the HL and P wires. In general, these trends suggest that the hydrophobic surface gives better performance than the hydrophilic surface, consistent with previous reports based on wires, tubes, and surfaces as fog harvesters [14, 43, 44]. This result is attributed to the efficiency of fog collection and it is related to the projected area analyzed by the procedure described above. Here, the attached liquid (droplets or film) increases the projected area and this is evaluated by the increase ratio in the projected area ϕ as defined by the following equation:

$$\phi = \frac{A_w - A}{A}, \quad (1)$$

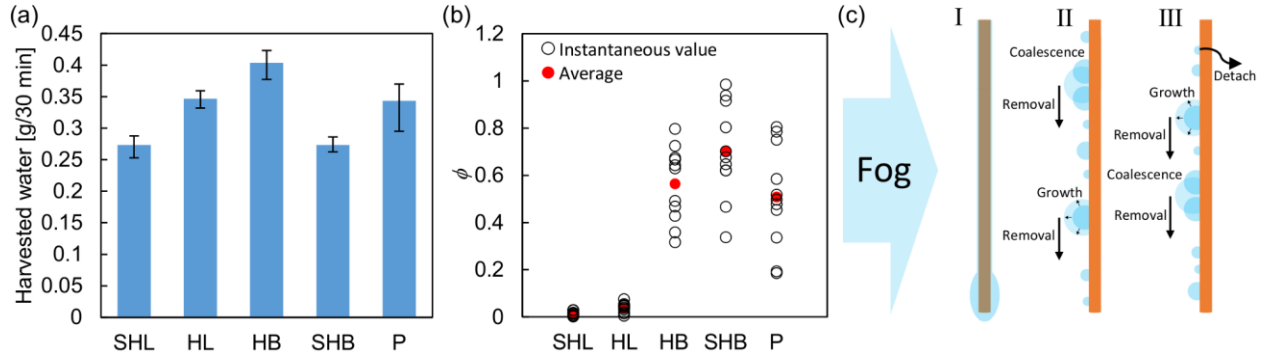


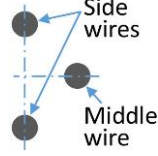
Fig. 4 (a) Amount of harvested water. (b) Relation between the wettability of wire and ratio of projected area. Because droplets attached below the shedding droplet were caught in the shedding droplet, open symbols for HB, SHB, and P were distributed over a wide range whereas SHL and HL had a narrow distribution range owing to the formation of a liquid film. (c) Mechanisms of liquid departure from each wire. I, II, and III corresponding to SHL and HL, HB and P, and SHB, respectively.

where A and A_w are the projected area without and with attached liquid, respectively. These results are shown in Fig. 4(b). The liquid film attached to the SHL and HL wires gave small values of ϕ . The other three wires had had larger values owing to numerous attached droplets. The enlarged projected area promotes collisions with fog droplets, which contributes to fog harvesting. Although the SHB wires had a larger average value of ϕ than that of the HB wire, as shown in Fig. 4(b), SHB gave the smallest amount of harvested water. This result contradicts our expectations from the projected area and understanding that the water-removal process determines water harvesting performance [14, 44]. These differences are attributed to the droplet mobility. Because the SHB surface has a much smaller $\Delta\theta$, as shown in Table 1, attached droplets can easily move in a circumferential direction on the wire under the influence of the fog stream. This leads to an increase of ϕ . However, this droplet motion has a drawback in terms of droplet shedding, as schematically shown in Fig. 4(c). Although the SHL and HL wires had completely different mechanisms that water droplets grew at the lower end of the

wire and fell down under the influence of gravity (Fig. 4(c)I), HB, SHB, and P had similar mechanisms whereby attached droplets shed from the wire under the influence of gravity and the fog stream when the droplet grew by capture of fog droplets or coalescence with neighboring droplets attached to the wire (Fig. 4(c)II and III). Average droplet height of shedding droplet which defined as the distance from the wire surface to the apex of a droplet were 1.16, 1.22, and 1.30 mm for HB, SHB, and P wires, respectively. In addition, droplets attached to the SHB wire were blown over by the fog stream (Fig. 4(c)III). These droplets were not collected by the container placed below the wire and the resulting amount of harvested water was lower compared with that from the HB wire. The performance of the P wire was better than that of SHB because droplet blow-over by the fog stream was not observed, however the fog harvesting performance was less than that from the HB. This result is attributed to the difference between the average value of ϕ for P and HB.

On the basis of the amount of water harvested by a single wire, we investigated the enhancement of fog collection in three-wire unit. Details of the arrangement of each unit are shown in Table 2. Unit S1 was composed by hydrophobic wires whereas other units were composed of 2 less wettable wires and 1 HL or SHL wire. The values of w and h were set to be 2.0 and 1.0 mm, respectively.

