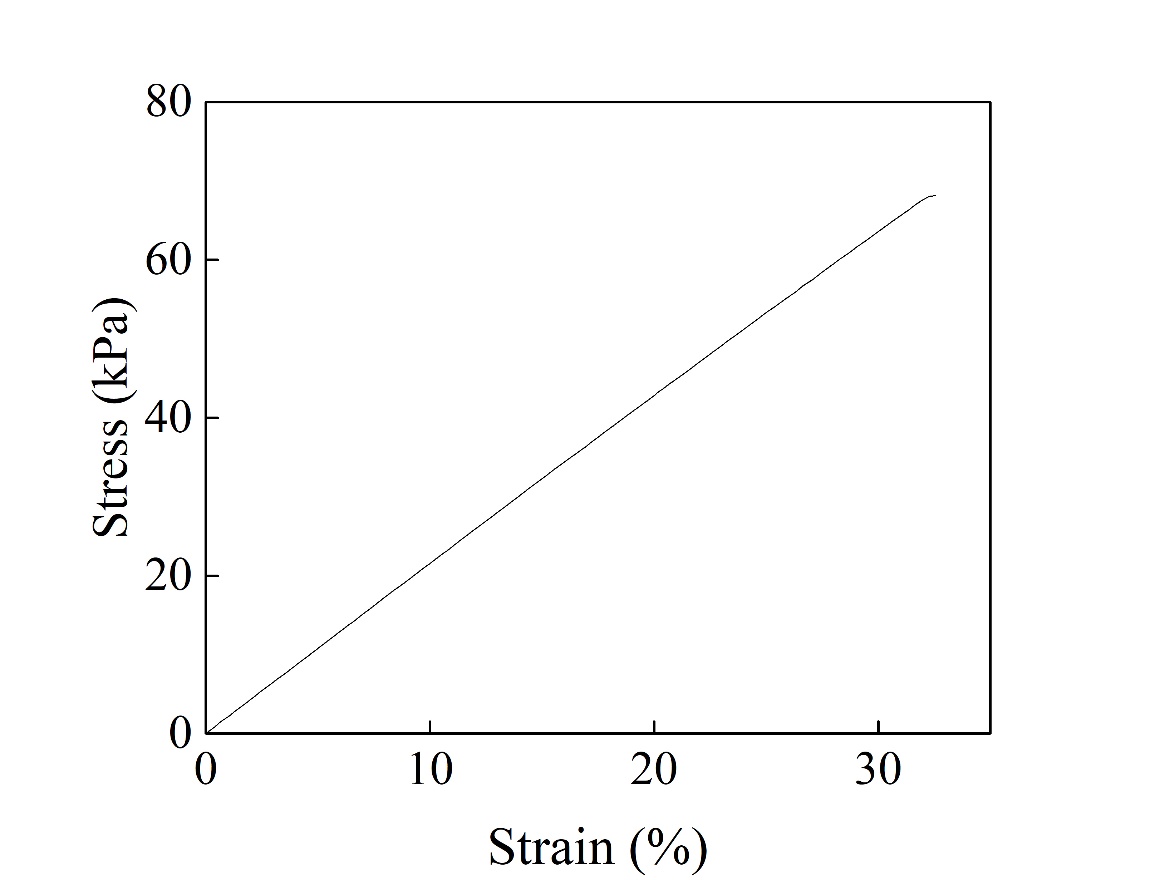
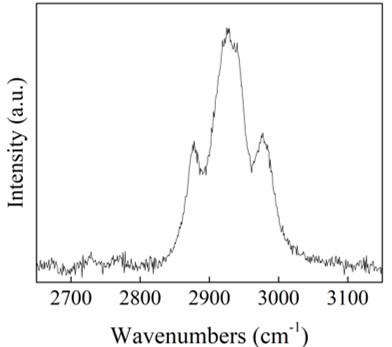
**Poly(n-isopropylacrylamide) Hydrogel for Diving/Surfacing Device**

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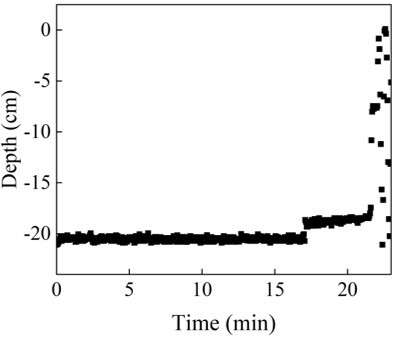
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**Figure S1**. Raman spectrum of PNIPAM hydrogel.

