Supporting Information

Improving Carrier Transport Properties of CZTS by Mg Incorporation with Spray Pyrolysis

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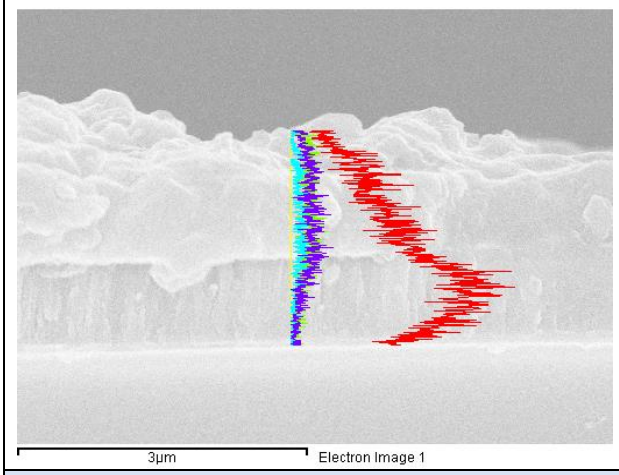
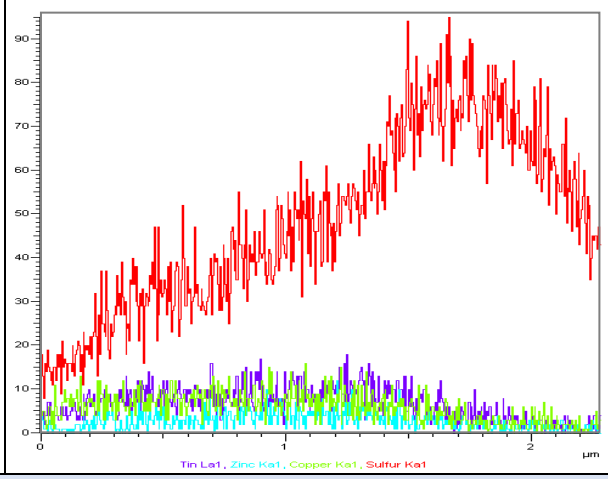
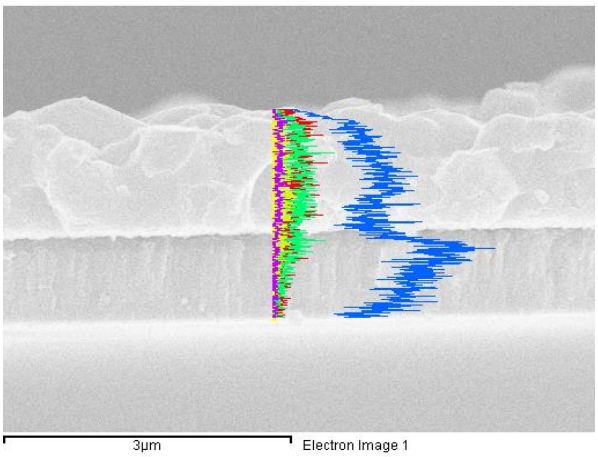
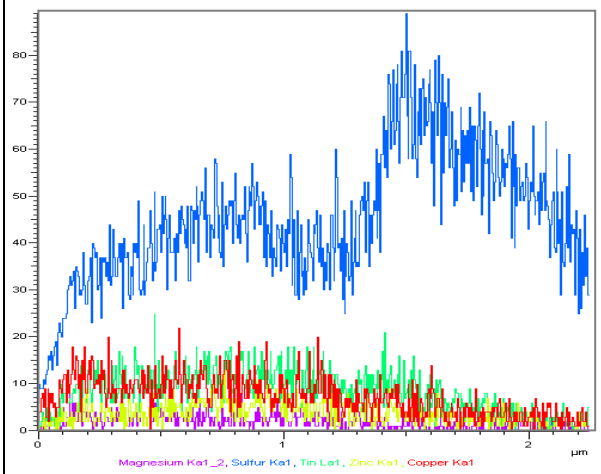
