

Φ – 575 Διάλεξη 08

Φυσική διατάξεων δισδιάστατων ημιαγωγών

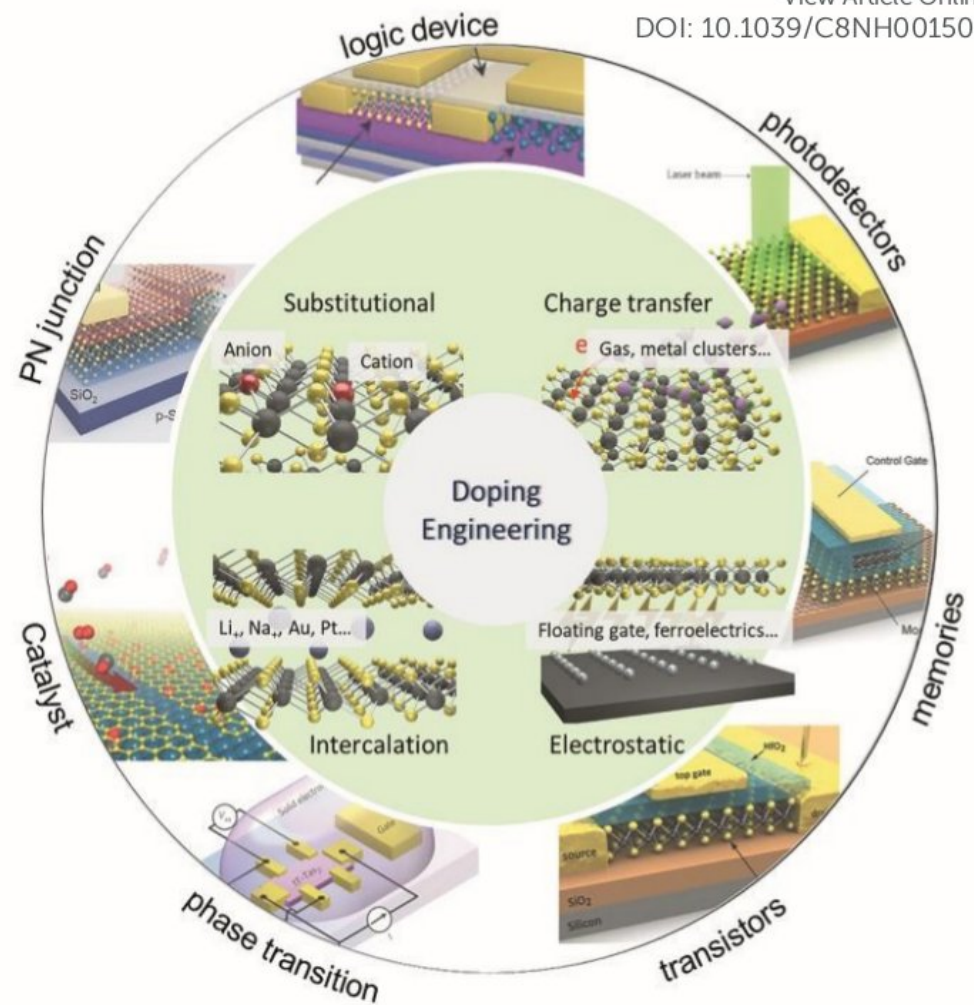
Γιώργος Δεληγεώργης (deligeo@physics.uoc.gr)

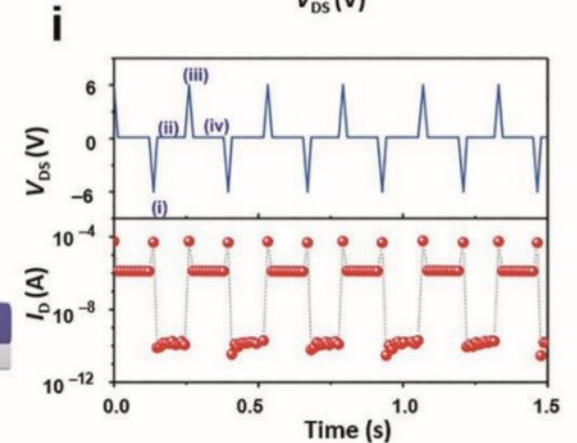
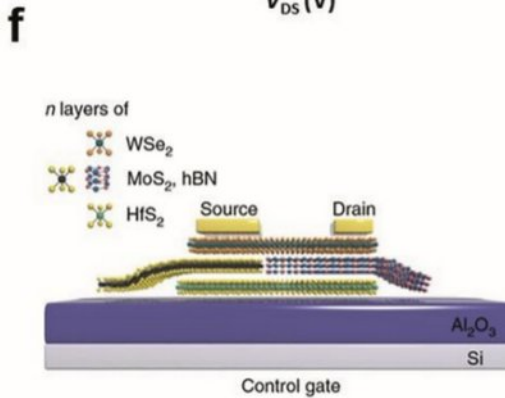
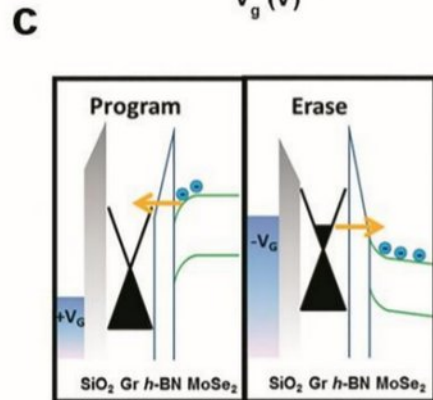
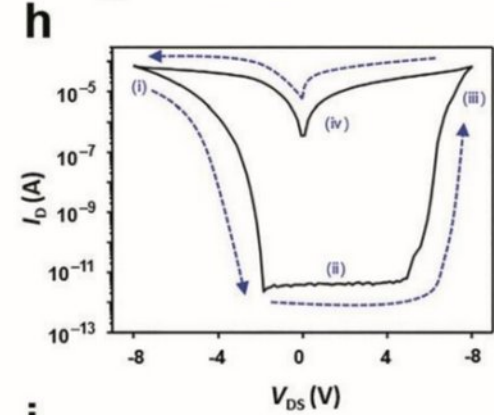
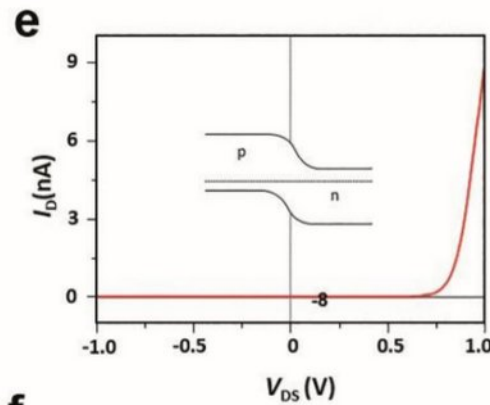
