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Enhancement of Separation of Dissolved Gas from Water using Synthesized Exhalation Mixed to Inlet of a Membrane Module

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Abstract-Dissolved oxygen can be used for a human to breathe underwater like a fish. Water contains limited amounts of dissolved oxygen while a human typically needs larger amounts of oxygen than a fish. The separation system which separates dissolved oxygen from water and applies to breathe underwater requires large amounts of water and large surface area between liquid and gas phase.

In this thesis, I used exhalation simulating gas mixed to inlet of the hollow fiber module to make efficient separating system. An exhalation gas contains some amounts of oxygen even if there is less than one in the air. Exhalation simulating gases were mixed through a hollow fiber membrane module and the amounts of gases separated from mixed water were measured, which could be proved to result into enhancement of separation.

Keywords- *Enhancement of separation, synthesized exhalation, mixed to inlet, hollow fiber.*

I. INTRODUCTION

Dissolved oxygen can be used for a human to breathe underwater like a fish. Water contains limited amounts of dissolved oxygen while a human typically needs larger amounts of oxygen than a fish. The separation system which separates dissolved oxygen from water and applies to breathe underwater requires large amounts of water and large surface area between liquid and gas phase.

To increase separation of dissolved oxygen from water, magnetic materials can be used [1]. Nano particles with magnetic characteristics are coated on the flat sheet membrane. Using these membranes, separation of dissolved oxygen from water was enhanced than normal membrane without magnetic materials.

Gills of a fish have been used to breathe under water since long time ago. Geometrical structure of the fish gill can be considered to be optimized for breathing under water for long time. Park et al. represented dimension of the fish gill based on measuring experiments [2].

If exhalation gases are used, the amounts of carbon dioxide need to be reduced [3]. As synthesized gases based on exhalation gases were inlet to the hollow fiber membranes, separated gases were investigated in view of the compositions of carbon dioxide. After hollow fiber membrane, the amounts of carbon dioxide were decreased. It's important for us to take use of exhalation gases in view of increasing the amounts of gases needed for breathing under water if composition of carbon dioxide is decreased.

In this study, I used exhalation simulating gas mixed to inlet of the hollow fiber module to make efficient separating system. An exhalation gas contains some amounts of oxygen even if there is less than one in the air. Exhalation simulating gases were mixed through a hollow fiber membrane module and the amounts of gases separated from mixed water were measured, which could be proved to result into enhancement of separation.

II. METHODS

Fig. 1 shows outline for experimental devices. Synthesized gases compose of oxygen, nitrogen and carbon dioxide. Its composition was determined on the basis of exhalation gases which were collected from humans. Synthesized gases are supplied into mixer. The hollow fiber membrane module is from a Liqui-Cel company and its specifications are represented in Table 1. Surface area of this membrane module is 8.1 m^2. Water is supplied into shell side inside membrane module using a water pump. Dissolved gases are separated from water through the lumen side using a vacuum pump. Flow rates of separated gases and composition of oxygen contained in the separated gases are measured using a flow sensor and an oxygen sensor.

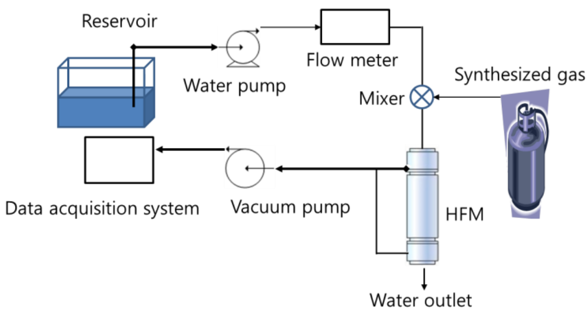


Figure 1. Outline for experimental devices

TABLE I. POLYPROPYLENE HOLLOW FIBER CHARACTERISTICS

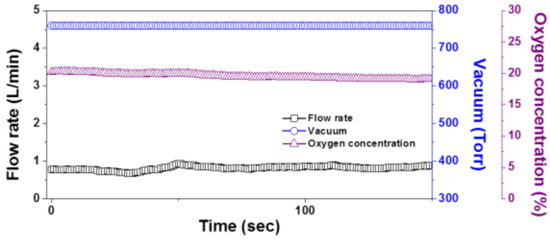
Name	Spec.
Material	Polypropylene
Potting materials	Epoxy
Surface area (m^2)	8.1
Porosity (%)	~25
OD/ID (μm)	300/200
Shell side volume (L)	1.26
Lumen side volume (L)	0.61
Height (mm)	512
Diameter (mm)	116.1
Maximum water flow (m^3/hr)	6.8
Pressure drop (bar) at 6.1 m^3/hr water flow	0.69