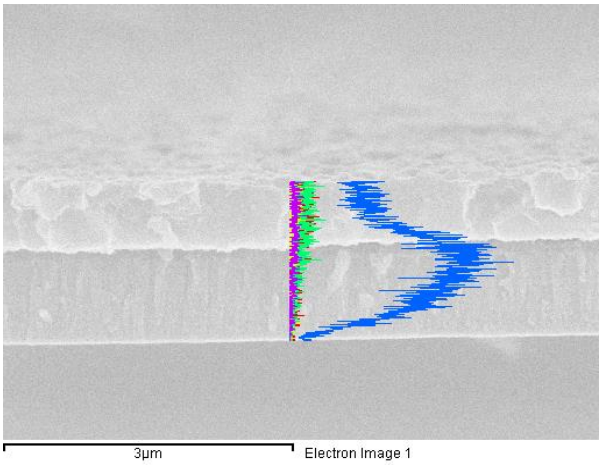
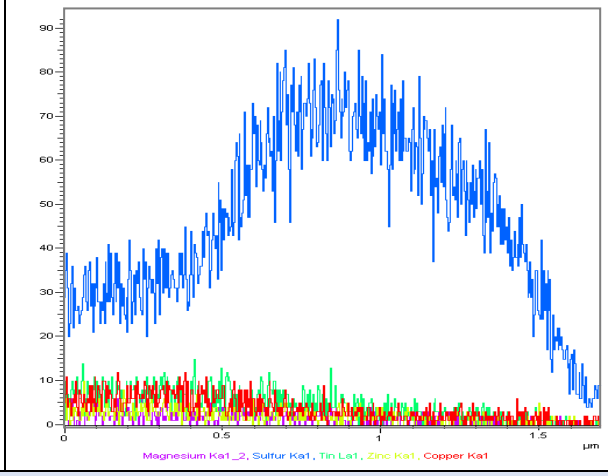
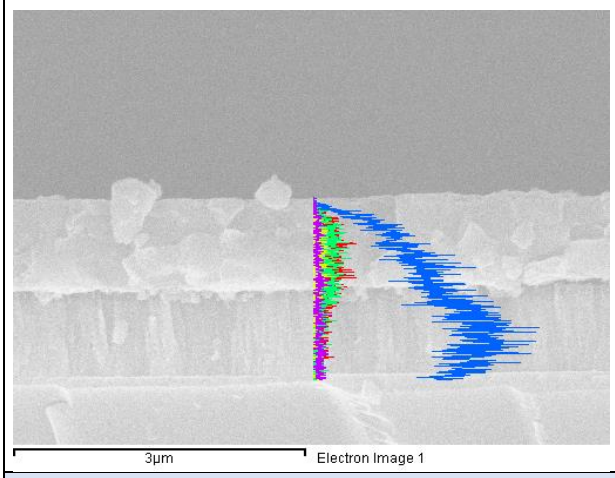
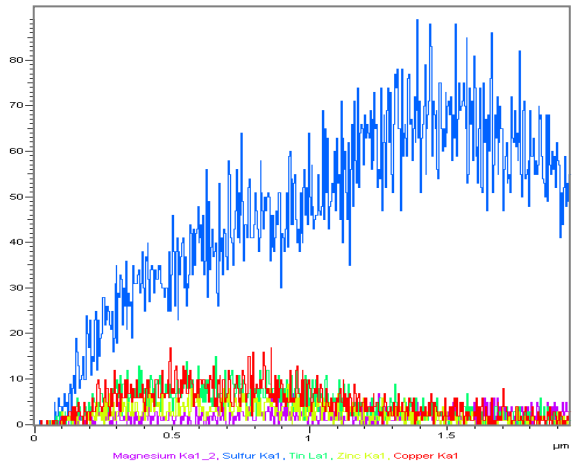
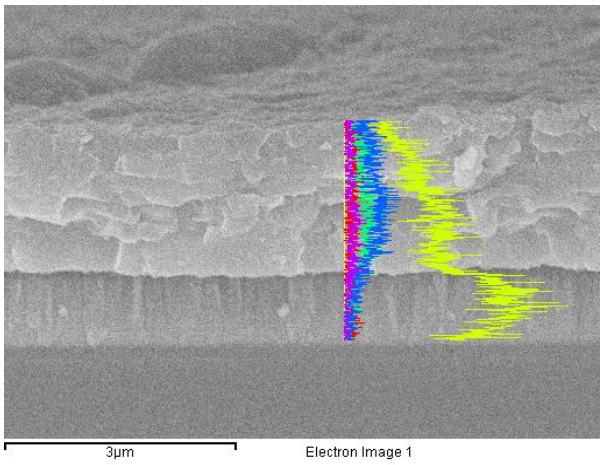
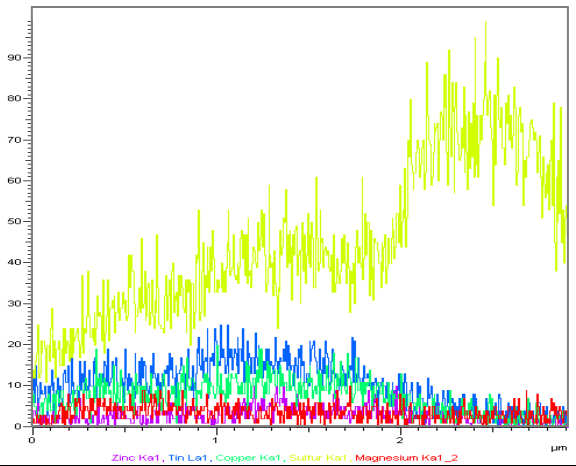
Electron Image	Elemental line scans (thickness vs counts)
a) x = 0	
	
