Solvent-free fabrication of broadband WS$_2$ photodetectors on paper

Wenliang Zhang$^1$, Onur Çakıroğlu$^1$, Abdullah Al-Enizi$^2$, Ayman Nafady$^2$, Xuetao Gan$^3$, Xiaohua Ma$^4$, Sruthi Kuriakose$^1$, Yong Xie$^{1,4}$* and Andres Castellanos-Gomez$^1$*

$^1$Materials Science Factory, Instituto de Ciencia de Materiales de Madrid (ICMM-CSIC), Madrid E-28049, Spain; $^2$Department of Chemistry, College of Science, King Saud University, Riyadh 11451, Saudi Arabia; $^3$Key Laboratory of Light Field Manipulation and Information Acquisition, Ministry of Industry and Information Technology, and Shaanxi Key Laboratory of Optical Information Technology, School of Physical Science and Technology, Northwestern Polytechnical University, Xi’an 710129, China; $^4$School of Advanced Materials and Nanotechnology, Xidian University, Xi’an 710071, China.

*Correspondence: Y Xie, E-mail: yxie@xidian.edu.cn; A Castellanos-Gomez, E-mail: andres.castellanos@csic.es

Supplementary information for this paper is available at https://doi.org/10.29026/oea.2023.220101
Effect of oxygen molecules on the electrical conductivity of the WS\(_2\) photodetector: The WS\(_2\) device soldered with longer copper wires was placed in a glass sealing jar filled with many oxygen absorbers. In this case, the sealing jar creates an oxygen-free environment (but does not remove the N\(_2\)) quickly when closed, and returns to the air environment immediately once opened. The current vs. voltage (IV) characteristics of the WS\(_2\) device in oxygen-free and air environments were measured by closing and opening alternately the sealing jar.

Effect of oxygen molecules on the electrical conductivity of the WS\(_2\) photodetector: The WS\(_2\) device soldered with longer copper wires was placed in a glass sealing jar filled with many oxygen absorbers. In this case, the sealing jar creates an oxygen-free environment (but does not remove the N\(_2\)) quickly when closed, and returns to the air environment immediately once opened. The current vs. voltage (IV) characteristics of the WS\(_2\) device in oxygen-free and air environments were measured by closing and opening alternately the sealing jar.

Fig. S1 | Current as a function of pressure for the paper-based WS\(_2\) photodetector (device A) at a constant bias voltage of 10 V during the vacuuming process.

Effect of oxygen molecules on the electrical conductivity of the WS\(_2\) photodetector: The WS\(_2\) device soldered with longer copper wires was placed in a glass sealing jar filled with many oxygen absorbers. In this case, the sealing jar creates an oxygen-free environment (but does not remove the N\(_2\)) quickly when closed, and returns to the air environment immediately once opened. The current vs. voltage (IV) characteristics of the WS\(_2\) device in oxygen-free and air environments were measured by closing and opening alternately the sealing jar.

Fig. S2 | Electrical properties of the paper-based WS\(_2\) photodetector (device D) in different environments. (a) IV curves measured in the alternatively changing oxygen-free and air environments. (b) Comparison of the obtained current values. The result demonstrated that the electrical conductivity of the WS\(_2\) device is strongly affected by the oxygen molecules.
Fig. S3 | Photocurrent of WS$_2$ photodetector on paper (device B) under different power intensities (wavelength, 617 nm) at increasing bias voltages from 1 V to 30 V.
Fig. S4 | Current vs. voltage characteristics of WS₂ photodetector on paper (device B) under different power intensities (wavelength, 617 nm) at increasing bias voltages from 1 V to 35 V.
Fig. S5 | Paper-based WS₂ device with interdigitated Au electrodes. (a) Temporal photocurrent of the interdigitated WS₂ device as the incident power intensity increases from 1.1 mW cm⁻² to 35 mW cm⁻². (b) The measured photocurrent as a function of power intensity. (c) The measured responsivity as a function of power intensity. (d) Variation of current of the interdigitated WS₂ device under a periodic ON/OFF switching of illumination with 35 mW cm⁻² power intensity. Inset shows the optical micrograph of a paper-based WS₂ device with interdigitated Au electrodes. Note: Measurements are carried out at a bias voltage of 5 V and a selected wavelength of 617 nm.
Fig. S6 | Device-to-device variation of paper-based WS$_2$ photodetectors. (a) Photocurrent and (b) responsivity as a function of power intensity measured on 10 WS$_2$ devices. Box plots summarizing (c) photocurrent and (d) responsivity values. Note: Measurements are carried out at a bias voltage of 10 V and a selected wavelength of 617 nm.
Fig. S7 | Temperature-dependent photoresponse of the paper-based WS₂ photodetector (device E) under the illumination of 617 nm in vacuum condition. (a) Temporal current of the WS₂ photodetector under illumination with various power intensities collected at different temperatures ranging from 21°C to 121°C. (b) The measured photocurrent as a function of power intensity. (c) The measured responsivity as a function of power intensity. (d) The measured photocurrent and responsivity as a function of temperature at a fixed power intensity of 35 mW cm⁻². Note: Measurements are carried out at a bias voltage of 10 V.