RPGR2017

MoS_2/CNT Core–Shell Nanocomposites for Enhanced Nonlinear Optical Performances

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Outline

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1. Background
2. Synthesis and Characterization
3. Nonlinear optical performances
4. Summary

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1 Background

2 Synthesis and Characterization

3 Nonlinear optical performances

4 Summary

Background

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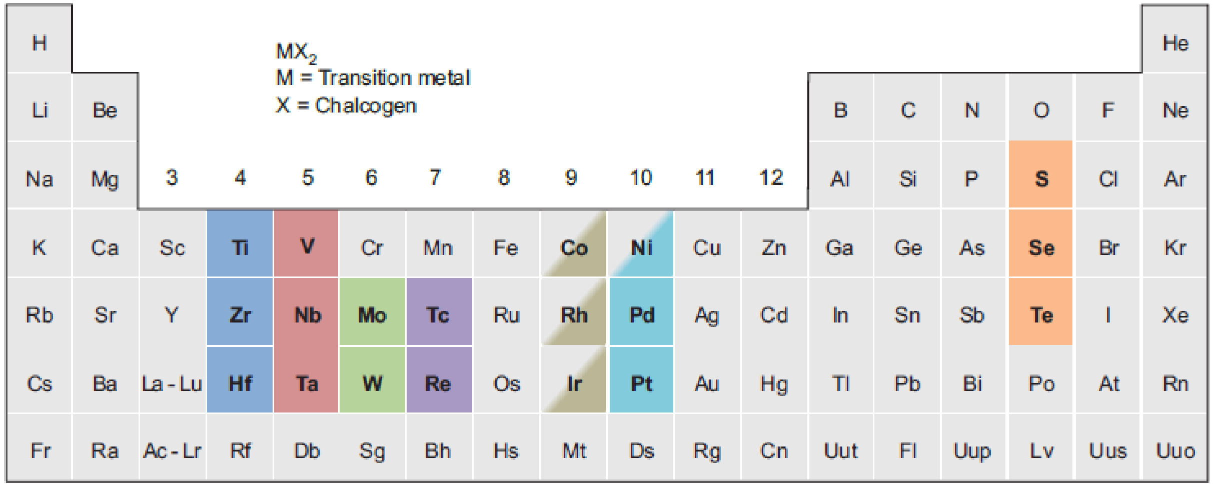
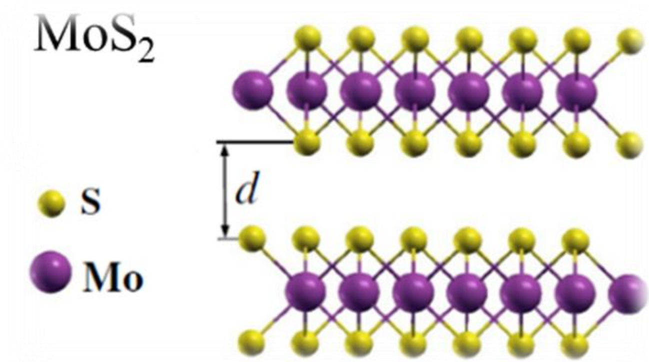


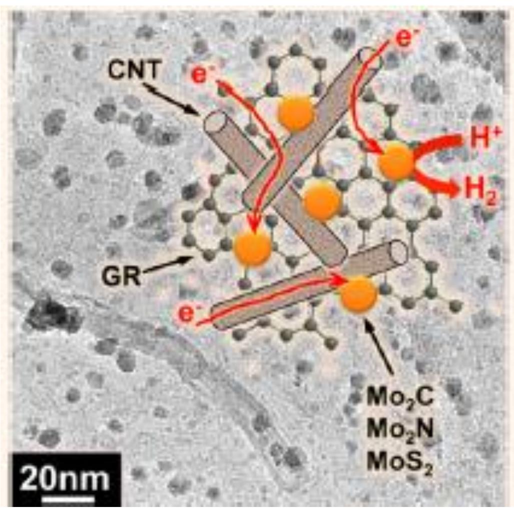


- Molecular-scale thickness;
- Indirect-to-direct bandgap transition as the decreasing of the number of monolayer;
- Ultrafast carrier dynamics (intraband ~fs, interband~ps);
- Sizable and layer-dependent bandgap, typically in the 1-2 eV;
- Fairly good photoluminence and electroluminescence properties;
- High optical gain, e.g., 2D nanolasers;
- Remarkable exciton effects, i.e., high binding energy, large oscillator strength and long lifetime.