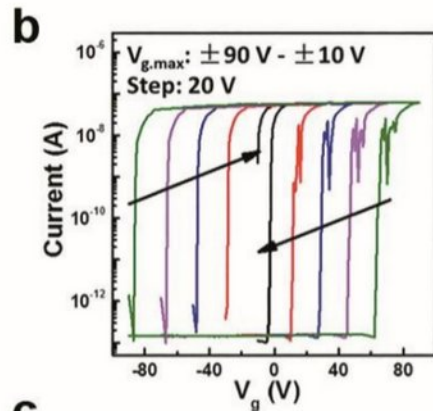
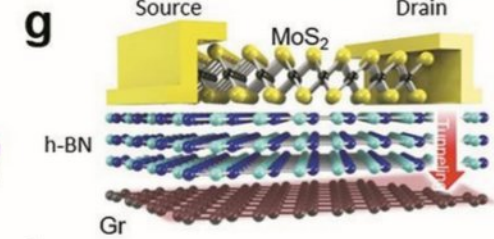
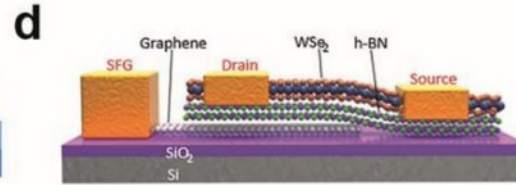
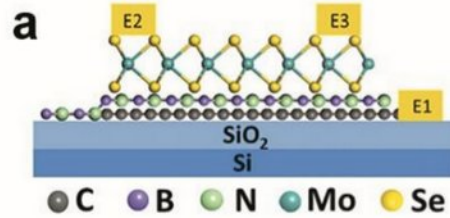


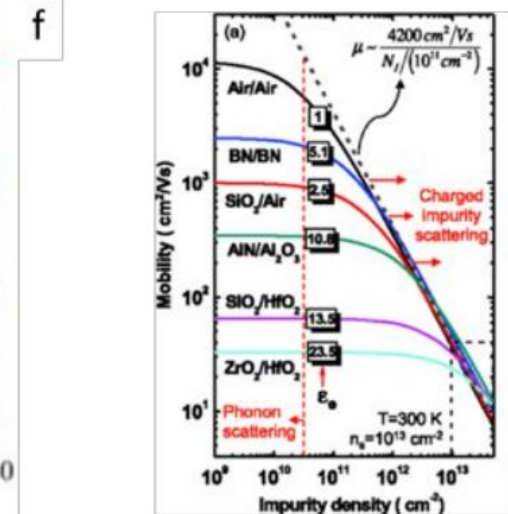
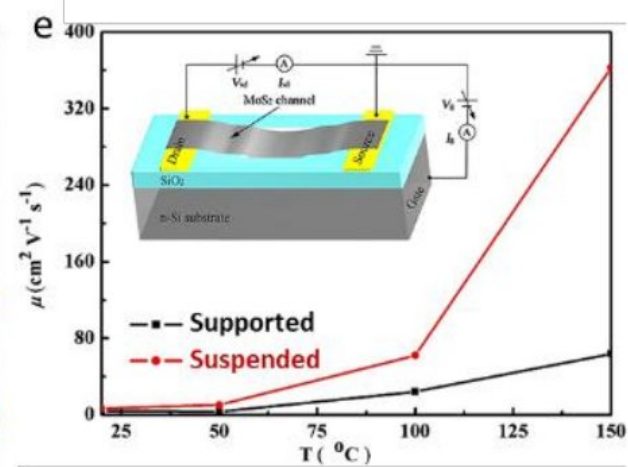
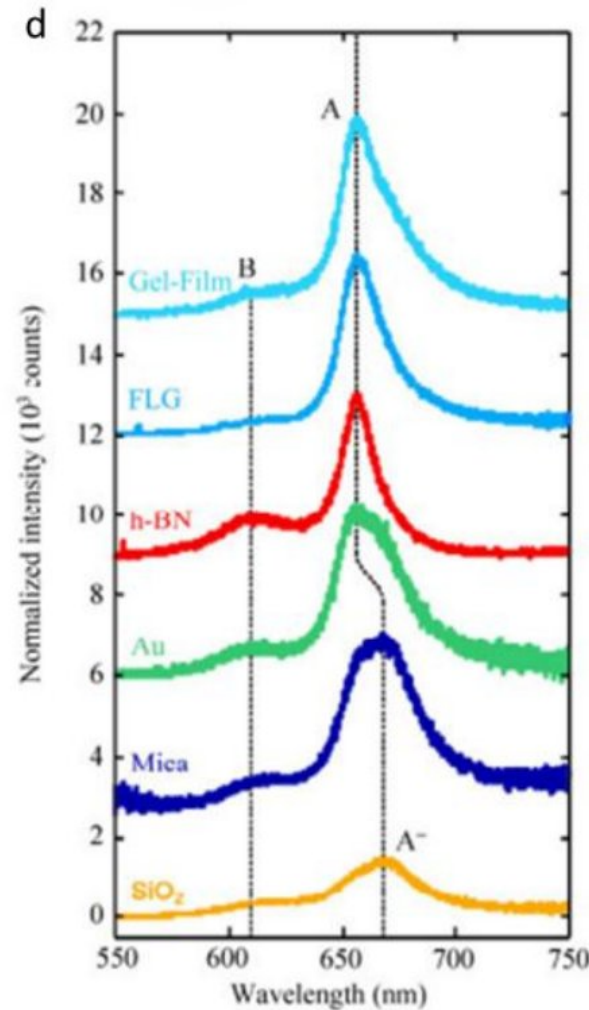
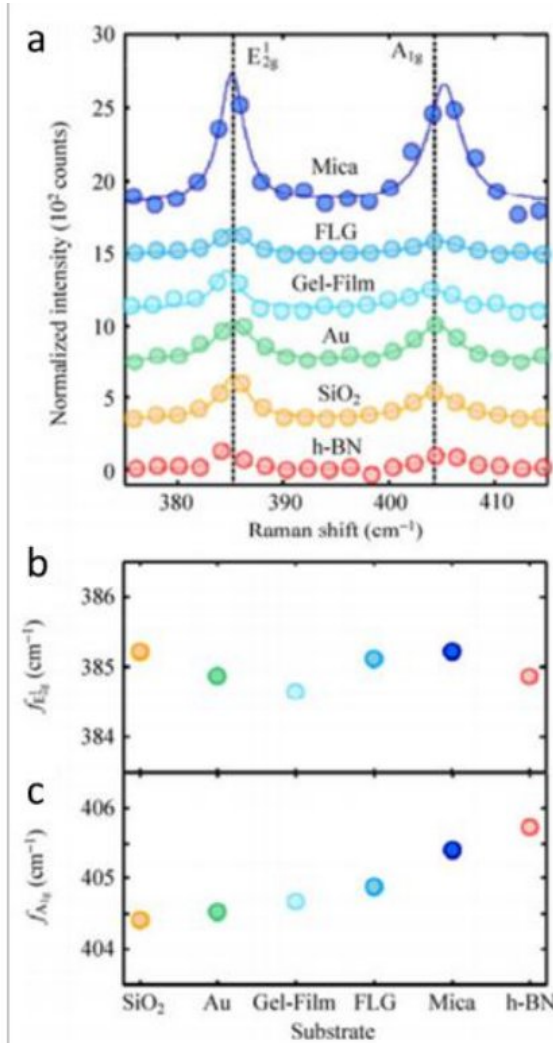
Υπάρχουν δύο προσεγγίσεις:

