(27b8)

c-f hybridization in f-electron compounds studied by optical conductivity

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We have measured the optical reflectivity $R(\omega)$ of various Yb- and Ce-based compounds and obtained their optical conductivity $\sigma(\omega)$ to study their microscopic electronic states, in particular the c-f hybridization states. For compounds in the mixed-valence regime with relatively strong hybridization, their $R(\omega)$ spectra show almost universally a dip below ~ 0.3 eV, and a corresponding peak in $\sigma(\omega)$. These "mid-infrared" (mIR) peaks in $\sigma(\omega)$ are observed for both highly metallic compounds (CeNi, $CeSn_3$, $YbAl_3$, $YbAl_2$, $YbCu_2Si_2$, $YbInCu_4$, etc) and gap-forming compounds (CeRhSb, YbB_{12}). Fig. 1 (next page) shows the $R(\omega)$ spectra of several Yb compounds. It is seen that the mIR peak shifts systematically depending on the magnitude of γ, the specific heat coefficient at low temperatures. Namely, the energy positions of the mIR peaks are clearly related with the degree of mass enhancement, and hence with the strength of c-f hybridization in these compounds. At the present time, however, it is not clear how the line shape of the mIR peak (peak energy, peak width, etc) can be interpreted in terms of actual physical quantities related with the c-f hybridized electronic states. Many theoretical calculations of $\sigma(\omega)$ have been made for f-electron compounds, but most of these works are oversimplified to be compared with the actual data. For example, the calculated $\sigma(\omega)$ spectra often show unrealistically sharp peaks. It is strongly desired that more realistic theories are developed, and the experimentally observed mIR peaks are consistently interpreted to give useful information, such as the magnitude of the c-f hybridization gap. Of course, more experiments are needed to further clarify the relation between the c-f hybridization and the low-energy electronic states in f-electron systems. The filled skutterudite compounds are ideal for this purpose, since many compounds having different strengths of hybridization are available under the same crystal structure. We have already measured several filled skutterudites compounds, including $CeOs_4Sb_{12}$ [1]. We will discuss future perspectives in the optical study of these compounds.

[1] M. Matsunami, H. Okamura, T. Nanba, H. Sugawara, H. Sato; J. Phys. Soc. Jpn. **72**, 2722 (2003).

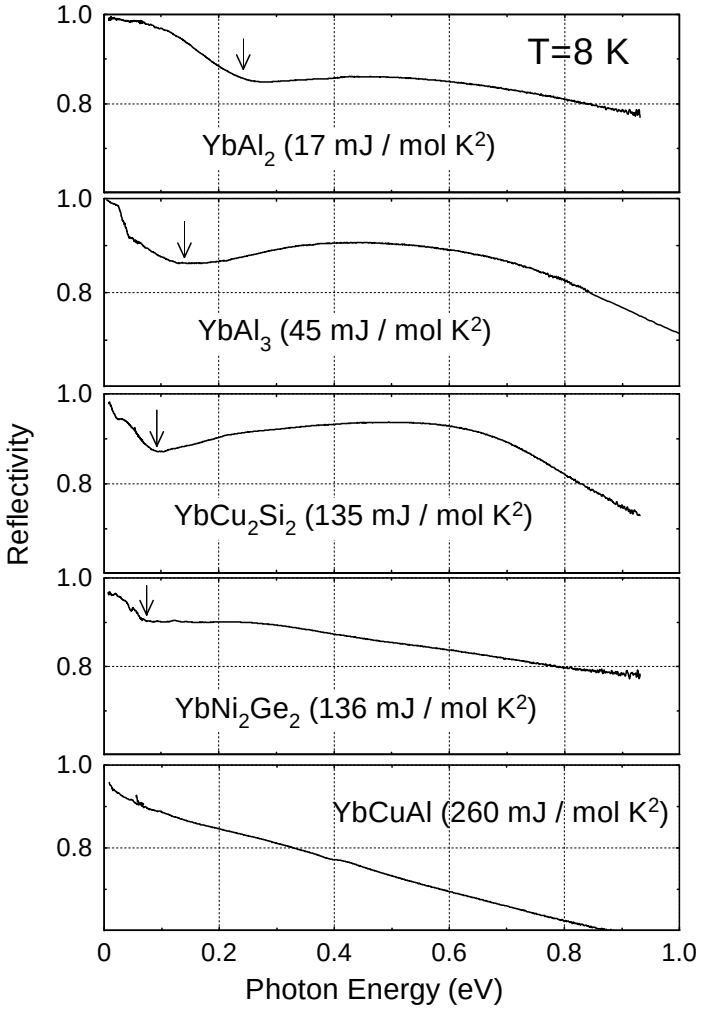

Figure 1: Optical reflectivity spectra of $YbAl_2$, $YbAl_3$, $YbCu_2Si_2$, $YbNi_2Ge_2$, and YbCuAl, measured at 8 K. Shown in the parentheses are the electronic specific heat coefficients of these compounds. The dips indicated by the arrows correspond to the mid-infrared peaks in $\sigma(\omega)$ discussed in the text. ($\sigma(\omega)$ can be obtained from the reflectivity using the Kramers-Kronig relations.)