Electronic Supplementary Material (ESI) for New Journal of Chemistry.


# Supplementary Material

# One Order Enhancement of Charge Carrier Relaxation Rate by Tuning Structural and Optical Properties in Annealed Cobalt Doped $MoS_2$ Nanosheets

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## S1. AFM Image Analysis

The surface topography and number of layers in 2% CoA $MoS_2$ nanoflakes are determined by atomic force microscopy (AFM) as shown in Fig. S1. The variation in AFM height profile as shown in Fig. S1 (b), is measured along the green solid line in Fig. S1 (a) indicates that the sample consists of 15 layers.

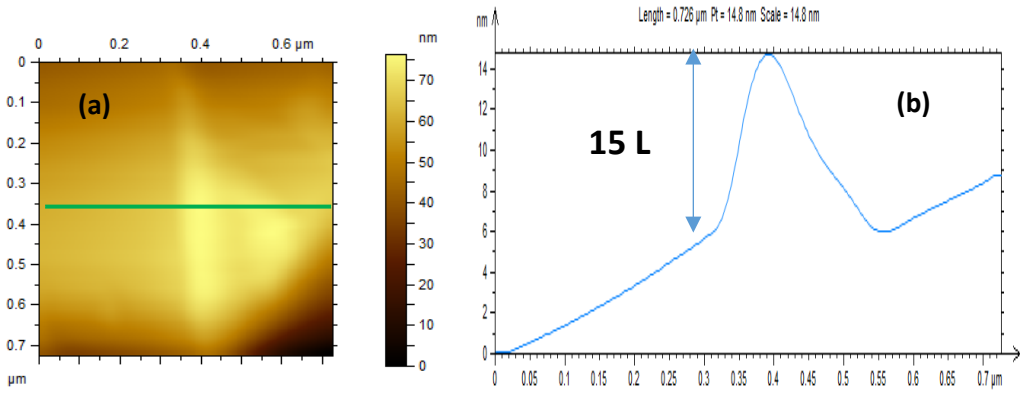


**Figure S1.** (a) AFM image of 2% CoA $MoS_2$ nanoflakes (b) Height profile of 2% CoA $MoS_2$ taken along the green solid line of (a).