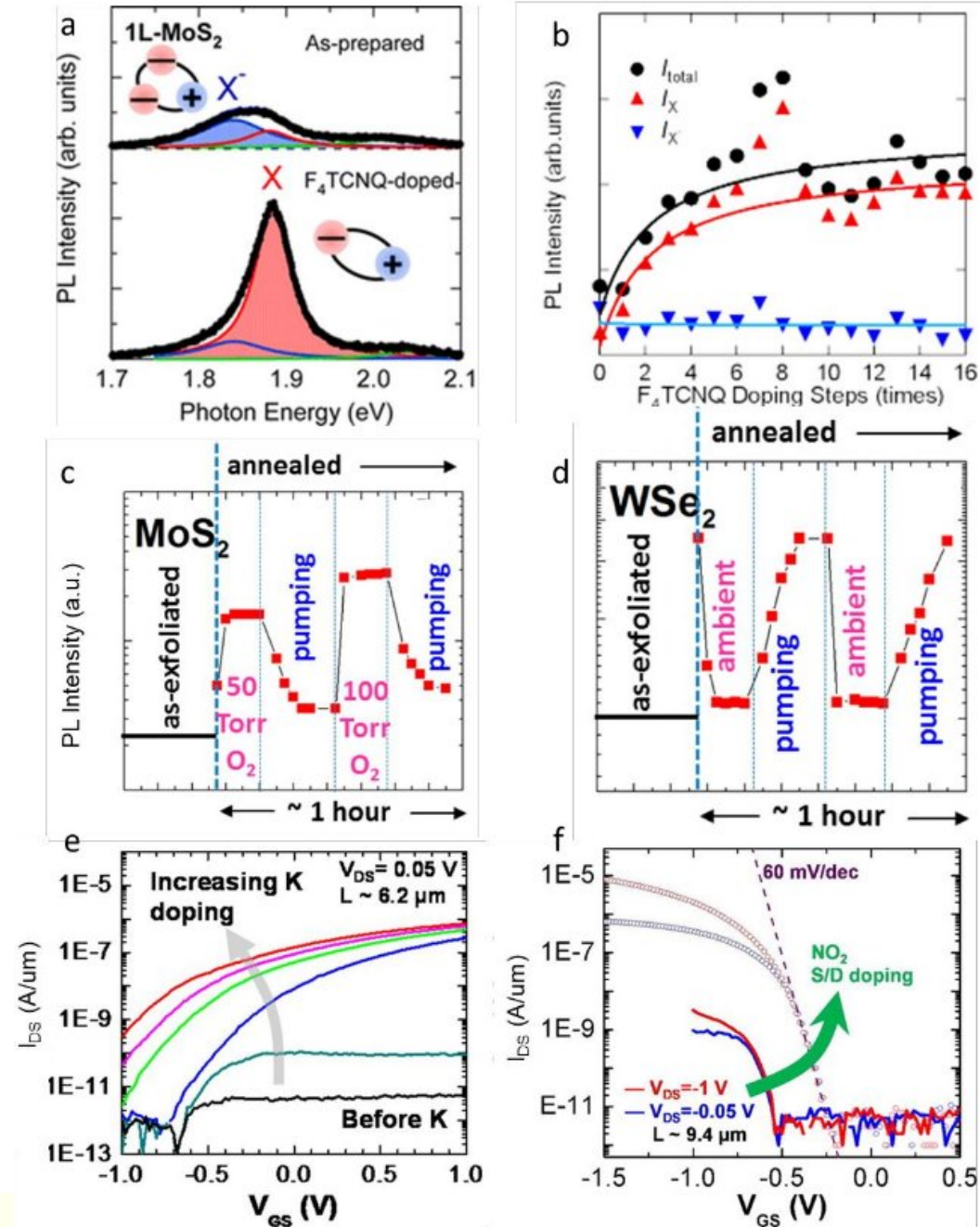
- **Non covalent doping (adsorption)**
 - **Charge transfer**
 - **Intercalation**
- **Covalent doping (substitutional)**
- **Dynamic doping (electrostatic)**

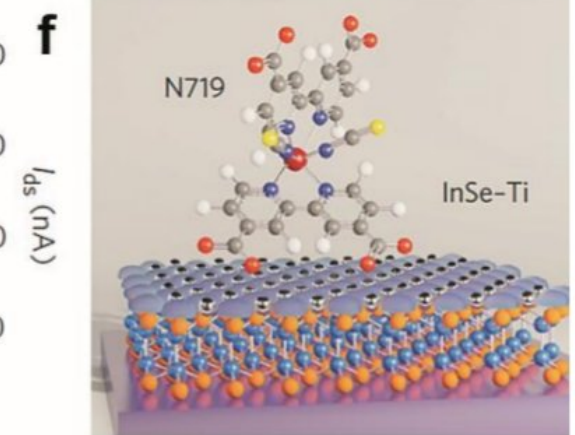
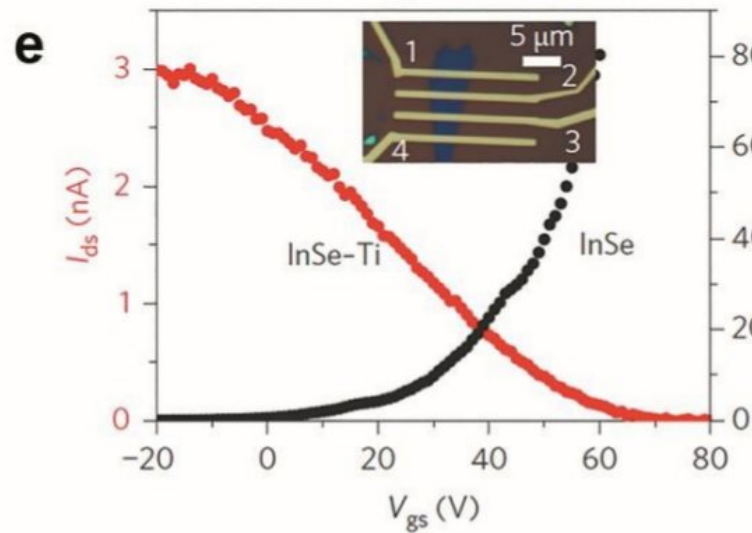
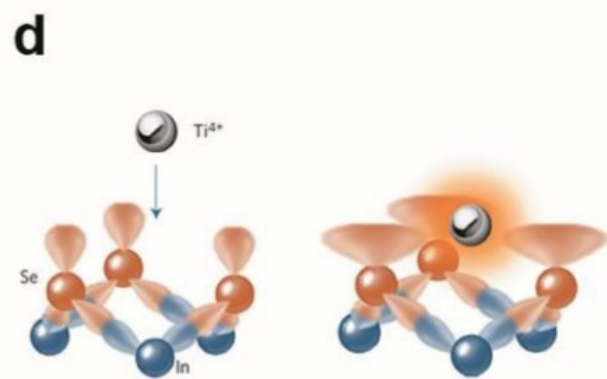
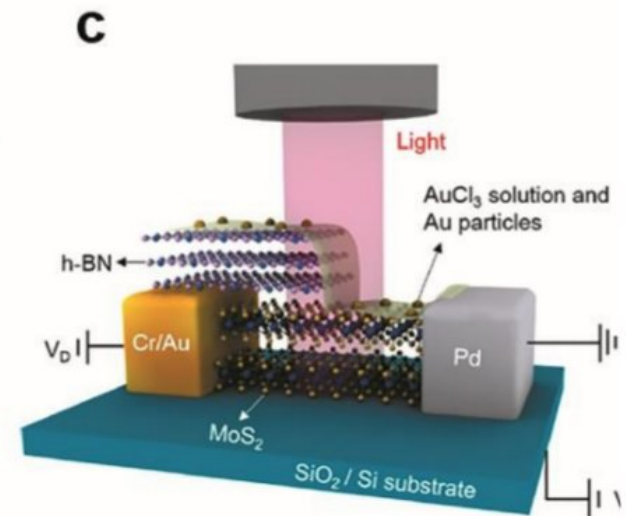