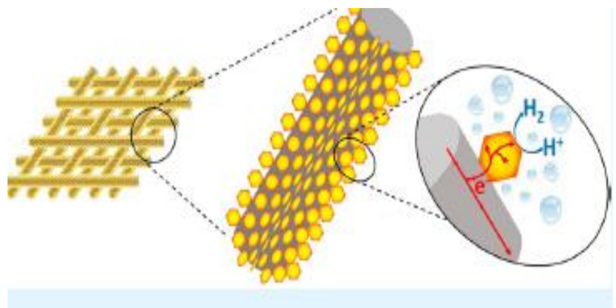
Background

Carbon nanotubes (CNTs) with highly delocalized π-electrons have attracted great interests with superior electric and optical properties owning to their unique structure.

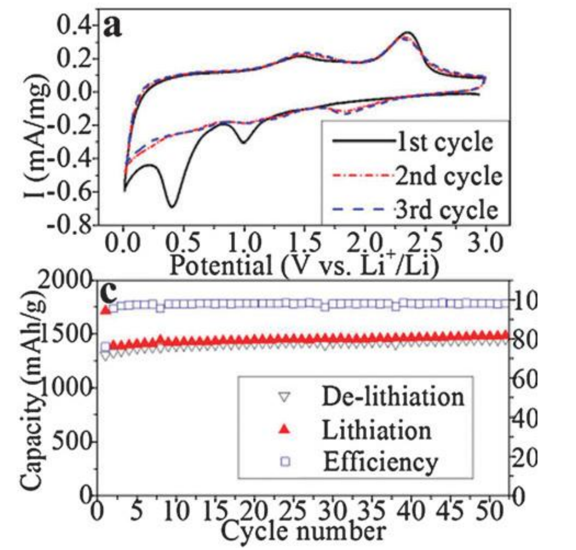
MoS_2/CNT nanocomposites



electrocatalysts for hydrogen evolution
Youn, et al., ACS Nano, 8, 5164 (2014)



electrocatalysts for hydrogen evolution
Zhang, et al., ACS Appl. Mater. Interfaces 7, 12193 (2015)



CNT–MoS_2 composite as anode material in lithium ion batteries
Chem. Commun., 50, 3338 (2014).

Our questions

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- **What is the nonlinear optical performances (NLO) of MoS_2/CNTs heterostructures?**

- **How does the charge transfer between MoS_2 and CNTs affect the NLO performances of the nanocomposites?**