**Figure S2**. The strain-stress curve of PNIPAM hydrogel. The modulus is 2.11 kPa and it is broken at almost 32 % strain.

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**Figure S3**. The first cycle of diving/surfacing of PNIPAM/Magnetite composite stimulated by ultrasound

**Velocity of Hydrogel**

Net force effecting the hydrogel in water is summation of gravity, buoyancy, and drag force. When all forces are balanced, net force is 0 N. Therefore, it can be written as formula (a1) and (a2).

When the hydrogel diving,

B + Fd - mg = 0 (a1)

When the hydrogel surfacing,

B - Fd - mg = 0 (a2)

B is the buoyancy force, Fd is drag force, m is the mass of hydrogel, and g is gravitational acceleration.

When Df is the density of fluid, Dp is the density of hydrogel, V is the volume of hydrogel, v is velocity of hydrogel, A is cross sectional area of the hydrogel, and Cd is drag coefficient,

Buoyancy can be calculated by B = DfVg, and drag force also be calculated as Dfv2ACd/2.

Therefore, when diving of the hydrogel,

DfVg + Dfv2ACd/2 – mg = 0

v2 = 2(mg- DfVg)/DfACd

= 2g(m- DfV)/DfACd

v = {2g(m- DfV)/DfACd}1/2

Because m = DpV,

v = {2g(DpV- DfV)/ρfACd}1/2

= {2gV(Dp - Df)/DfACd}1/2

When surfacing of hydrogel

DfVg - Dfv2ACd/2 – mg = 0

v2 = 2(DfVg-mg)/DfACd

= 2g(DfV-m)/DfACd

v = {2g(DfV-m)/DfACd}1/2

Because m = DpV,

v = {2g(DfV- DpV)/DfACd}1/2

= {2gV(Df – Dp)/DfACd}1/2

**Swelling Ratio**

Swelling ratio of hydrogels were calculated by formula (b).

SR = (ms -md)/md (b)

SR is the swelling ratio, ms is the mass of the hydrogel after fully swelling, md is the mass of dried hydrogel.

**Density of PNIPAM Hydrogel**

Density of PNIPAM gel was measured by pycnometer. The density was measured by formula (c).

Dp = Dwmp/(m1-m2+mp) (c)

The Dp is density of PNIPAM hydrogel, Dw is density of water, mp is the mass of fully swelled PNIPAM gel. The m1 is the mass of pycnometer filled with water, and m2 is the mass of the pycnometer filled with gel and water.

Formula (c) is induced as followed:

When Vp is the volume of PNIPAM gel,

1. Dp = mp/Vp

When PNIPAM gel placed in full filled pycnometer, the same volume of water is pushed out. Therefore, when Vw is the volume of pushed water, mw is the mass of pushed water, and m0 is the mass of pycnometer without water and gel, Vp is calculated as followed:

1. Vp = Vw

= mw/Dw

={(m1-m0)-(m2-m0-mp)}/Dw

= (m1-m2+mp)/Dw

1. Dp = mp/Vp

= mp/{(m1-m2+mp)/Dw}

=Dwmp/(m1-m2+mp)

**Density Change of Hydrogel**

Density of hydrogel was controlled by swelling ratio change. Relationship between swelling ratio change and density change is induced as followed:

when, SR is the swelling ratio, D is the density of swollen hydrogel, V is the volume of swollen hydrogel, md is the mass of dried hydrogel, ms is the mass of hydrogel after swelling,

1. SR= (ms-md)/md

= ms/md – 1

Therefore, ms = md(SR+1)

1. D = ms/V

= md(SR+1)/V

1. D2/D1 = {md(SR2+1)/V2}/{md(SR1+1)/V1}

= (SR2+1)V1/(SR1+1)V2

= {(SR2+1)/(SR1+1)} \* (V1/V2)

When D2/D1 < 1, the density is decreased.

Therefore, if (SR1+1)/(SR2+1) > V1/V2, the density is decreased after swelling ratio change.

**Cost of the device**

0.4 g of PNIPAM(21.036 USD), 0.04 g of N,N’-methylenebisacrylamide(0.088 USD), 0.01 g of irgacure 2959(0.046 USD), and 1 ml of chloroform(0.131 USD) were used to fabricate 80 mm3 of the device. Therefore, the cost of 100 mm3 of the device is 26.62 USD. Almost 720 mm3 ofPNIPAM gel was used at experiment in Figure 5.