## S2. XPS study

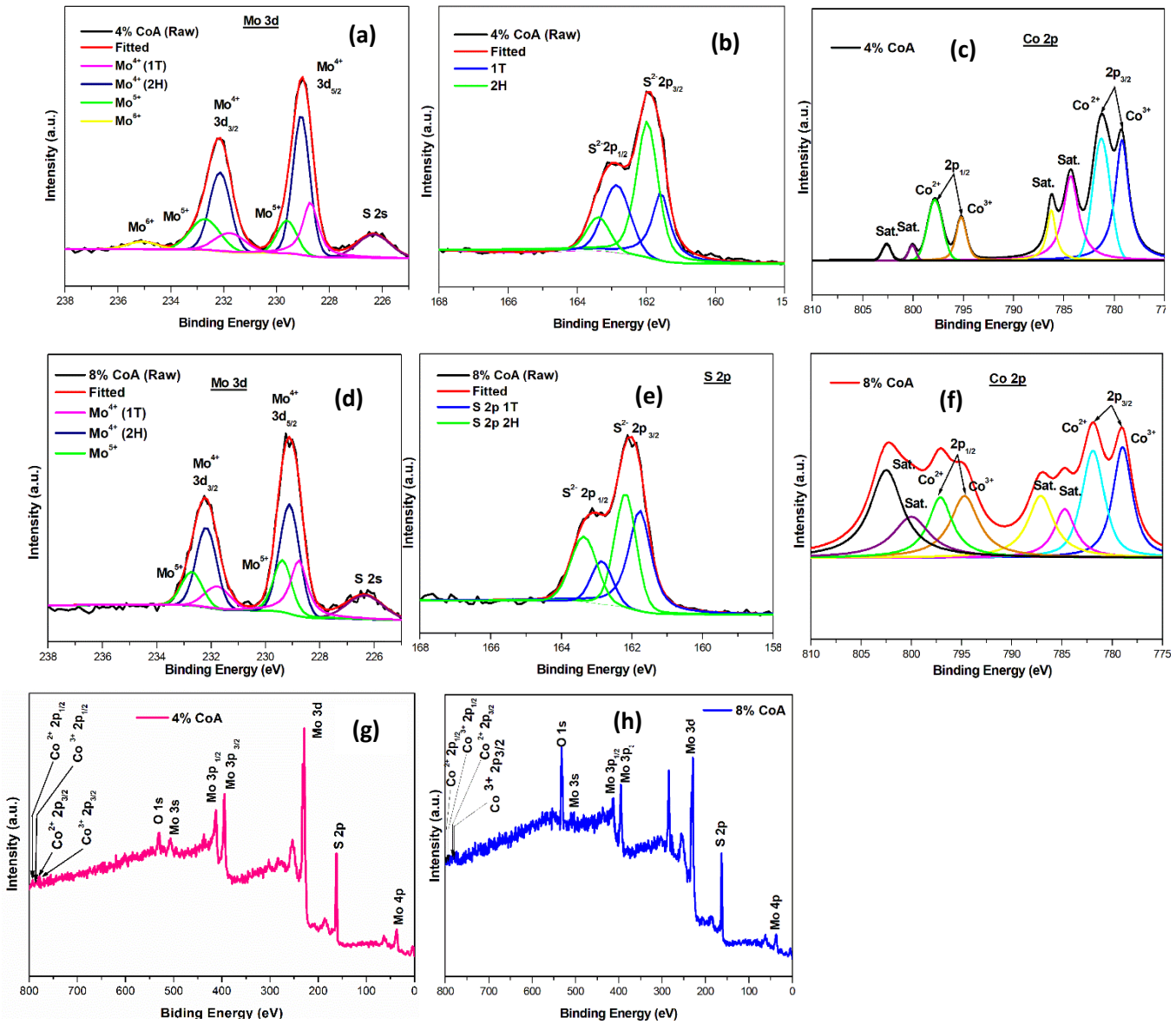


**Figure S2**. XPS narrow scan spectra of Mo 3d (a), (d), S 2p (b), (e) and Co 2p (c), (f) for 4% CoA, 8% CoA $MoS_2$. Survey spectra of Mo (3d, 3p, 3s), S 2p, C1s, Co 2p are shown in (g) and (h) corresponding to 4% CoA, 8% CoA $MoS_2$.

**Table S1** Variation of oxidation peaks of Mo, S and Co in annealed $MoS_2$ with cobalt doping

| Doping percentages | 1T | | 2H | | 1T | | 2H | | $Co^{3+}$ | | $Co^{2+}$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mo $3d_{5/2}$ (eV) | Mo $3d_{3/2}$ (eV) | Mo $3d_{5/2}$ (eV) | Mo $3d_{3/2}$ (eV) | S $2p_{3/2}$ (eV) | S $2p_{1/2}$ (eV) | S $2p_{3/2}$ (eV) | S $2p_{1/2}$ (eV) | Co $2p_{3/2}$ (eV) | Co $2p_{1/2}$ (eV) | Co $2p_{3/2}$ (eV) | Co $2p_{1/2}$ (eV) |
| 4% CoA | 228.71 | 231.76 | 229.06 | 232.14 | 161.57 | 162.86 | 161.97 | 163.39 | 779.22 | 795.21 | 781.26 | 797.81 |
| 8% CoA | 228.76 | 231.77 | 229.11 | 232.18 | 161.77 | 162.85 | 162.18 | 163.36 | 778.96 | 794.72 | 781.90 | 797.13 |

**Table S2** Variation in position of oxidation peaks of $Mo^5$, $Mo^{6+}$ and S2s in unannealed and annealed $MoS_2$ with cobalt doping

| Doping percentages | $Mo^{5+}$ | | $Mo^{6+}$ | S2s |
|---|---|---|---|---|
| | $3d_{5/2}$ (eV) | $3d_{3/2}$ (eV) | $3d_{5/2}$ (eV) | (eV) |
| 0% Co | 229.72 | 232.41 | 234.42 | 226.38 |
| 0% CoA | 229.66 | 232.73 | ------ | 226.39 |
| 2% Co | 229.75 | 232.99 | 235.64 | 226.36 |
| 2% CoA | 229.72 | 232.86 | ------- | 226.71 |
| 4% Co | 229.61 | 233.37 | 235.57 | 226.38 |
| 4% CoA | 229.6 | 232.71 | 235.09 | 226.32 |
| 8% CoA | 229.37 | 232.66 | -------- | 226.36 |