- **What is the direction of charge transfer in MoS_2/CNTs heterostructures?**

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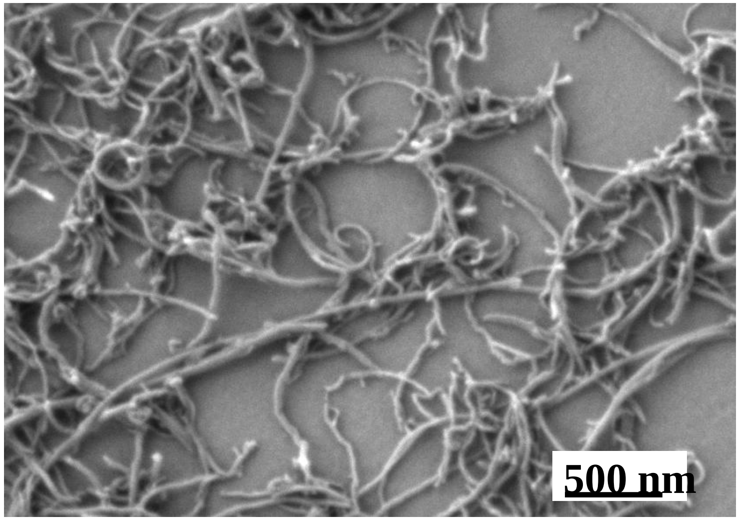
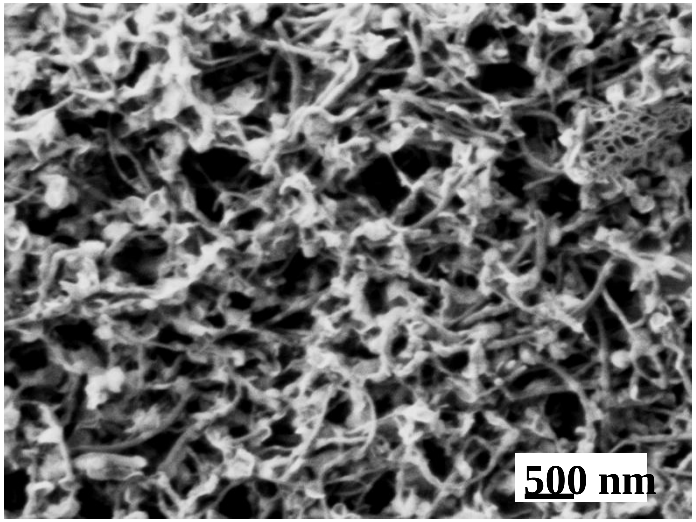
SEM results

Synthesis method:

solvothermal method (NMP as solvent)

