

## Supplementary information

### **Near infrared photothermal-responsive poly(vinyl alcohol)/black phosphorus composite hydrogels with excellent on-demand drug release capacity**

GuanghaiYang<sup>ab§</sup>, XuejuanWan<sup>a§\*</sup>, Zhipeng Gu,<sup>c</sup> Xierong Zeng<sup>a</sup> and JiaoningTang<sup>a\*</sup>

<sup>a</sup>Shenzhen Key Laboratory of Polymer Science and Technology, College of Materials Science and Engineering, Shenzhen University, Shenzhen 518060, PR China

<sup>b</sup>Key Laboratory of Optoelectronic Devices and Systems of Ministry of Education and Guangdong Province, College of Optoelectronic Engineering, Shenzhen University, Shenzhen 518060, PR China

<sup>c</sup>Department of Biomedical Engineering, Sun Yat-Sen University, Guangzhou 510006, P.R. China.

§These authors contributed equally to this work

\* Corresponding author: [wanxj@szu.edu.cn](mailto:wanjx@szu.edu.cn); [tjn@szu.edu.cn](mailto:tjn@szu.edu.cn)

## 1. Calculation of the photothermal conversion efficiency

The photothermal conversion efficiency ( $\eta$ ) of composite hydrogel was measured by a method reported by Roper and Wang, where  $\eta$  can be calculated using the following equations<sup>1, 2</sup>:

$$\eta = \frac{hS(T_{max} - T_{surr}) - Q_{dis}}{I(1 - 10^{-A_{808}})} \quad (1)$$

In this equation,  $h$  is heat transfer coefficient,  $S$  is the surface area of the container.  $T_{max}$  is the equilibrium temperature,  $T_{surr}$  is ambient temperature of the surroundings, and  $(T_{max} - T_{surr})$  was 28.6 °C according to Figure 7(c).  $Q_{dis}$  expresses heat dissipated from light absorbed by the quartz sample cell itself, and it was measured independently to be 11.35 mW using a quartz cuvette cell containing pure water.  $I$  is the laser power density (2 W/cm<sup>2</sup>),  $A_{808}$  is the absorbance of composite hydrogel at the excitation wavelength of 808 nm ( $A_{808} = 9.58$ ). Note that the concentration of pBP in the tested hydrogel was set as 0.1 mg/mL, due to the absorbance of hydrogel with higher pBP concentration will exceed the measuring range of the spectrometer. Thus, only the  $hS$  remains unknown for calculating  $\eta$ .

In order to get the  $hS$ , a dimensionless driving force temperature,  $\theta$  is introduced using the maximum system temperature ( $T_{max}$ ) and a sample system time constant ( $\tau_s$ ):

$$hS = \frac{\sum mC_p}{\tau_s} \quad (2)$$

$$\tau_s = -\frac{t}{\ln(\theta)} \quad (3)$$

$$\theta = \frac{T_{surr} - T}{T_{surr} - T_{max}} \quad (4)$$

where  $m$  and  $C_p$  are the mass and specific heat capacity of the composite hydrogel.  $t$  is the time of cooling process,  $T$  is the real-time temperature of  $t$ . It is worth to note that the mass ratio of PVA in composite hydrogel was only 8% and the water was totally entrapped within the formed hydrogel, therefore, according to Wang *et al*'s study,<sup>2</sup> the specific heat capacity of the hydrogel can be approximate to pure water ( $C_{H_2O} = 4.2$  J/g).

As shown in Figure 7(d), by applying the linear time data ( $t$ ) from the cooling process versus

negative natural logarithm of driving force temperature ( $\theta$ ),  $\tau_s$  is determined to be 187 s. Thus, according to Eq. (2), the  $hS$  is deduced to be 22.45 mW/°C. According to Eq. (1), the photothermal conversion efficiency ( $\eta$ ) of PVA/pBP hydrogel is calculated to be 31.5%.

## 2. Supplementary Figures

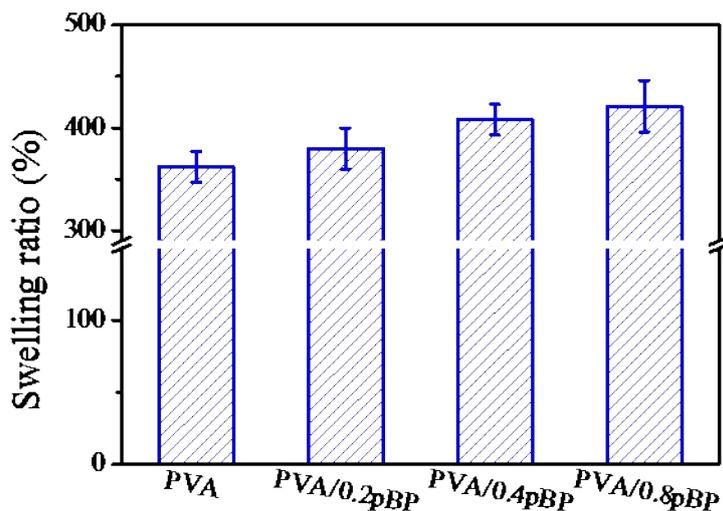


Figure S1. Swelling ratio of the PVA/pBP composite hydrogels.