b) x = 0.05	
	
c) x = 0.1	
	
x = 0.2	


3µm
Electron Image 1

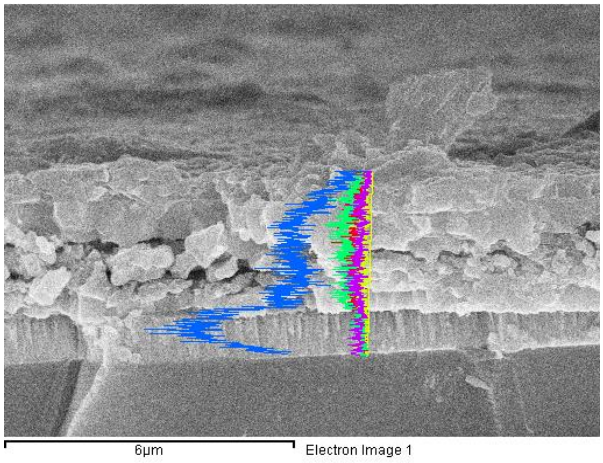

Magnesium Ka1_2, Sulfur Ka1, Tin La1, Zinc Ka1, Copper Ka1
µm

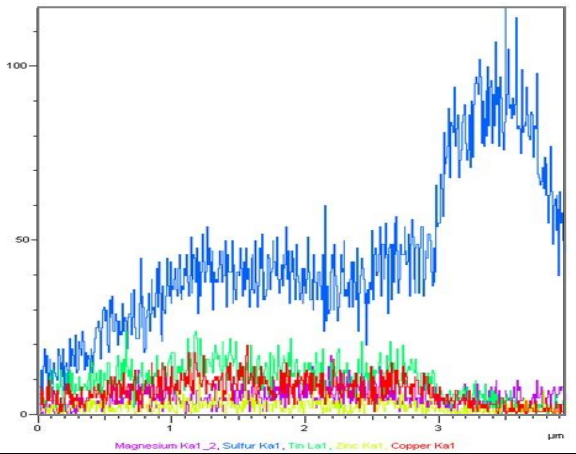
x = 0.4


3µm
Electron Image 1


Zinc Ka1, Tin La1, Copper Ka1, Sulfur Ka1, Magnesium Ka1_2
µm

x = 0.6


6µm
Electron Image 1


Magnesium Ka1_2, Sulfur Ka1, Tin La1, Zinc Ka1, Copper Ka1
µm

g) x = 0.8

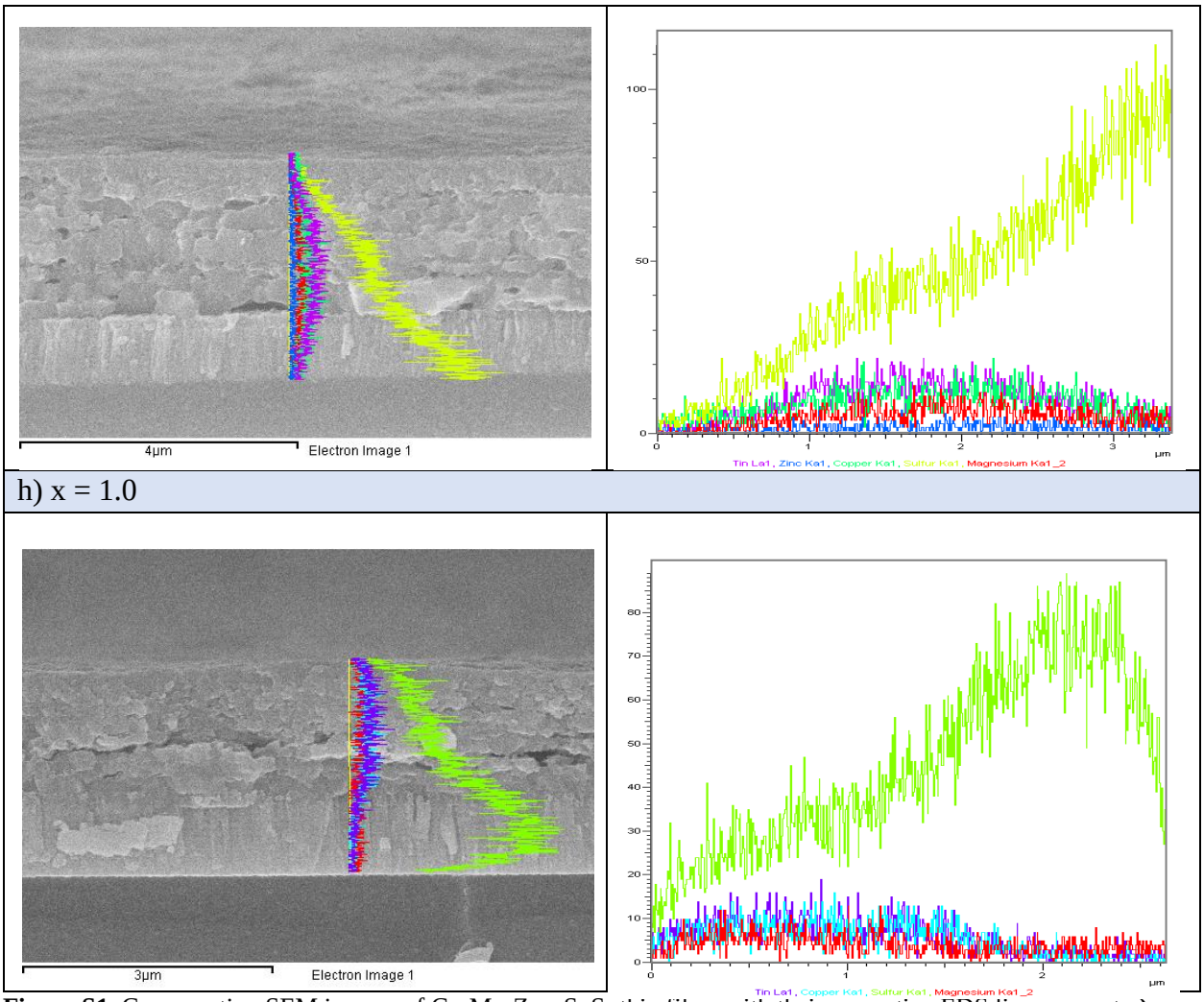


Figure S1. Cross section SEM images of $Cu_2Mg_xZn_{1-x}SnS_4$ thin films with their respective EDS line scans at **a)** x = 0, **b)** x = 0.05, **c)** x = 0.1, **d)** x = 0.2, **e)** x = 0.4, **f)** x = 0.6, **g)** x = 0.8 and **h)** x = 1.0