Table 2 Wettability patterns for three wires arrangements. Figure showing top view of three wire arrangement. Fog stream comes from the left side of the arrangement.

Unit No.	Side wires	Middle wire	Arrangement
S1	HB	HB	
S2	HB	HL	
S3	SHB	HL	
S4	P	HL	
S5	HB	SHL	
S6	SHB	SHL	
S7	P	SHL	

1 The amount of harvested water for each unit is shown in Fig. 5(a). Filled columns indicate
2 the result of the units. Notably, S1 had gave quite low performance despite individual HB wires giving
3 the best performance. S2 had 10% better performance than that of S1 based on changing the middle
4 wire to HL instead of HB. We confirmed lower performance when placing HL as the side and HB as

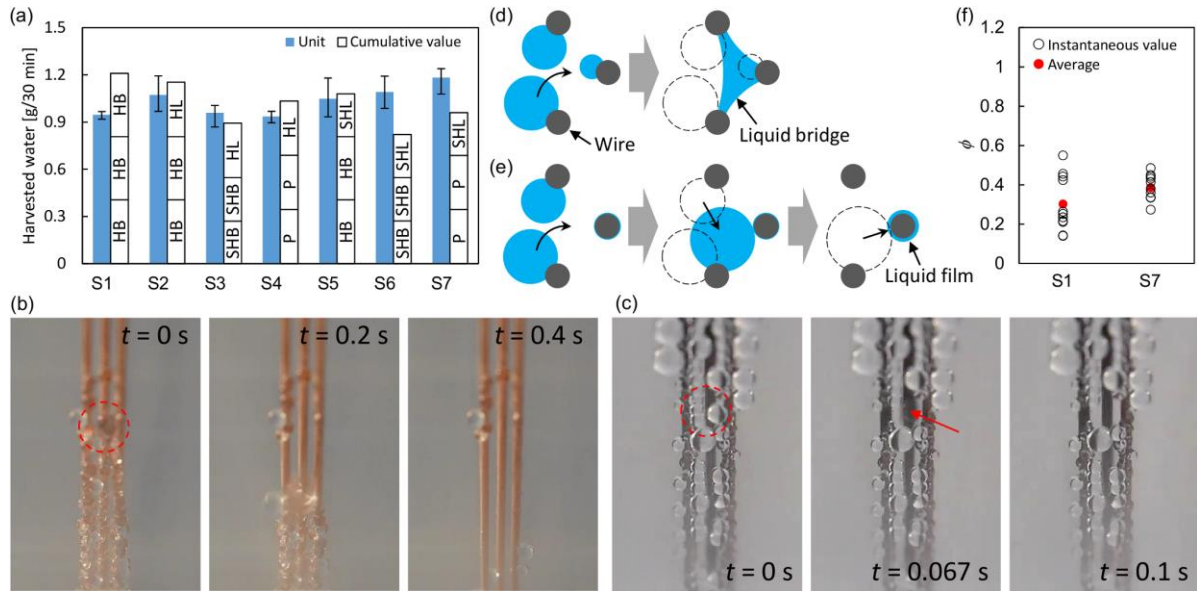


Fig. 5 (a) Amount of harvested water by unit S1-S7 and cumulative value of each wire. Snapshots of droplet removal process on (b) S1 and (c) S7. (d) Schematic image of a liquid bridge formation on S1. (e) Schematic image of a droplet transfer process on S7. Droplet immediately transferred to SHL wire after it touched the liquid film on the SHL wire. Top views of arrangements and fog stream directed from left to right in panel (d) and (e). (f) Increase in the ratio of projected area on S1 and S7.

the middle wires. The arrangements S3 and S4 had similar performance to that of S1. Units that included a SHL wire generally had better performance. In particular, S7 had more than 25% better performance than that of S1. In addition, the open columns shown in the Fig. 5(a) indicate the cumulative value of each wire. This result indicates the estimated value when three wires were placed with adequate separation. As an example, this value for S1 was estimated to be three times as high as that of the HB wire, as shown in Fig. 4(a). The results of S1 were 20% lower than the cumulative value; the performances of S7 and S6 were 20% and 30% higher than expected, respectively.