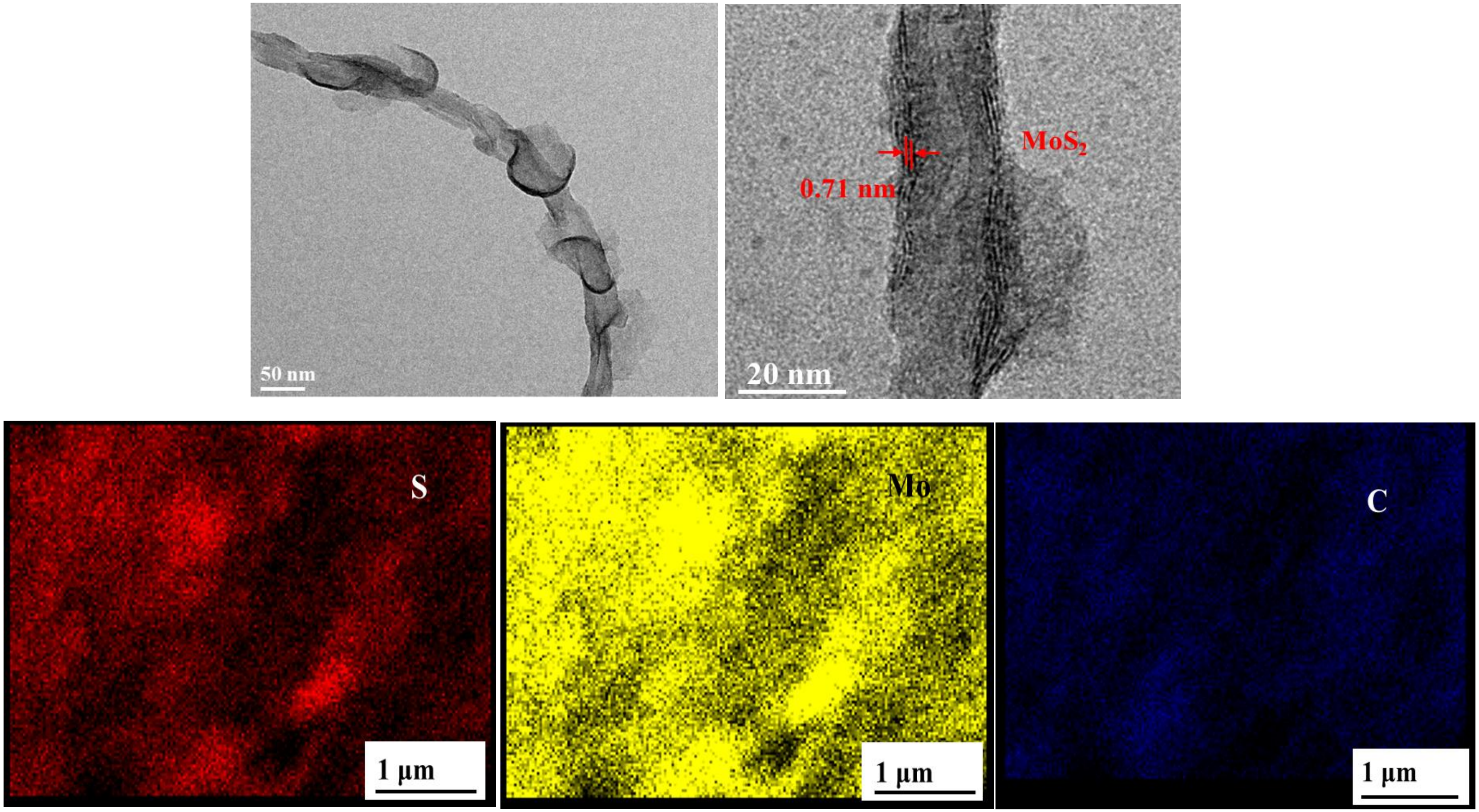




Pure CNTs **MoS_2/CNTs nanocomposites**

Zhang et al. *Chem. Eur. J., 2017, 23, 3321*

TEM and EDS results



Core-shell structured MoS_2/CNTs nanocomposites

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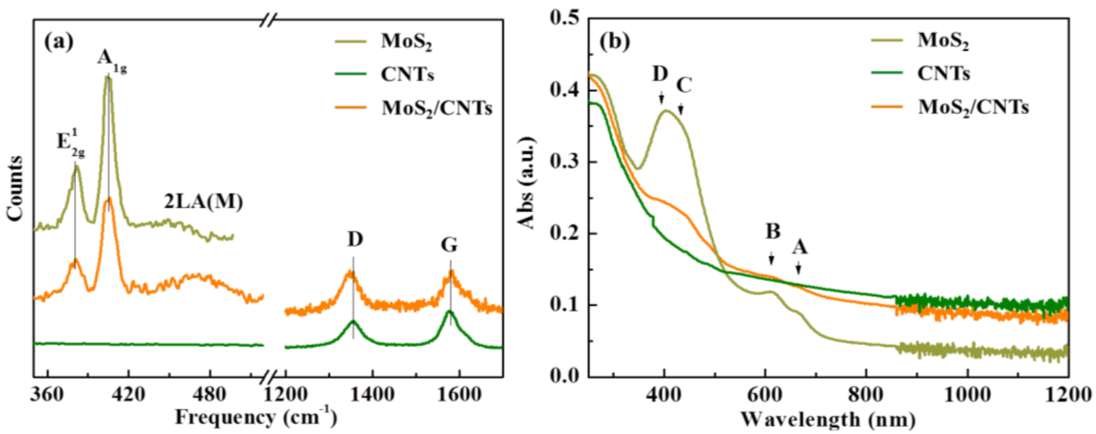
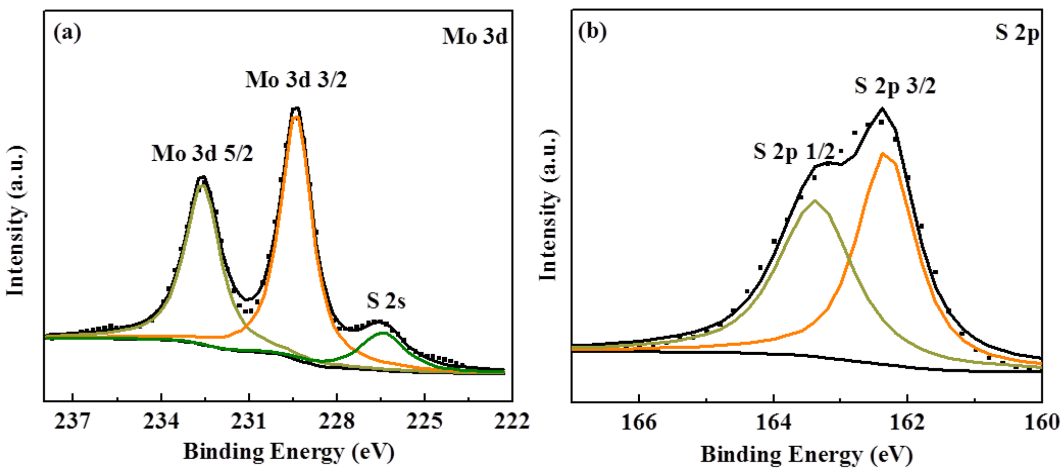
Raman and absorption results



