Meyer-Neldel Rule in Cadmium Sulfide

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Abstract

Photo–induced current transient spectroscopy (PICTS) measurements were performed on polycrystalline CdS thin films prepared by rf magnetron sputtering. Traps with activation energy E_t in the range 0.031-0.770 eV and apparent capture cross section σ in the range 7.2×10^{-19}-3.0×10^{-7} have been detected. It is shown that the data obey the Meyer-Neldel rule (MNR) which states that the prefactor in the expression for the emission rate increases exponentially with the activation energy. An isokinetic temperature of 353± 15 K has been determined . At this temperature all traps in CdS have the same emission time of 1.1×10^{-7} s. After correcting the prefactor for the change in E_t , a nonactivated capture cross section of 5.4×10^{-19} cm^2 was determined for all traps in CdS .

CdS thin films with thickness in the range 210-1200 nm and electrical conductivity in the range 4.5×10^{-1}-2.6×10^{-5} $\Omega^{-1}cm^{-1}$ were prepared using r.f. magnetron sputtering. The carriers traps were investigated using photo-induced current transient spectroscopy (PICTS)[1]. The PICTS signal was computed using the four gate (4G) method. Upon changing the time window on the photo-current decay curve, the emission time constant τ_t and consequently the temperature of the PICTS-peak T_m could be varied. Fig 1 shows an example of the PICTS spectra obtained for a shallow trap (E_t= 0.031 eV) . The time constant τ_t increases downward in the figure (1.5ms<τ_t <3.5 ms). Clearly, the PICTS peak shifts to lower temperature as τ_t increases. Since the trap emission rate is given by $\tau_t^{-1}= \gamma\, T^2 \exp(E_t/kT)$, it was possible to calculate E_t and γ from the Arrhenius plot Ln $\tau_t T_m^2$ vs $1000/T_m$ (fig. 2) for each PICTS peak. The values of γ (= $1.34\times10^{20}\, \sigma$ for electron traps in CdS) were used to calculate the apparent capture cross section σ .

The Meyer-Neldel rule (MNR) [2] states that γ is activated which implies that $\sigma = \sigma_o \exp(E_t /kT_i)$ where T_i is the isokinetic temperature and σ_o is the nonactivated capture cross section that has a fixed magnitude for a given material [3]. Fig.3 shows the MNR plot for CdS. It is shown that Ln σ increases with E_t in agreement with the MNR. The least square fit to the data yields T_i= 353±20 K and σ_o = 5.4×10^{-19} cm^2. At the temperature T_i all traps in CdS have the same emission time $\tau_t = [1.34\times10^{20}\, \sigma_o\, T_i^2]^{-1} = 1.1\times10^{-7}$ s and therefore their detrimental impact on the device performance is the same. At higher temperatures the emission time decreases. The ensemble of the present results indicates that the trap emission process in CdS obeys MNR as has been shown to be the case in a number of other semiconductor systems [3].

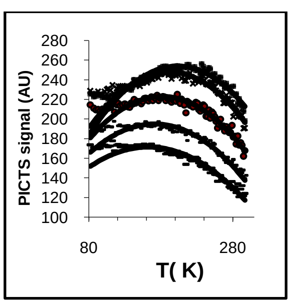


Fig.1: PICTS spectra for a trap with E_t=31 meV.

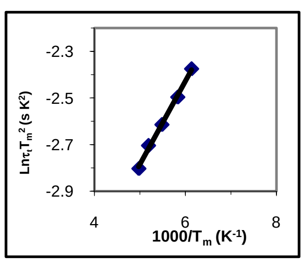
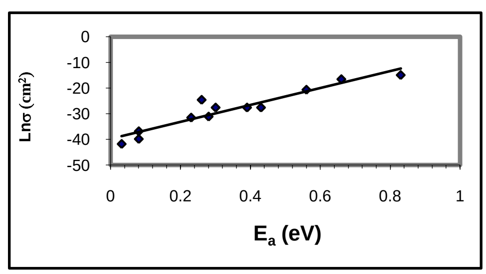


Fig.2: Arrhenius plot for the trap in fig.1



Fg.3 Meyer-Neldel plot for CdS

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2- W. Meyer and H. Neldel , Z. Tech. Phys. **12**, 588(1937)
3- See for example :J.A.M.Abushama,S.W. Jonston,R.S.Crandall and R.Noufi , Appl. Phys. Let. **87**,123502 (2005)