These differences can be discussed in terms of the droplet removal process, as illustrated in Fig. 5(b) and (c), which corresponds to the mechanism taking place in S1 and S7 (details can be seen in Movie 1 and 2, supporting information). Under the influence of the fog stream, attached droplets on the side wire in S1 can move in a circumferential direction and coalesce with droplets attached to other wires (droplets seen in the dashed circle in Fig. 5(b)). Then, these droplets form a liquid bridge between the three wires (Fig. 5(d)), which sweeps droplets attached below the bridge. As a result, only a few droplets remain at the wire. However, for S7, a droplet moves on the wire and contacts the liquid film on the SHL wire diagonally behind (droplets seen in the dashed circle in Fig. 5(c)). Therefore, this droplet transferred to the SHL wire (as indicated by the arrow in Fig. 5(c)) because of the large wettability difference and becomes part of the liquid film (Fig. 5(e)). All droplets attached below the transferred droplet remained on the wires. Hence, the projected area of S7 does not show a notable decrease similar to that of S1. To confirm this mechanism, we analyzed the results shown in Fig. 5(f). The average value of ϕ for S7 was higher than that of S1. Here, although the average ϕ

value of S7 was greater than the average of the sum of two individual P and one SHL wires, as shown in Fig. 4(b), the average ϕ value of S1 was lower than the average of three individual HB wires (i.e., ϕ of HB shown in Fig. 4(b)). This result is attributed to droplets attached below the liquid bridge were caught in the shedding liquid bridge, thereby decreasing the fog harvesting performance. Furthermore, S2, S3, and S4 had lower performance than that of S7 because HL did not have adequate hydrophilicity to enable transfer of droplets between wires. S5 and S6 showed also lower performance than that of S7. This result is attributed to be related to the force balance and the size of shedding droplets. According to the Fumidge theory, required force F to move the droplet is described as follows:

$$F \approx l\gamma(\cos\theta_r - \cos\theta_a) \quad (2)$$

where l is the width of droplet and γ is the liquid-gas surface tension, respectively. [45] On the basis of this and the results shown in Table 1, droplets on HB and SHB wires required smaller force to move compared to that on P wire. This reflects to the average height of shedding droplet as mentioned above. In addition, the height of shedding droplet is correlated to the area to receive the fog stream. Although it depends on the position where droplets attached, large droplets can receive enough aerodynamic force to move circumferential direction on the wire and then droplets reached to the SHL wire. However, smaller droplets on HB wire coalesced with droplets on same wire during the circumferential motion. It reduced the projected area to collide with fog droplets and accordingly, harvested water amount decreased. In the case of SHB wire, the effect of fog stream is obvious according to the droplet departure process shown in Fig. 4(c)III. However, droplets that detached in

1 the direction without the SHL wire would not be harvested.

2 As discussed above, unit S7 gave the best performance; however, we next considered the
3 optimal arrangement of wires. The amounts of water harvested from units with various h values at
4 constant w (2.0 mm) are shown in Fig. 6(a). Here, $h = 0$ indicates that all wires are on the same plane
5 and a negative value means that the middle wire was located to the upper side of the fog stream.
6 Although the difference was small, $h = 1.0$ mm collected the most water. The lowest value was
7 obtained at $h = 0$ mm because the increase of the projected area was suppressed by frequent transport
8 of droplets to the SHL wire. In addition, suppression of the fog supply owing to the narrow interspace

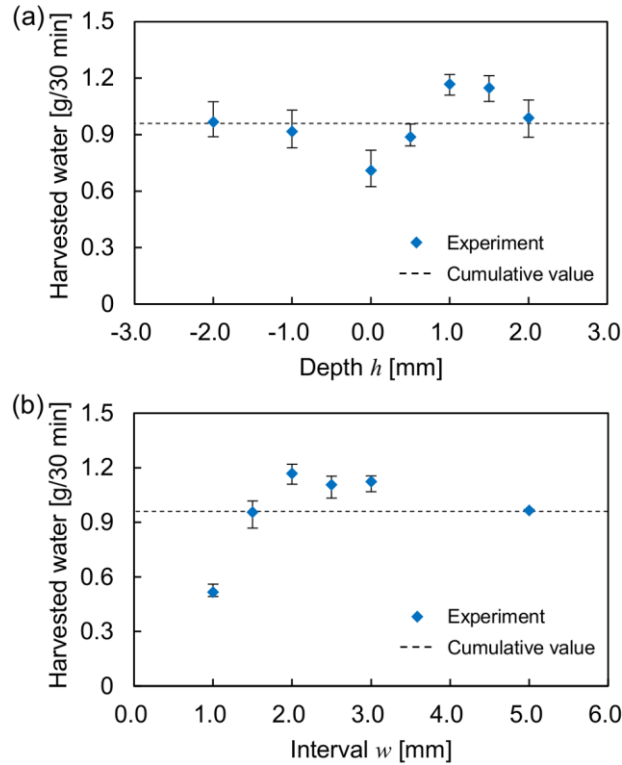


Fig. 6 Harvested water amount as a function of (a) h ($w = 2.0$ mm) and (b) w ($h = 1.0$ mm). Combination of wires corresponds to unit S7.

between the wires might have influenced this result. [43] The harvested amount was recovered and approached the cumulative value when the middle wire was moved further to the upstream side. In addition, the obtained result approached the cumulative value at $h = 2.0$ mm. This result suggests that the suppression effect was no longer active when h was greater than 2.0 mm and that $w = 2.0$ mm is an adequate separation to avoid the influence from other wires.