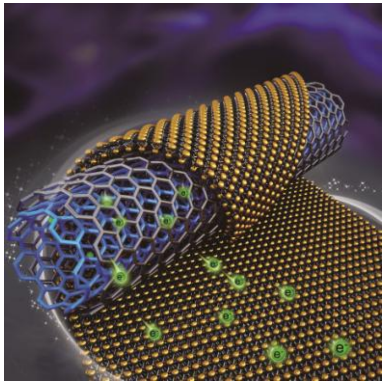
Raman: Two Raman mode;
Absorption: Four exciton absorption peaks ;

2H-MoS_2/CNTs



Upshift

~ 0.4 eV



Electrons from CNTs to MoS_2

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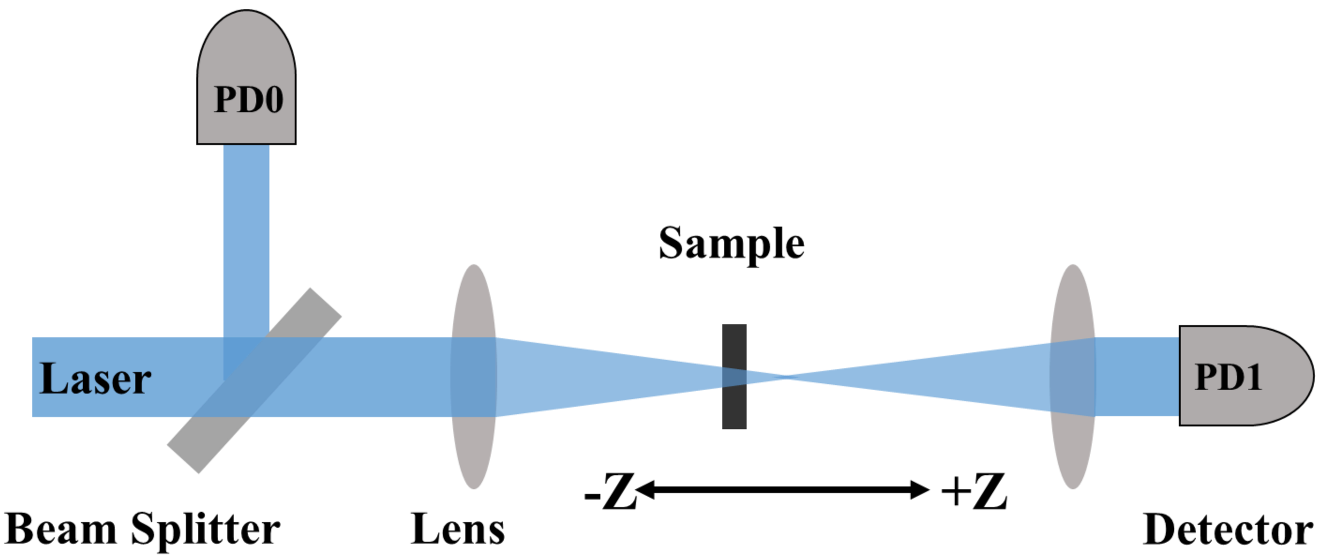
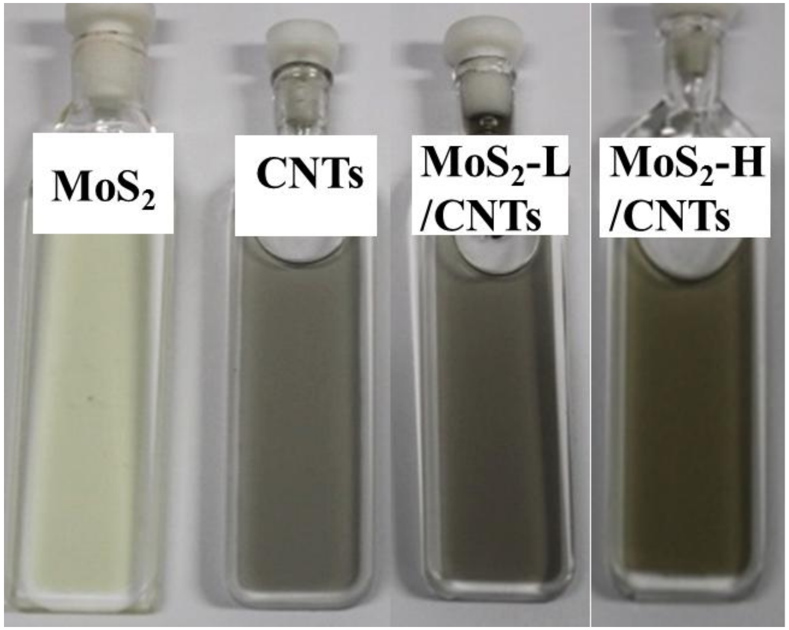
Nonlinear optical (NLO) performances

