Multiwavelength excitation Raman scattering of $Cu_2ZnSn_{1-x}Ge_x(S,Se)_4$ single crystals for earth abundant photovoltaic applications

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Abstract: Raman spectroscopy was used to evaluate the zone-center optical phonons of $Cu_2ZnSn_{1-x}Ge_x(S,Se)_4$ single crystals, leading to a complete characterization of their vibrational properties. High quality of the samples grown by chemical vapour transport was approved by analysis of X-ray dispersion and diffraction spectra. The analysis has

been performed by using Raman scattering excited with different wavelengths, which allowed presenting the fingerprint spectra of the solid solutions in the resonant and non-resonant conditions. The Raman spectra show more than 30 characteristic peaks for different $Cu_2ZnSn_{1-x}Ge_xS_4$ and $Cu_2ZnSn_{1-x}Ge_xSe_4$ samples. The two mode behavior was found for most of the peaks in both solutions. However, the most intense mode exhibited one mode behavior in selenium containing compounds and two mode behavior in sulfur containing compounds. Possible reasons for this difference are discussed.

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