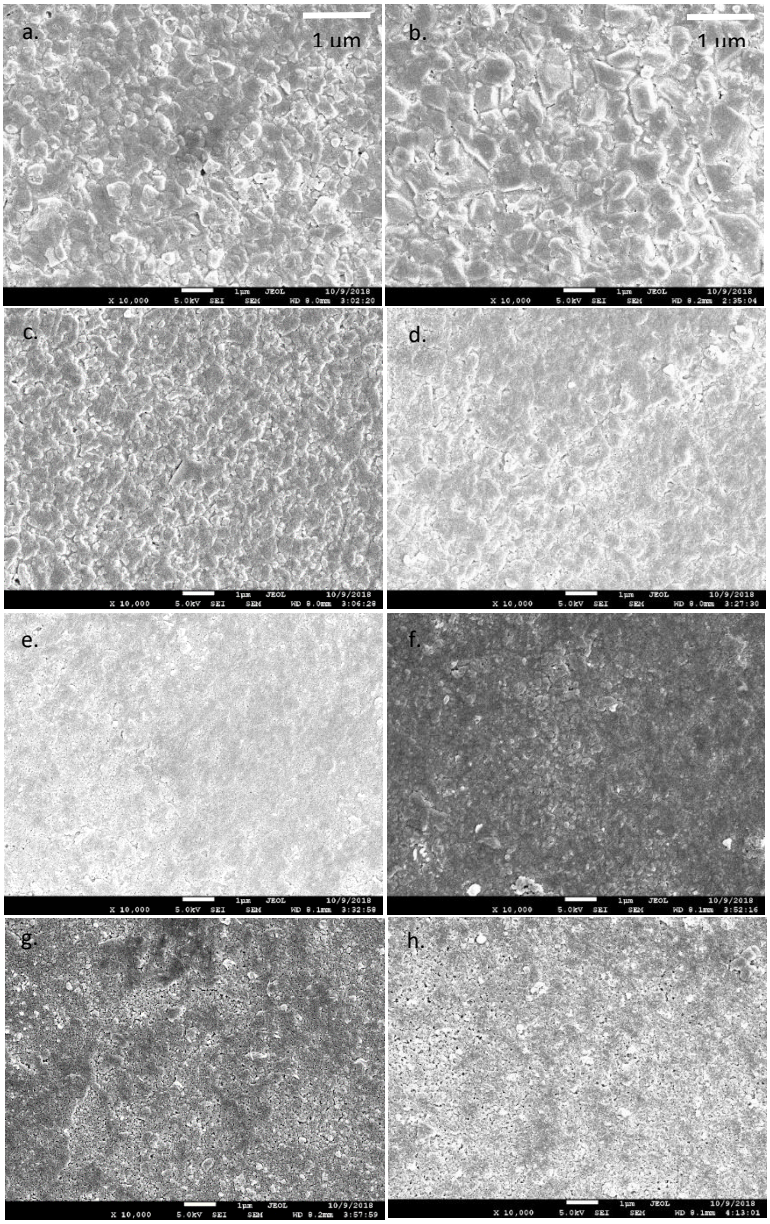


Figure S2. Plan-view SEM images of $Cu_2Mg_xZn_{1-x}SnS_4$ thin films with **a)** x = 0, **b)** x = 0.05, **c)** x = 0.1, **d)** x = 0.2, **e)** x = 0.4, **f)** x = 0.6, **g)** x = 0.8 and **h)** x = 1.0