Nonlinear optical measurements: open-aperture Z-scan technology

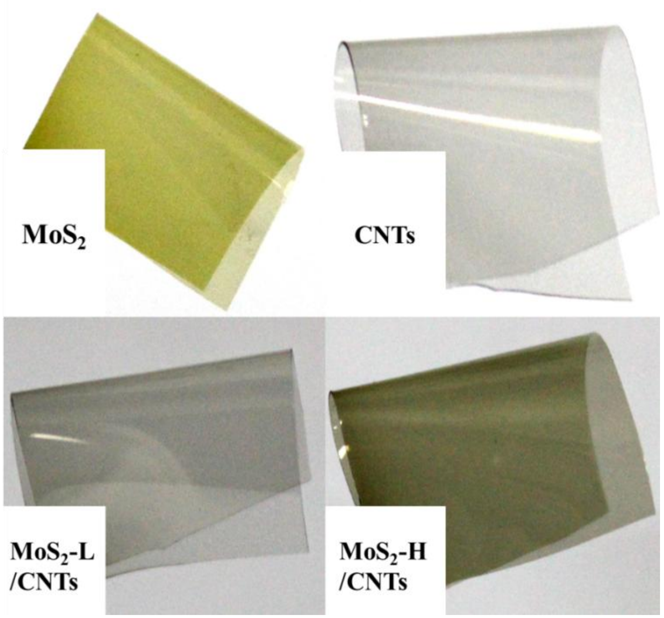
Set-up:



Dispersions and PVA polymers

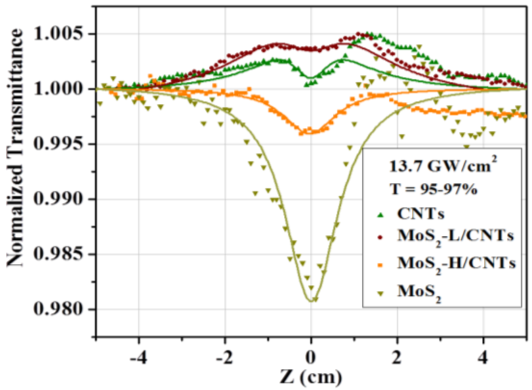


Dispersions prepared by LPE method



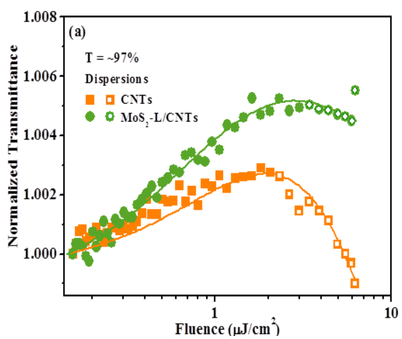
PVA films

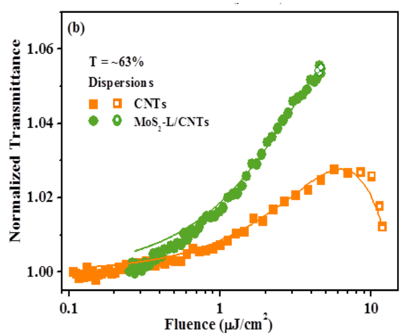
NLO, fs, 1030 nm

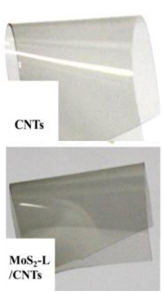


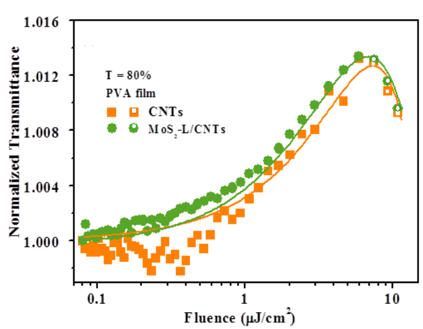
MoS_2-H/CNTs: OL, better than MoS_2-L/CNTs and pure CNTs,
MoS_2-L/CNTs: more pronounced SA than pure CNTs.

Strong coupling effect between CNTs and MoS_2 in MoS_2-L/CNTs.









- **MoS_2-L/CNTs in dispersions: ~one times larger than CNT alone;**
- **Low saturation intensity.**

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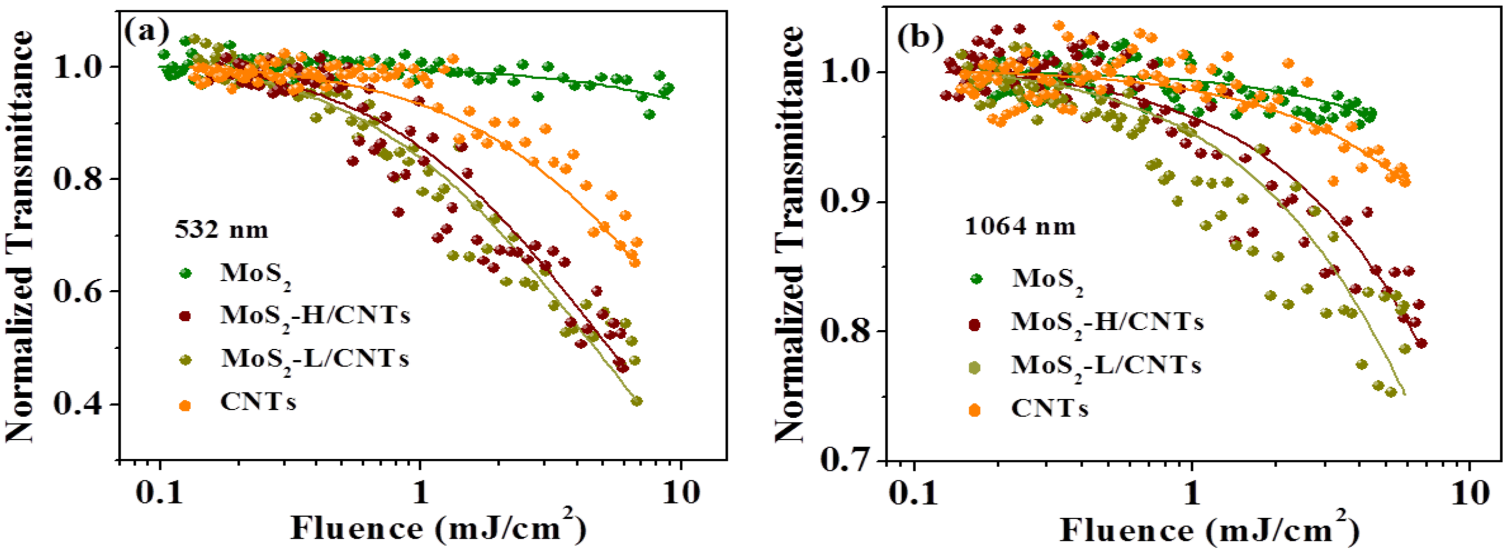
NLO, fs, Polymer films

NLO parameters of the samples measured using the Z-scan technique for fs at 1030 nm. [a]= NMP dispersions; [b]= PVA films.