III. RESULTS AND DISCUSSIONS

Fig. 2 shows flow rates of separated gases and compositions of oxygen included in separated gases with 1 LPM of synthesized gas and 10 LPM of water flow. 1st stage, 2nd stage and 3rd stage mean no vacuum state, medium vacuum state and high vacuum state. Black lines mean flow rates of separated gases, blue lines vacuum state and red lines composition of oxygen included in separated gases. As the vacuum state was increased, flow rates of separated gases were increased. Flow rates of separated gases with synthesized gases which were feed backed to inlets of the membrane module were more than ones without synthesized gases. It's meaningful for us to get more separated gases from water. Fig. 3 shows flow rates of separated gases and compositions of oxygen included in separated gases with 1 LPM of synthesized gas and 20 LPM of water flow. Fig. 4 shows results with 1 LPM of synthesized gas and 30 LPM of water flow. Fig. 5 shows with 1 LPM of synthesized gas and 40 LPM of water flow. As water flow was increased, flow rates of separated gases were also increased.

Fig. 6 shows flow rates of separated gases and compositions of oxygen included in separated gases with 2 LPM of synthesized gas and 10 LPM of water flow. As the vacuum state was increased, flow rates of separated gases were also increased. Fig. 7 shows flow rates of separated gases and compositions of oxygen included in separated gases with 2 LPM of synthesized gas and 20 LPM of water flow. Fig. 8 shows results with 2 LPM of synthesized gas and 30 LPM of water flow. Fig. 9 shows results with 2 LPM of synthesized gas and 40 LPM of water flow. As water flow was increased, flow rates of separated gases were also a little increased. As synthesized gases were increased, flow rates of separated gases were also increased.

Fig. 10 shows flow rates of separated gases and compositions of oxygen included in separated gases with 3 LPM of synthesized gas and 10 LPM of water flow. As the vacuum state was increased, flow rates of separated gases were also increased. Fig. 11 shows flow rates of separated gases and compositions of oxygen included in separated gases with 3 LPM of synthesized gas and 20 LPM of water flow. Fig. 12 shows results with 3 LPM of synthesized gas and 30 LPM of water flow. Fig. 13 shows results with 3 LPM of synthesized gas and 40 LPM of water flow. As water flow was increased, flow rates of separated gases were also a little increased. As synthesized gases were increased, flow rates of separated gases were also increased.



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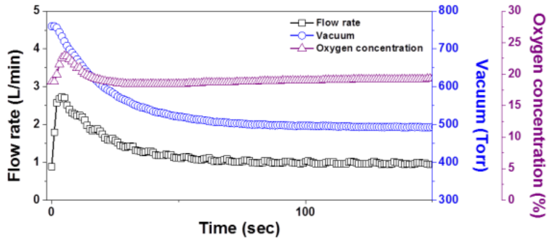

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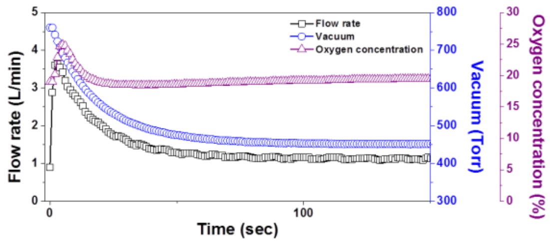

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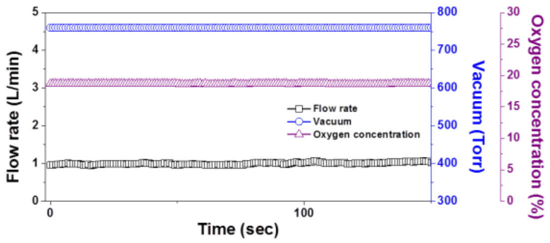
Figure 2. Separation of gases from water with 1 LPM of synthesized gas and 10 LPM of water flow