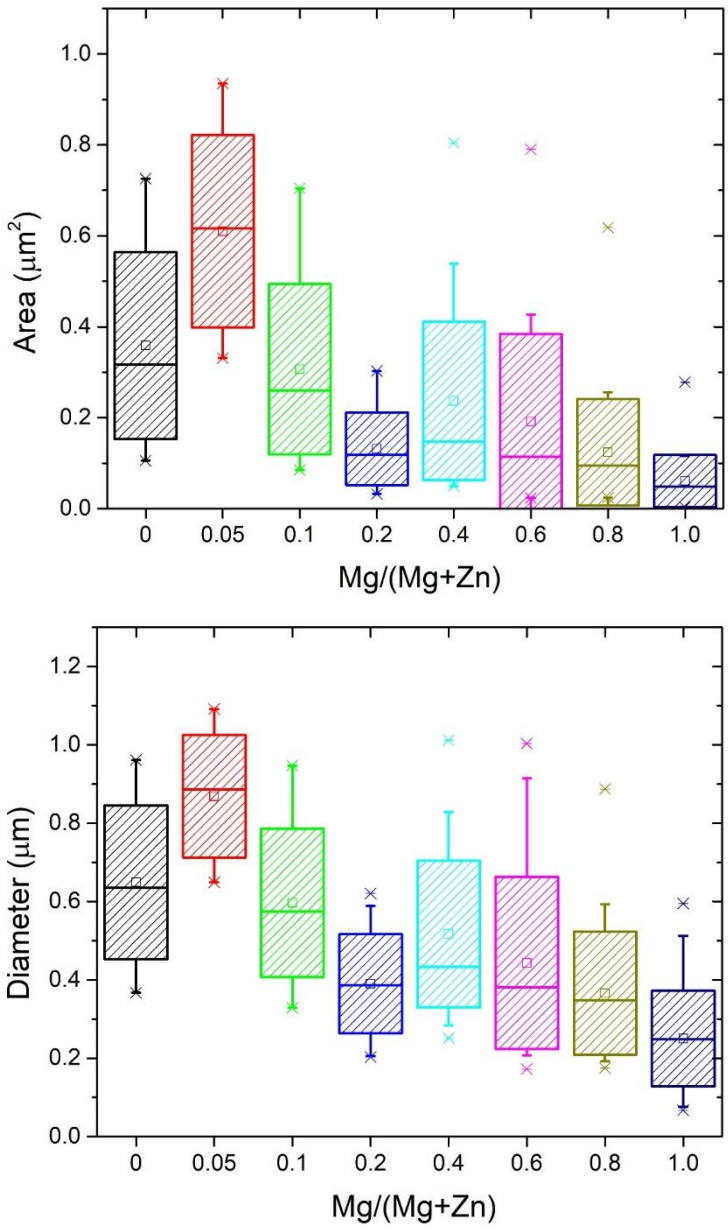


Figure S3. Grain size distribution for $Cu_2Mg_xZn_{1-x}SnS_4$ thin films based on area (top) and diameter (bottom)