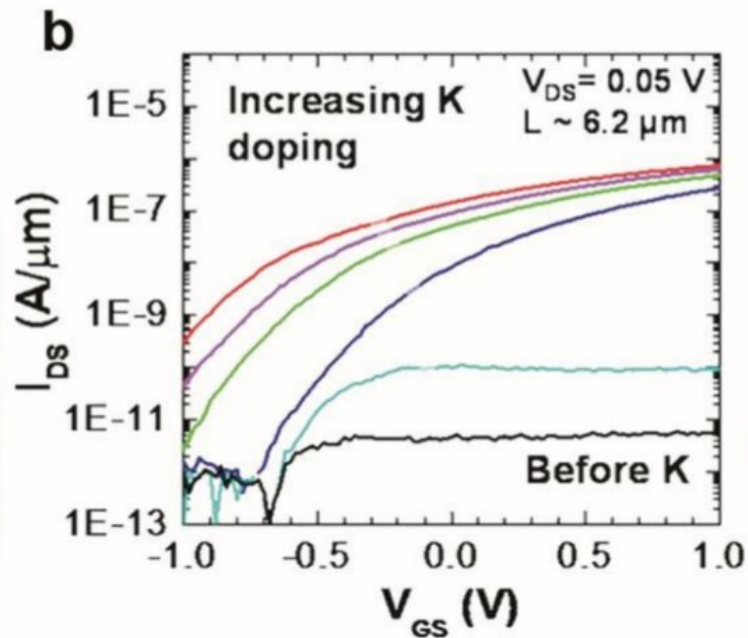
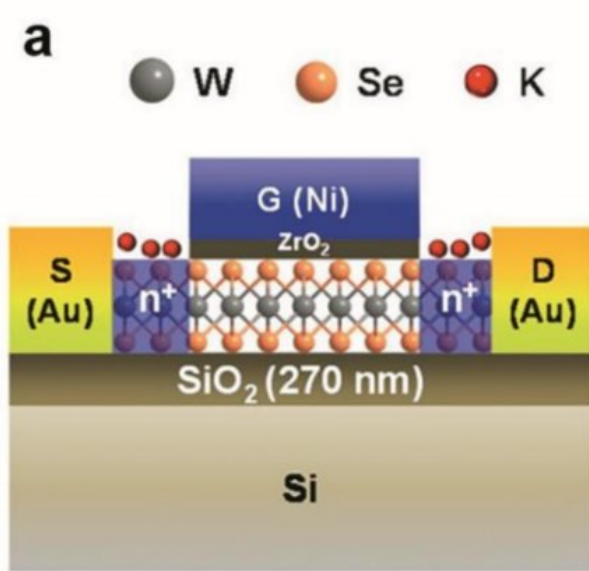
View Article Online
DOI: 10.1039/C8NH00150B











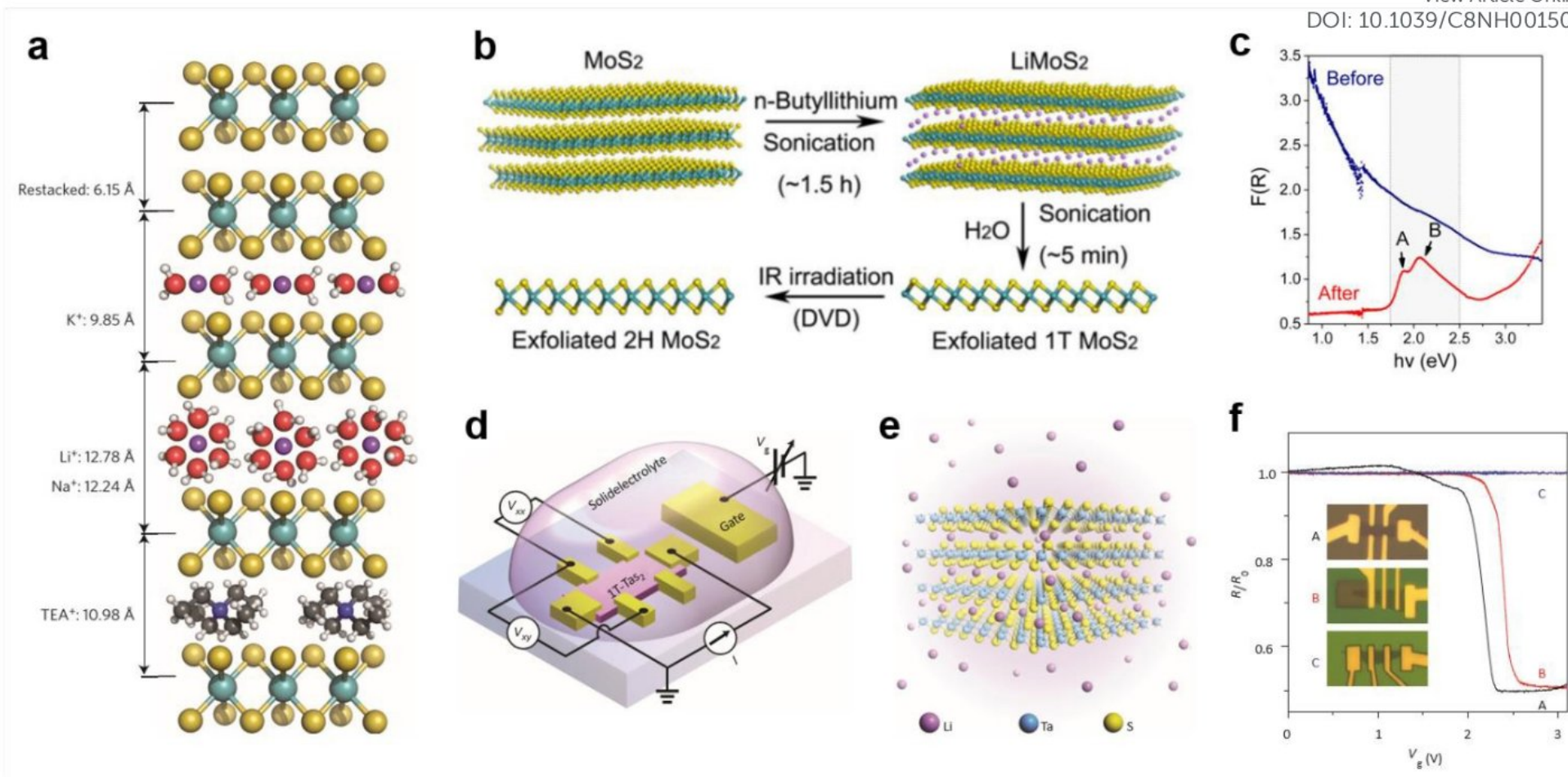


Figure 9. Intercalation modulation to MXs: (a) intercalation of MoS₂ by alkali ions (Li⁺, Na⁺, K⁺) with solvent molecules and the case by TEA⁺, reprinted with permission from ref.184, Copyright 