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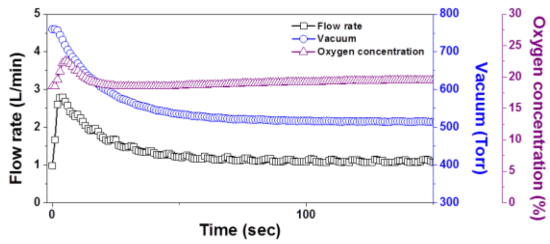

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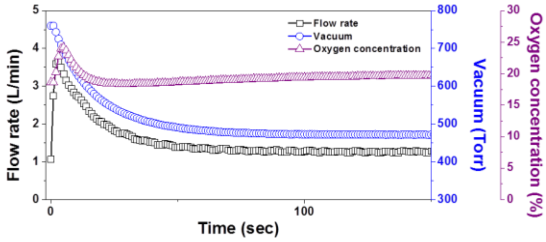

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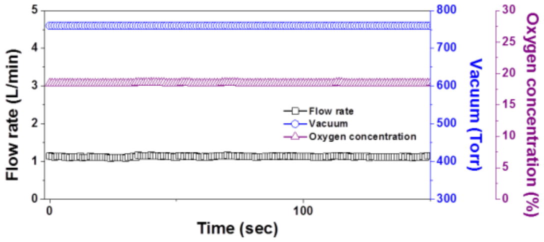
Figure 3. Separation of gases from water with 1 LPM of synthesized gas and 20 LPM of water flow



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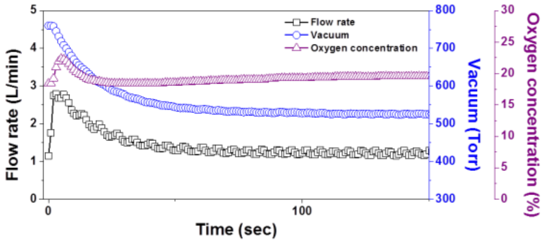

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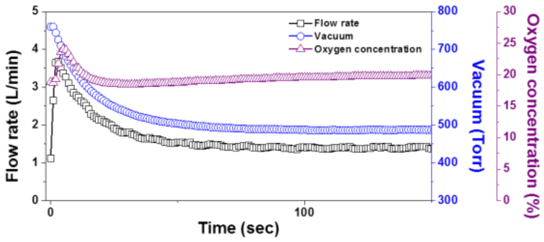

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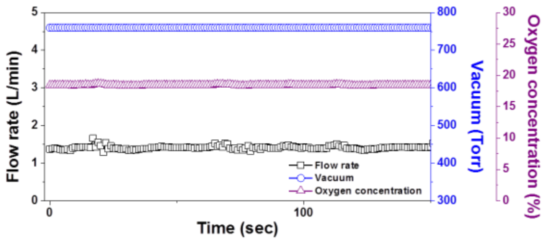
Figure 4. Separation of gases from water with 1 LPM of synthesized gas and 30 LPM of water flow



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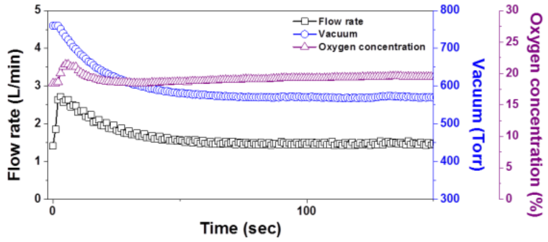

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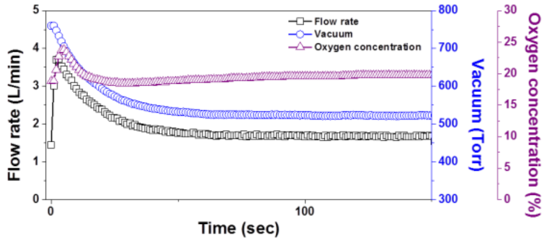

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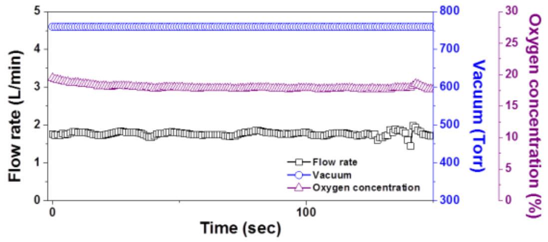
Figure 5. Separation of gases from water with 1 LPM of synthesized gas and 40 LPM of water flow