Sample	**T [%]**	α_0 **[cm^{-1}]**	**NLO response**	β_{eff} **[cm GW^{-1}]**	I_{sat} **[GW cm^{-2}]**
CNTs[a]	97	0.30	SA+OL	$(0.99\pm0.15)\times10^{-2}$	11.0±2.1
MoS_2-L/ CNTs[a]	96	0.40	SA+OL	$(0.93\pm0.17)\times10^{-2}$	15.8±3.5
CNTs[a]	63	4.62	SA+OL	$(5.50\pm0.23)\times10^{-2}$	48.2±4.9
MoS_2-L/ CNTs[a]	62	4.78	SA+OL	**$(6.25\pm0.26)\times10^{-2}$**	31.8±4.2
CNTs[b]	80	26.3	SA+OL	$(25.5\pm3.5)\times10^{-2}$	58.3±5.1
MoS_2-L/ CNTs[b]	80	28.3	SA+OL	**$(30.9\pm4.5)\times10^{-2}$**	52.1±4.9

NLO, ns, Dispersions



Normalized transmission as functions of input laser fluence for MoS_2, CNTs, and MoS_2/CNTs dispersions with the transmission of ~80% for ns, respectively.

Nonlinear extinctive coefficient β_{eff}: ~ 33.9 for 532 nm, ~ 7.2 for 1064 nm;

Imaginary third-order susceptibility Im$\chi^{(3)}$: ~ 2.7 for 532 nm, ~ 3.5 for 1064 nm.

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NLO, ns, Dispersions

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NLO coefficients of the nanocomposites dispersions in NMP for ns at 532 nm and 1064 nm.

Sample	λ [nm]	I_0 [μJ]	T [%]	α_0 [cm^{-1}]	β_{eff} [cm GW^{-1}]	$\mathrm{Im}\chi^{(3)}$ [× 10^{-13}, esu]
MoS_2	532	200	74	0.30	0.045±0.02	0.16±0.07
MoS_2-L/CNTs			80	0.22	**1.51±0.2**	**5.49±0.73**
MoS_2-H/CNTs			81	0.21	1.31±0.1	4.76±0.36
CNTs			78	0.25	0.56±0.02	2.03±0.07
MoS_2	1064	400	82	0.20	0.054±0.01	0.39±0.07
MoS_2-L/CNTs			81	0.21	**0.39±0.03**	**2.83±0.22**
MoS_2-H/CNTs			80	0.22	0.27±0.02	1.96±0.15
CNTs			80	0.22	0.11±0.01	0.80±0.07

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- **Few-layer MoS_2 and CNTs core-shell heterostuctures were successfully synthesized.**
- **Higher SA performance than nanotubes alone under fs pulses at 1030 nm were observed.**
- **For ns pulses, improved OL performances were revealed relative to those of single MoS_2 and CNTs.**
- **Photo induced electron transfer and the effective coupling between CNTs and MoS_2 contribute to the enhanced nonlinear modulation behavior towards different temporal pulses.**

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Acknowledgements

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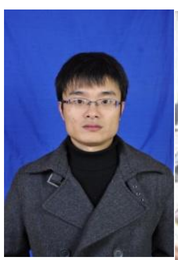
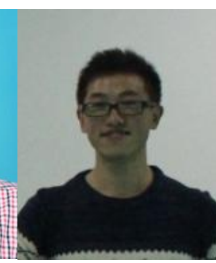
Thanks for your attention !










KP Wang **YY Feng** **GZ Wang** **X Cheng** **YX Li** **CR Shen** **YF Xie** **JW Huang**