MULTIPHONON RELAXATION IN LOW PHONON-ENERGY Pr^{+3} GLASSES

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Recently there has been a great deal of interest in optical fibre amplifiers and lasers operating in the 1.3 μm wavelength telecommunications window; for this application, Pr^{+3}-doped low phonon-energy glasses have attracted a great deal of attention. In these glasses the lifetime of the metastable level is dominated by non-radiative relaxations, of which the two most important processes are multiphonon decay and concentration quenching. The doping levels are thus limited by the need to avoid the latter; while the former effectively determines the lifetime in lightly-doped glasses. The aim of this work has been to investigate the crucial parameters which control the multiphonon decay rate in low phonon-energy glasses and their dependence on glass constituents.

The multiphonon decay rate is described by the Pekarian function[1]:

$$W_{MP} = W_0 \, (n+1)^p \, e^{-g} \, \frac{g^p}{p!}$$

where $n = (\hbar\omega/kT)^{-1}$ is the phonon occupation number,
$p = \Delta E/\hbar\omega$ is the number of phonons mediating the decay process,
g is the electron-phonon coupling constant,
ΔE is the energy gap,
$\hbar\omega$ is the individual phonon energy.

It is thus evident that the rate increases with both the coupling constant g and the phonon energy $\hbar\omega$: therefore in order to increase the lifetime one or both must be reduced.

In general, the phonon energy can be reduced by substituting heavier ions for the appropriate glass constituents, in accordance with the Szigeti[2] equation

$$\omega \sim (K/M)^{1/2}$$

where K is the bond strength and M is the reduced mass. However, since the phonon energy and the coupling constant are independent parameters, a composition which decreases $\hbar\omega$ may also coincidentally increase g, thus cancelling any beneficial effect on the lifetime.

In this work we measure the two parameters $\hbar\omega$ and g, demonstrate their variation with composition, and use the obtained values to calculate the expected multiphonon decay rate. The predicted rate is then compared with the observed fluorescence lifetime and with predictions achieved by other models. The method is used to assess low phonon-energy glasses for their suitability as hosts for Pr^{+} in applications at 1.3 μm wavelength.

References:
1. R. Englman, *Non-Radiative Decay of Ions and Molecules in Solids*, North-Holland, 1979.
2. P. W. France, ed., *Fluoride Fibres for Optical Amplifiers*, Blackie, 1990.