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Metal-insulator transition of filled skutterudite compounds studied by optical conductivity

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The filled skutterudite compounds have recently attracted a great deal of attention due to their wide variety of strongly correlated electronic properties. Among these compounds, $PrRu_4P_{12}$ and $SmRu_4P_{12}$ undergo a metal-insulator (M-I) transition at $T_{MI} = 60$ K and 16 K, respectively. For $PrRu_4P_{12}$, a subttle structural phase transition has been found at T_{MI} in the electron and X-ray diffraction measurement. Also, the band calculation study points out that the Fermi surface of RRu_4P_{12} should have a strong tendency for nesting. For $SmRu_4P_{12}$, recent works have revealed that the M-I transition occurs in two successive steps around T_{MI}, which may be attributed to the antiferro-quadrupolar (AFQ) ordering and the antiferro-magnetic ordering. Therefore, it is suggested that the M-I transition of $SmRu_4P_{12}$ is strongly related to the orbital ordering.

We have investigated the optical properties of $PrRu_4P_{12}$ and $SmRu_4P_{12}$, in order to obtain information on the charge carrier dynamics, the electronic structure near E_F, and the infrared-active phonon. The optical conductivity spectra of $PrRu_4P_{12}$ and $SmRu_4P_{12}$ reveal the clear opening of a charge gap and its temperature evolution. In addition, anomalies of infrared-active phonons are observed around T_{MI}. For $PrRu_4P_{12}$, new phonon peaks appear in the spectra below T_{MI}, which is understood as a sign of charge densitiy wave transition. Therefore, M-I transition of $PrRu_4P_{12}$ can be interpreted by the scenario of the Fermi-surface nesting. On the other hand, for $SmRu_4P_{12}$, no additional phonon peaks appear below T_{MI}, but anomalous softening is observed upon decreasing temperature around T_{MI}, which may be related to the AFQ ordering. In addition, the charge gap formation in $SmRu_4P_{12}$ is observed between 40 K and 80 K, which is inconsisitent with $T_{MI} = 16$ K determined by the other experimental results. However, temperature dependence of the dc resistivity, which shows rapid increase below 16 K, has indeed the broad minimum near 50 K. Accordingly, these facts may indicate the precursors to the M-I transition due to AFQ ordering.