## S3 Steady-state and Transient Absorption Spectroscopy

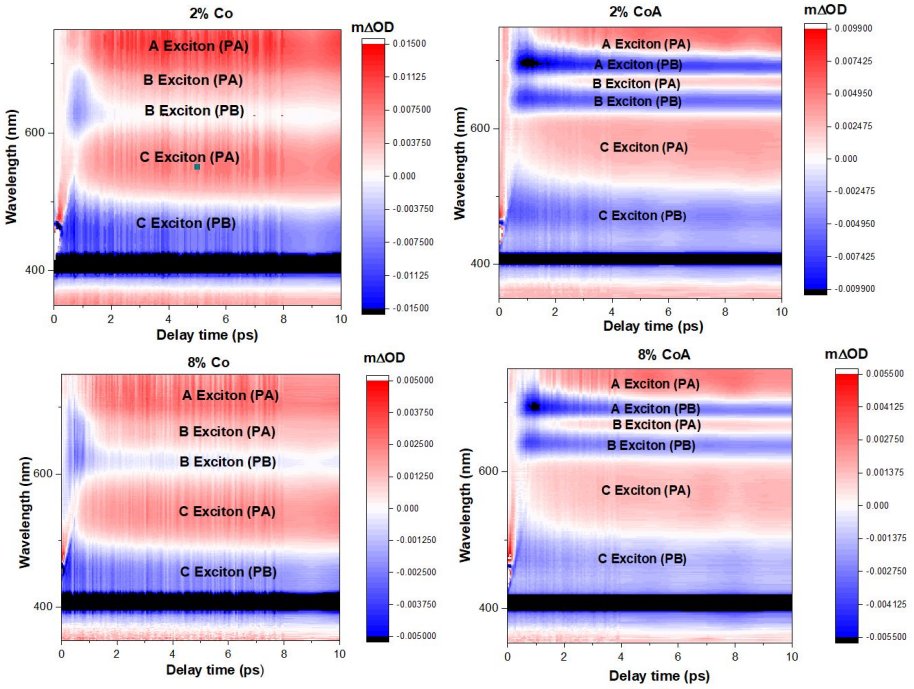


**Figure S3.** .Differential absorption ($\Delta A/A_0$) map of (a) 2%, (b) 2% CoA (c) 8% Co (d) 8% CoA as the function of both delay time and probe photon energy with the pump photon energy of 3.1 eV at average pump fluence of 22 μJ/cm$^2$ and 77 μJ/cm$^2$ for unannealed and annealed sets respectively.