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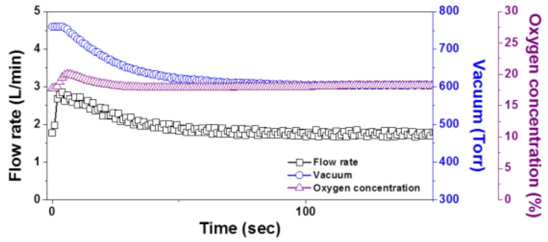

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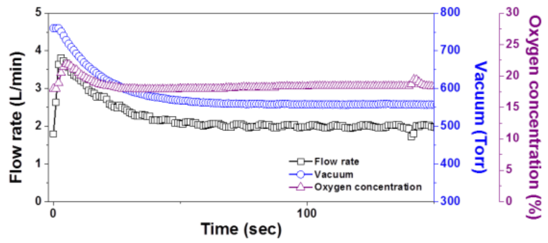

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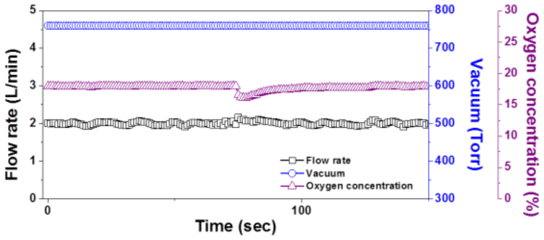
Figure 6. Separation of gases from water with 2 LPM of synthesized gas and 10 LPM of water flow



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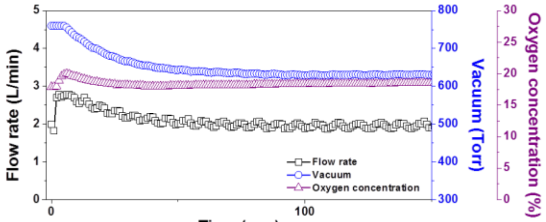

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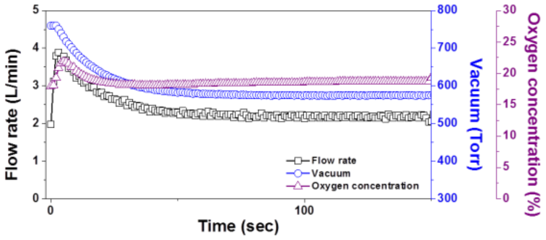

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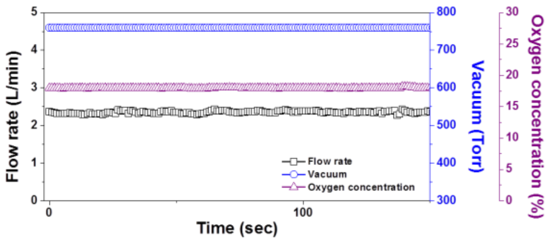
Figure 7. Separation of gases from water with 2 LPM of synthesized gas and 20 LPM of water flow



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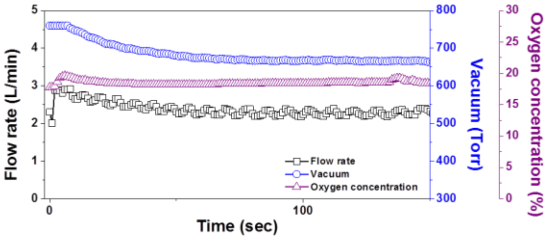

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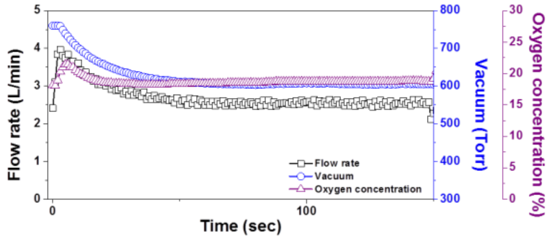