2015 Nature Publishing group. (b) Sonication assisted exfoliation of MoS₂ into 1T phase and the IR irradiation assisted restoration, and (c) the resulted reflectance spectra change, reprinted with permission from ref. 191, Copyright 2015 American Chemical Society. (d) Electrochemical setup and (e) the illustration of Li intercalation in TaS₂, (f) patterned control of Li⁺ intercalation in to devices and the resulted gate modulation characteristic, reprinted with permission

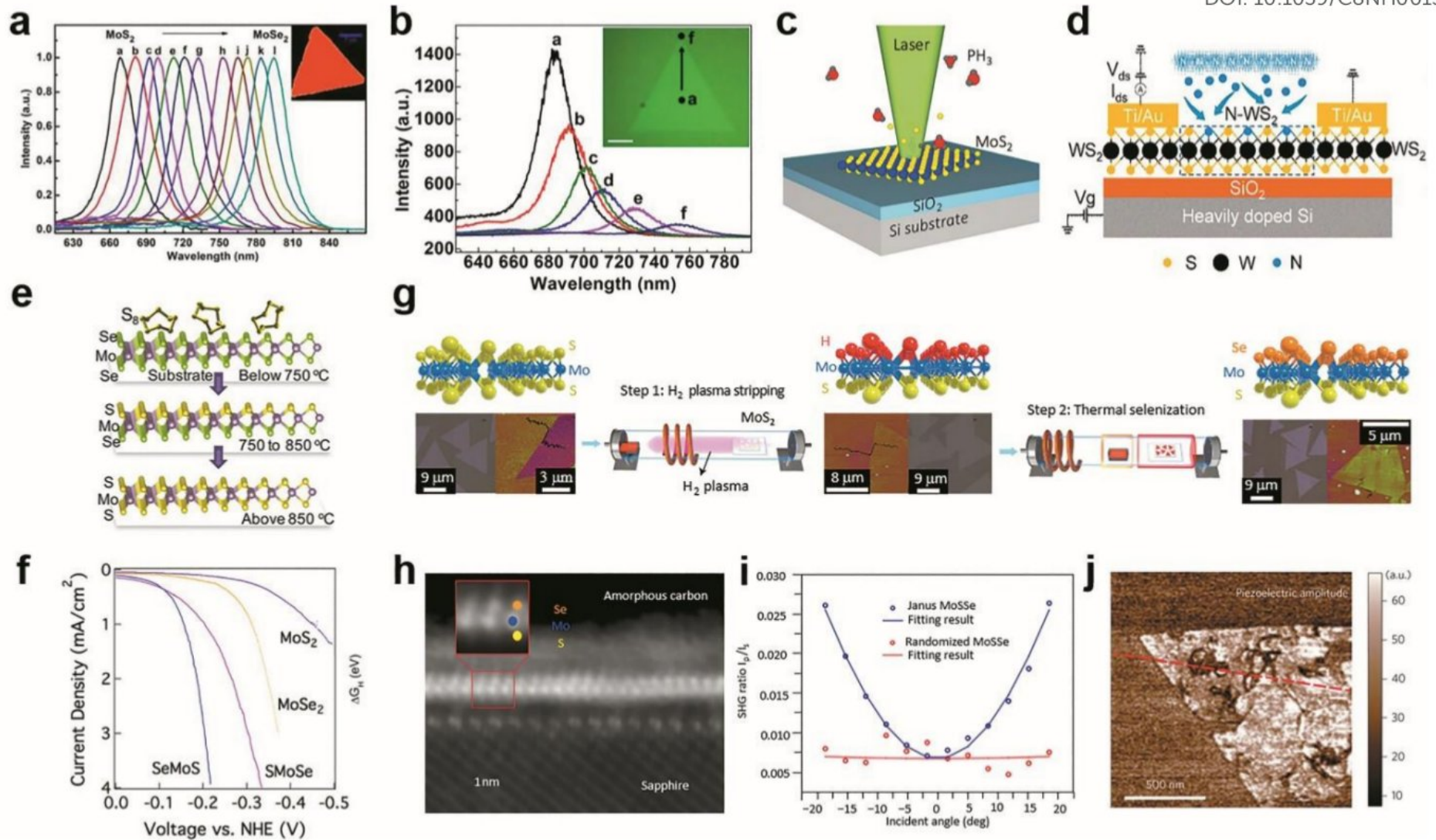


Figure 4. Substitutional doping at anion sites: (a) the PL of composition tuned $\text{MoS}_{2x}\text{Se}_{2(1-x)}$ with uniform distribution and (b) the one with composition gradient in a single flake, reprinted with permission from ref. 102 and 109, Copyright 2014, 2015 American Chemical Society. (c) Laser assisted selective area doping by PH_3 , reprinted with permission from ref. 100, Copyright 2016 American Chemical Society. (d) Schematic of N_2 plasma doping to WS_2 , reprinted with permission from ref. 101, Copyright 2016 American Chemical Society.