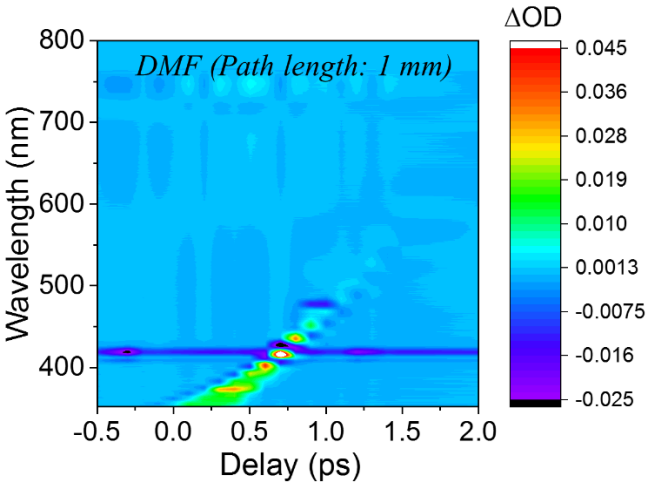


**Figure S4.** Transient absorption spectrum of DMF following 415 nm pump excitation.

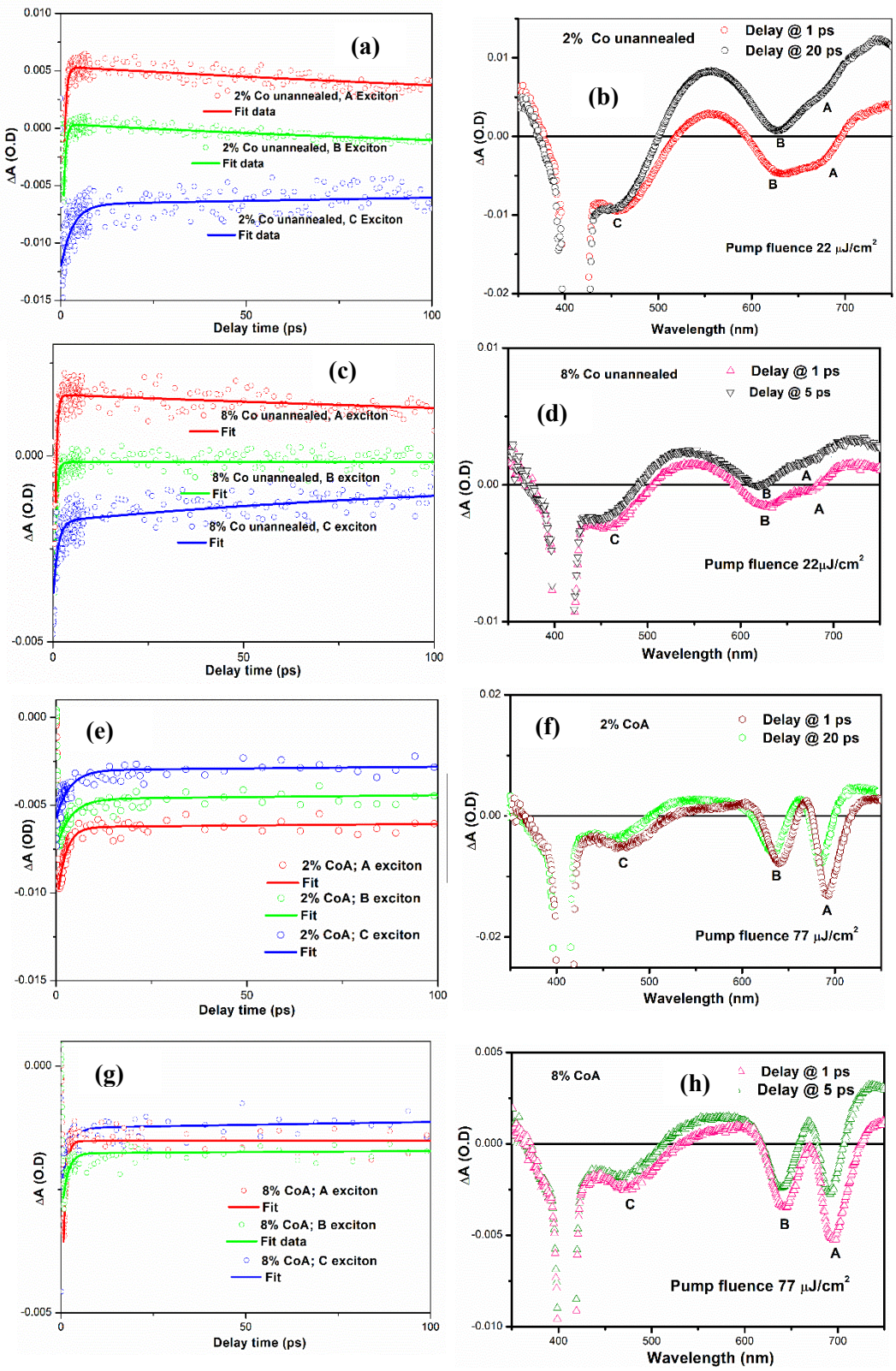


**Figure S5.** Transient absorption dynamics of (a) 2% Co unannealed, (c) 8% Co unannealed $MoS_2$ (e) 2% CoA, (g) 8% CoA $MoS_2$ having pump wavelength of 400 nm and probe wavelength of 460, 627, 681 nm (unannealed) and 462, 632 and 687 nm (annealed) respectively. The solid lines are fits of a biexponential decay function. Figs. 12. (b), (d), (f) and (h) depicts the transient absorption spectra of 2% Co unannealed, 8% Co unannealed, 2% CoA, 8% CoA $MoS_2$ respectively at 1 ps and longer time 5 ps (8% Co, 8% Co A) and 20 ps (2% Co, 2% Co A) delay.