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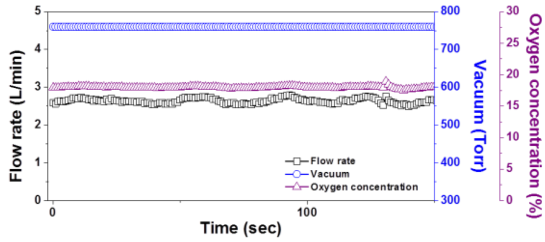
Figure 8. Separation of gases from water with 2 LPM of synthesized gas and 30 LPM of water flow



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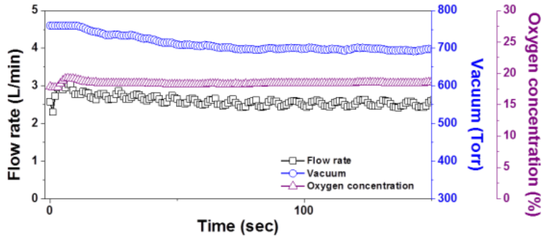

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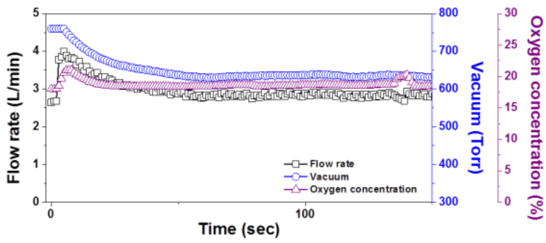

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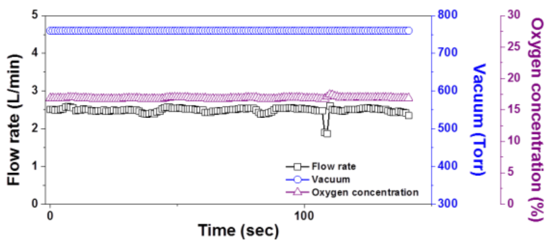
Figure 9. Separation of gases from water with 2 LPM of synthesized gas and 40 LPM of water flow



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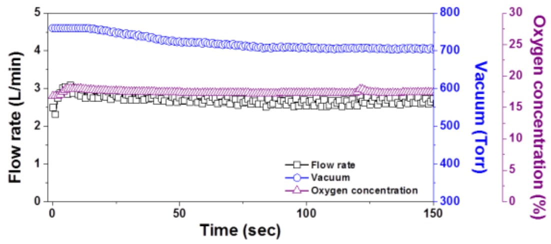

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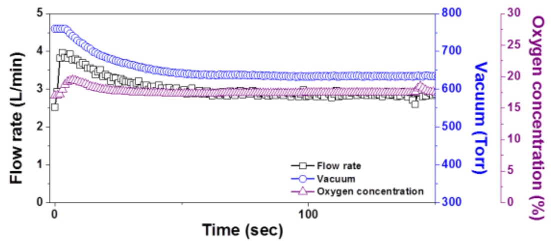

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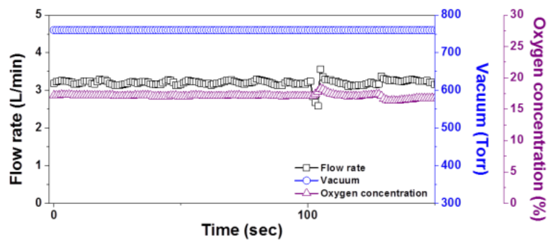
Figure 10. Separation of gases from water with 3 LPM of synthesized gas and 10 LPM of water flow



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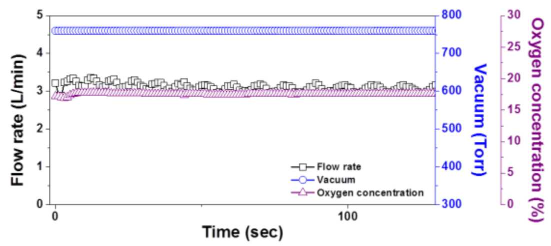

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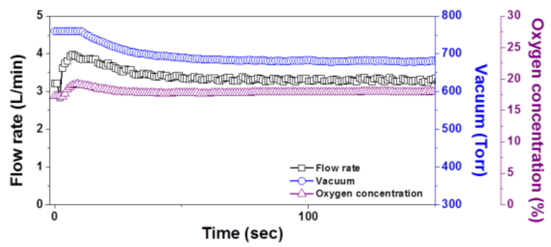