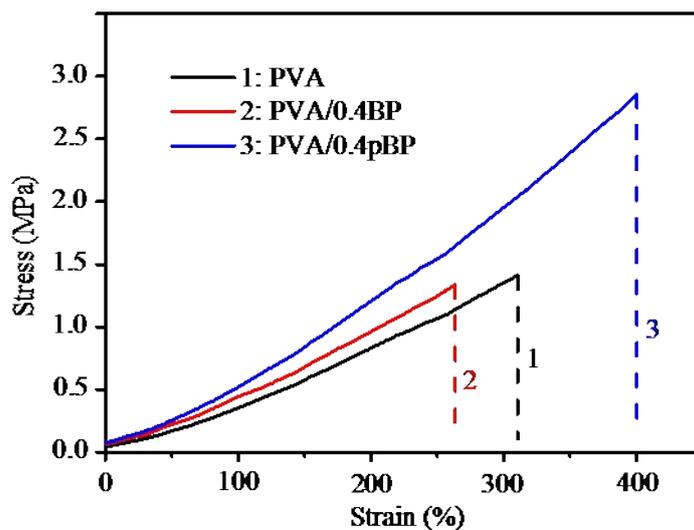
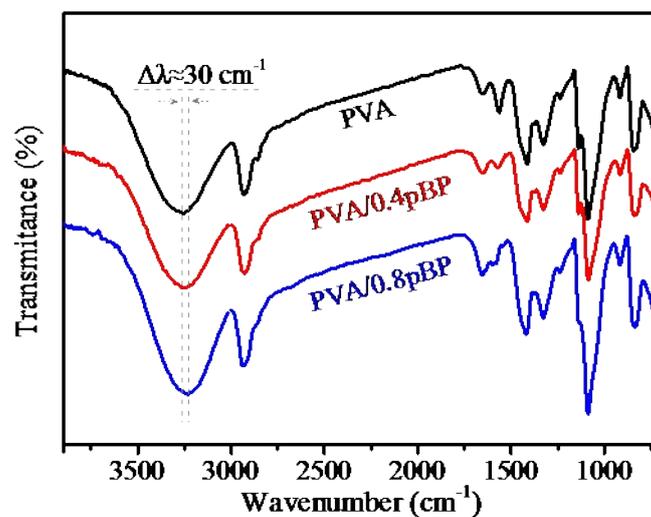
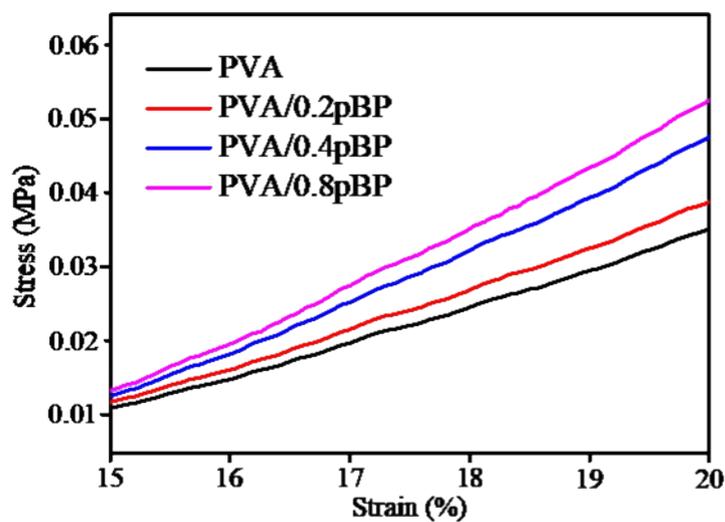


Figure S2. Stress-strain curves of PVA hydrogel, PVA/0.4BP hydrogel and PVA/0.4pBP hydrogel.



**Figure S3.** FTIR spectra of the PVA/pBP composite hydrogels.



**Figure S4.** The clarified linear portion of the stress-strain curves of the composite hydrogels under compression.

## References

1. D. K. Roper, W. Ahn and M. Hoepfner, *J Phys Chem C*, 2007, **111**, 3636-3641.
2. J. L. Zhao, J. L. Li, C. P. Zhu, F. Hu, H. Y. Wu, X. H. Man, Z. S. Li, C. Q. Ye, D. W. Zou and

S. G. Wang, *Acs Appl Mater Inter*, 2018, DOI: 10.1021/acsami.7b17608.