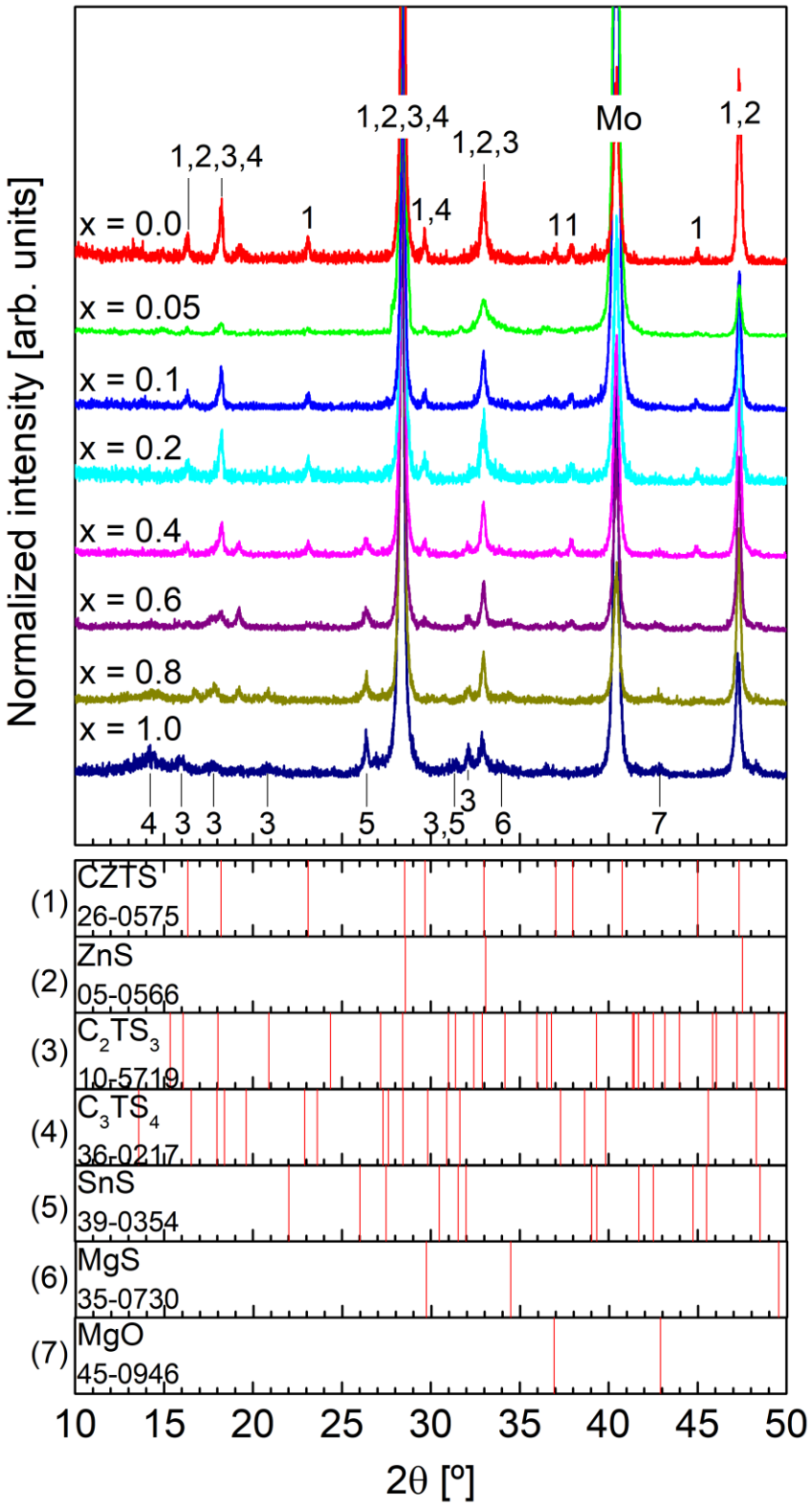


Figure S4. X-ray diffraction pattern of $Cu_2Mg_xZn_{1-x}SnS_4$ thin film (x = 0 -1.0). In the bottom is list of the signature peaks of possible quaternary, ternary and secondary phases from ICDD database.

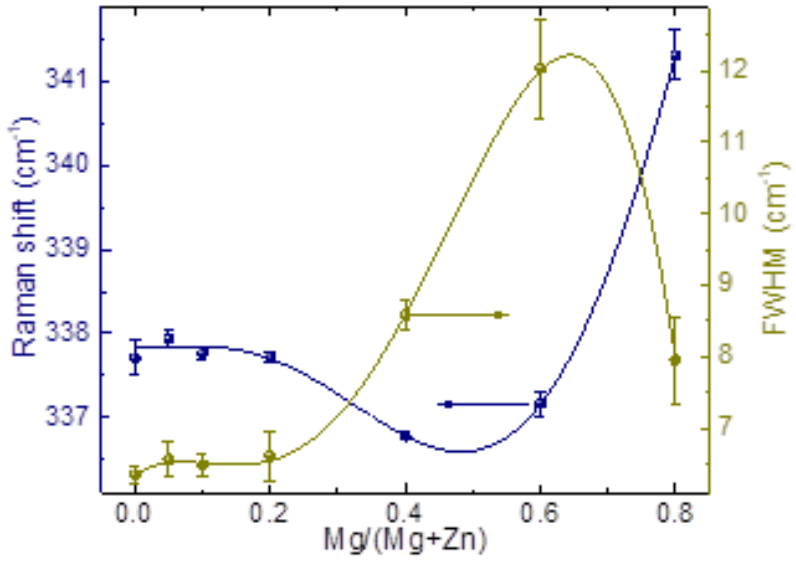