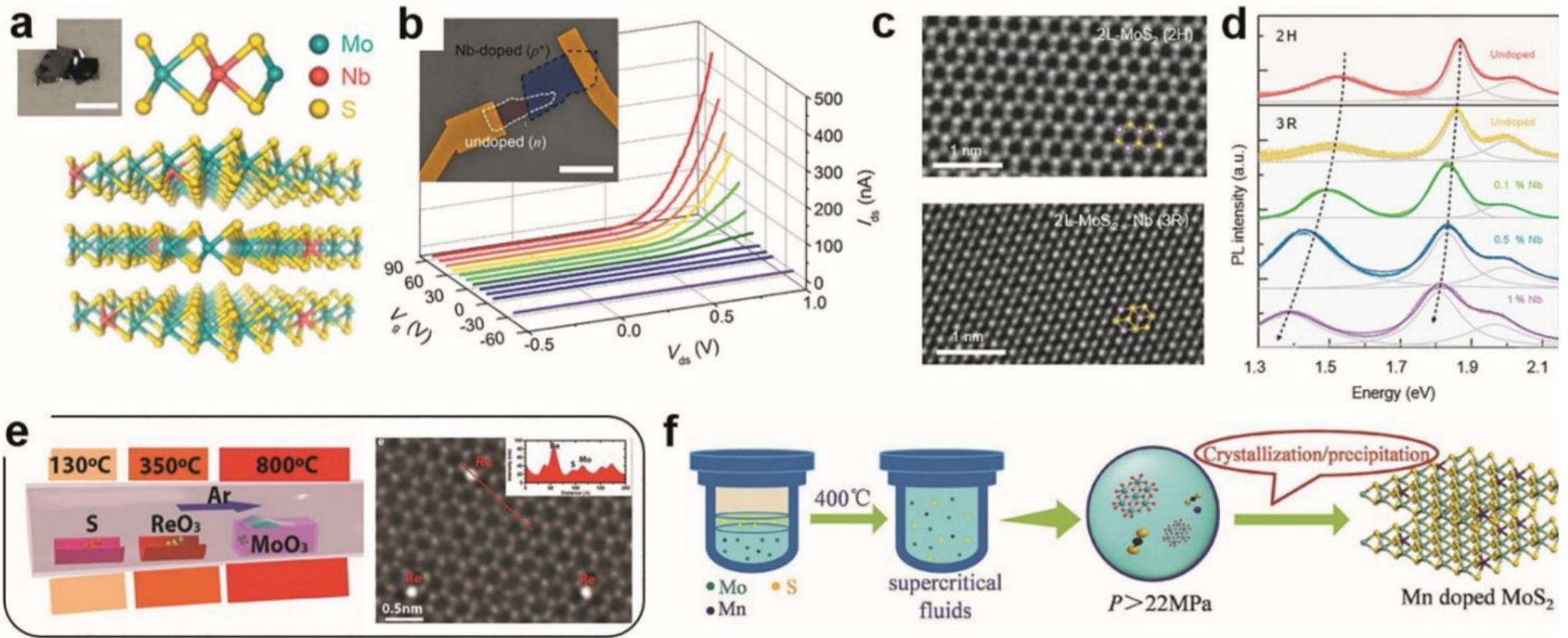


Figure 3. Substitutional doping at cation sites: (a) schematic illustration of substitutional Nb doping in MoS₂ in partial replacement of Mo atoms, (b) the resulted rectification behaviour in a gate modulated junction formed between Nb-doped and undoped MoS₂, reprinted with permission from ref. 25, Copyright 2014 American Chemical Society. (c) high resolution TEM image of bilayer MoS₂ in 2H and 3R phase induced by Nb doping, and (d) their PL characteristics, reprinted with permission from ref. 40, Copyright 2018 Nature Publishing group. (e) A typical CVD configuration for in-situ doping during growth using multiple source evaporation and the TEM image of resulted Re doped MoS₂, reprinted with permission from ref. 71, Copyright 2018, Wiley-VCH. (f) Illustration of hydrothermal procedures to achieving Mn doped MoS₂ in supercritical conditions, reprinted with permission from ref. 99, Copyright 2017, Wiley-VCH.



- 1) H. Zhu, X. Gan, A. McCreary, R. Lv, Z. Lin, and M. Terrones, "Heteroatom doping of two-dimensional materials: From graphene to chalcogenides," *Nano Today*, vol. 30, p. 100829, Feb. 2020, doi: 10.1016/j.nantod.2019.100829.
- 2) K. Zhang and J. Robinson, "Doping of Two-Dimensional Semiconductors: A Rapid Review and Outlook," *MRS Advances*, vol. 4, no. 51–52, pp. 2743–2757, ed 2019, doi: 10.1557/adv.2019.391.
- 3) H. Zhang and R. Lv, "Defect engineering of two-dimensional materials for efficient electrocatalysis," *Journal of Materiomics*, vol. 4, no. 2, pp. 95–107, Jun. 2018, doi: 10.1016/j.jmat.2018.02.006.
- 4) T. H. Ly, Q. Deng, M. H. Doan, L.-J. Li, and J. Zhao, "Facile Doping in Two-Dimensional Transition-Metal Dichalcogenides by UV Light," *ACS Appl. Mater. Interfaces*, vol. 10, no. 35, pp. 29893–29901, Sep. 2018, doi: 10.1021/acsami.8b09797.
- 5) P. Luo et al., "Doping engineering and functionalization of two-dimensional metal chalcogenides," *Nanoscale Horiz.*, vol. 4, no. 1, pp. 26–51, Dec. 2018, doi: 10.1039/C8NH00150B.
- 6) S. Feng, Z. Lin, X. Gan, R. Lv, and M. Terrones, "Doping two-dimensional materials: ultra-sensitive sensors, band gap tuning and ferromagnetic monolayers," *Nanoscale Horiz.*, vol. 2, no. 2, pp. 72–80, Feb. 2017, doi: 10.1039/C6NH00192K.
- 7) B. Cai, S. Zhang, Z. Yan, and H. Zeng, "Noncovalent Molecular Doping of Two-Dimensional Materials," *ChemNanoMat*, vol. 1, no. 8, pp. 542–557, Dec. 2015, doi: 10.1002/cnma.201500102.