Figure 6(b) shows the result when w was changed while h was fixed at 1.0 mm. The system with $w = 2.0$ mm gave the best performance and according to separate from $w = 2.0$ mm, the performance deteriorated gradually. This result is attributed to droplet transport as mentioned above and suppression of the fog supply. [43] The suppression was enhanced by closer intervals, which decreased the harvested amount. However, owing to transport of droplets to the SHL wire, the performance at $w = 2.5$ and 3.0 mm was enhanced. This result approached the cumulative value when w was large.

Fog harvesting performance was enhanced by placing the SHL wire near wires with poor wettability, in particular, in an arrangement with $w = 2.0$ mm and $h = 1.0$ mm with P wires. However, it is not clear why this arrangement gave the best performance even though similar droplet transport was observed in other arrangements. One possible explanation might refer to the height of droplets. According to our observations, the average height of shedding droplets was 1.30 mm and these droplets can move to the circumferential direction on the wire according to the fog stream. This value corresponds to the distance between the wire surfaces for the arrangements of $w = 2.0$, $h = 1.5$ mm and $w = 3.0$, $h = 1.0$ mm (a detailed estimate is provided in the supporting information). This result

1 is in good agreement with those shown in Fig. 6 because the amount of harvested water exceeded the
2 cumulative values for these arrangements. On the other hand, coalescence with neighboring droplets
3 attached on the wire also triggered droplet motion. However, because the height of these droplets can
4 be smaller, they could not reach the SHL wire when the wire arrangement had a large separation;
5 hence, the performance of these arrangements was not notably enhanced.

6 Although the results of the present study were obtained from single- and three-wire systems,
7 the final target is to enhance the fog harvesting performance of a wider arrangement. Therefore, we
8 estimate the performance enhancement when proposed arrangement is applied to a large-scale fog
9 harvester. On the basis of our evaluation, the minimum interval to give the same performance as a
10 single wire is 2.0 mm when the experimental condition is assumed to be same as present experiment,
11 as discussed above; thus, a width of 4.0 mm is required to satisfy the arrangement of three HB wires
12 in a straight line perpendicular to the fog stream and to give an amount of water comparable with that
13 of S7, as shown in Fig. 5(a). In other words, our approach has the potential to double the amount of
14 harvested water per unit width. This represents great progress for securing of water resources and
15 designing future fog harvester systems.

16 For actual application, the frame with full of wire arrangement will be practical configuration.
17 Although the mesh is used commonly, the clogging may decrease the performance. However,
18 proposed wire arrangement can avoid the clogging due to out-of-plane directional droplet transport
19 from nanostructured hydrophobic wires. This will be an advantage when proposed configuration is
20 stacked to the fog stream direction. It might be helpful to increase the ratio of the amount of harvested

liquid for the amount of fog flowed in the wire arrangement. The manufacturing process required much time compared to use the bare mesh while the cost is still significantly low compared to use the techniques such as microfabrication processes.

CONCLUSIONS

In the present study, the fog harvesting performance of a multiwire unit with a three-dimensional arrangement was investigated. A unit composed of nanostructured hydrophobic wires with large $\Delta\theta$ and superhydrophilic wire gave the best performance and was 20% more efficient than the estimated value despite the hydrophobic wire collecting the most water in single wire experiments. Detailed observations revealed characteristic unidirectional droplet transport, by which droplets reached a superhydrophilic wire diagonally behind and were transported immediately owing to the wettability difference. In addition, the amount of harvested water depends on the wire arrangement, which has an optimal interval and depth. Our proposed arrangement shows great promise for enhancing the collection efficiency and avoiding clogging. In addition, the mechanism will help the development of further highly efficient and economical fog harvesters.

Associated content

Supporting Information

More detailed information about movies, and estimation of distance between wires (PDF)

Movie 1: Droplet removal process from unit S1 (AVI)

Movie 2: Droplet removal process from unit S7 (AVI)

Notes

The authors declare no competing financial interest.

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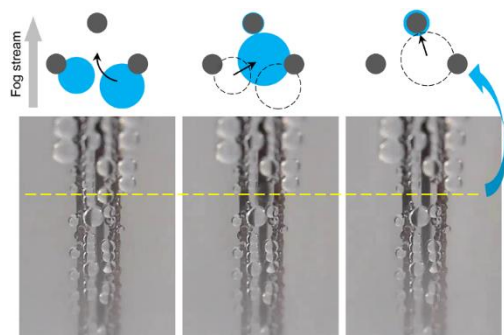
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