Figure S5. Position and FWHM of the A1-like peak in $Cu_2Mg_xZn_{1-x}SnS_4$ thin films.

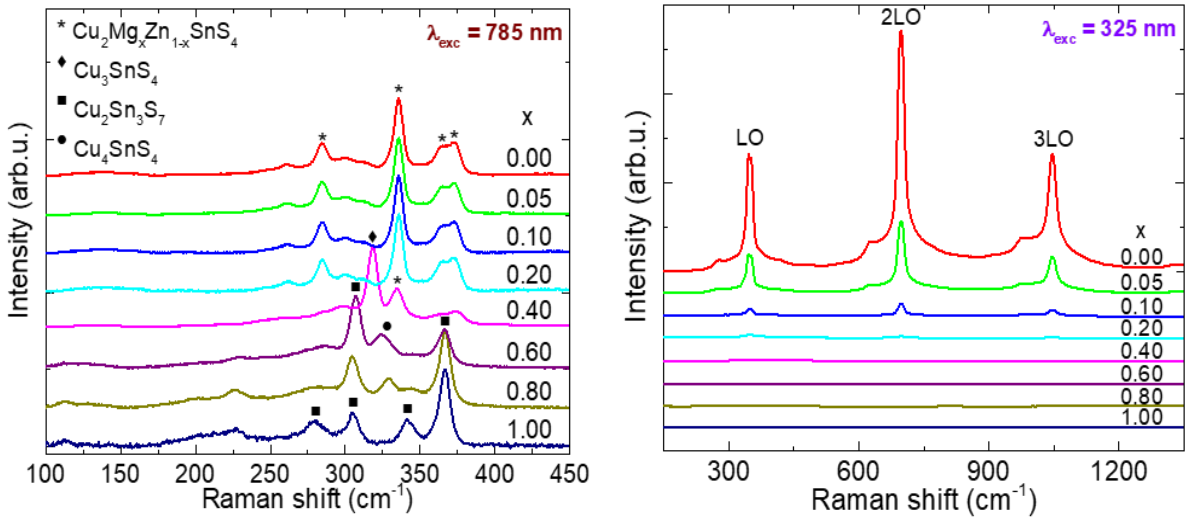


Figure S6. Raman scattering spectra of $Cu_2Mg_xZn_{1-x}SnS_4$ thin films measured under 785 (left) and 325 (right) nm excitation wavelength. In the right spectra the first (LO), second (2LO) and third (3LO) order of main ZnS peak are indicated.