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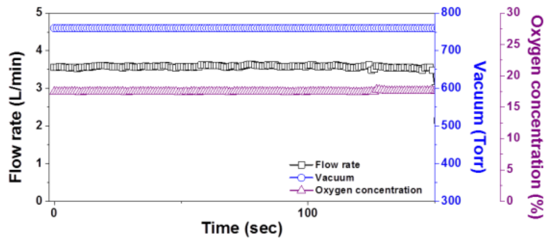
Figure 11. Separation of gases from water with 3 LPM of synthesized gas and 20 LPM of water flow



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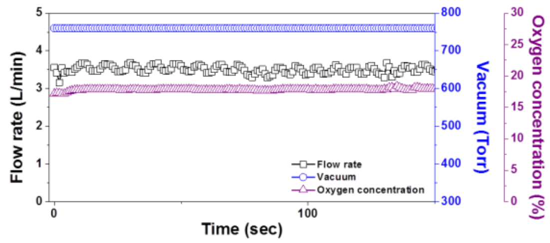

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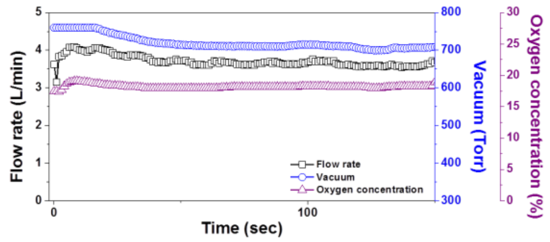

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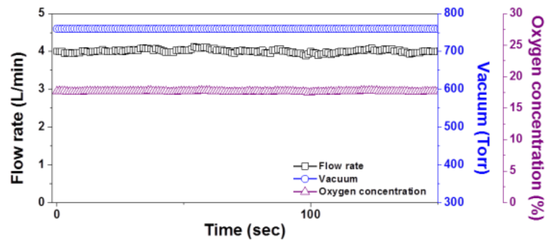
Figure 12. Separation of gases from water with 3 LPM of synthesized gas and 30 LPM of water flow



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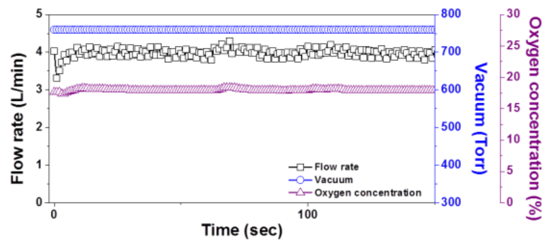

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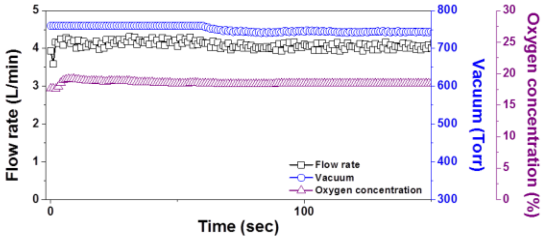

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Figure 13. Separation of gases from water with 3 LPM of synthesized gas and 40 LPM of water flow

IV. CONCLUSIONS

In this thesis, I used exhalation simulating gas mixed to inlet of the hollow fiber module to make efficient separating system. An exhalation gas contains some amounts of oxygen even if there is less than one in the air. Exhalation simulating gases were mixed through a hollow fiber membrane module and separation of dissolved gases was measured. As water flow was increased, flow rates of separated gases were increased. And also, as synthesized exhalation gases were increased, flow rates of separated gases were also increased. It's important in view of decreasing weight and size of separation system to increase separated gases. And it's possible for us to make separation system with small size when we need large amounts of separated gases under water based on low composition of carbon dioxide and proper composition of oxygen.

REFERENCES

[1] Velianti, S. B. Park, and P. W. Heo, The enhancement of oxygen separation from the air and water using poly(vinylidene fluoride) membrane modified with superparamagnetic particles, J. Membr. Sci., pp. 274-280, 2014.

[2] K. H. Park, W. J. Kim and H. Y. Kim, Optimal lamellar arrangement in fish gills, PNAS, pp. 8067-8070, 2014.

[3] P. W. Heo and I. S. Park, Separation of dissolved gases from water using synthesized gases based on exhalation characteristics, Journal of the Korean Society of Marine Engineering, Vol. 38, No. 10, pp. 1347~1353, 2014.