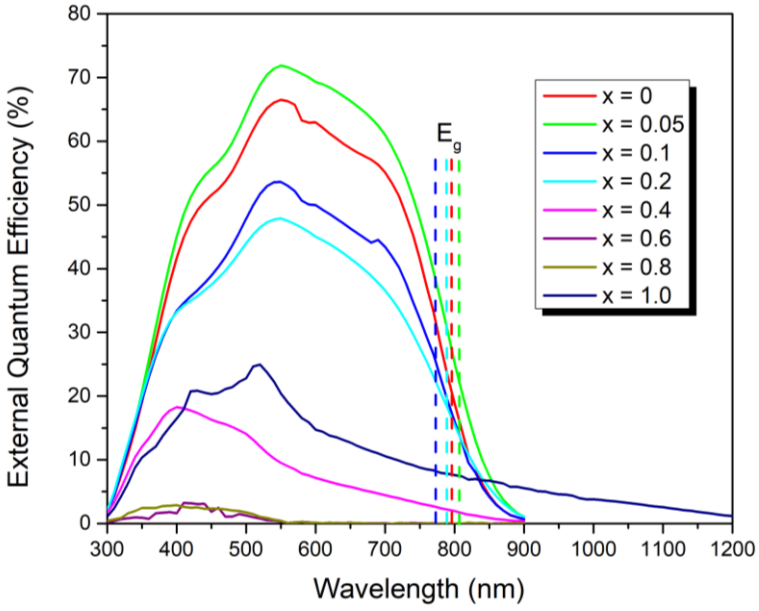


Figure S7. External Quantum Efficiency of $Cu_2Mg_xZn_{1-x}SnS_4$

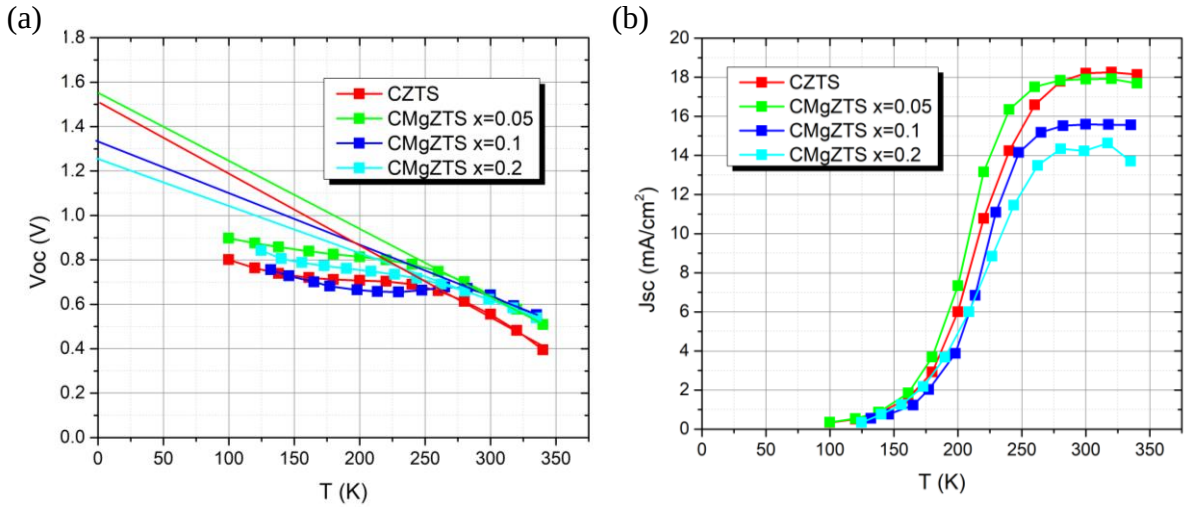


Figure S8. a) Voc vs temperature (T) and **b)** Jsc vs T under 1 sun measurement of $Cu_2Mg_xZn_{1-x}SnS_4$ for x = 0.0 – 0.2