Optical Studies of Weak-Ferromagnetic Superconductors $RuSr_2RCu_2O_8$ (R = Eu, Sm, and Nd)

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The weak-ferromagnetic superconductors $RuSr_2RCu_2O_8$ (R = Eu, Sm, and Nd) polycrystalline samples were prepared. Their Curie temperature increases from 133 K for smaller rare earth Eu^{3+} (ionic radius r = 0.107 nm), to 142 K for larger Sm^{3+} (r = 0.108 nm), but decreases to 120 K for even larger Nd^{3+} (r = 0.112 nm). Furthermore, superconducting transition temperature occurs at T_c = 36 K for Eu^{3+}, but Sm^{3+} and Nd^{3+} show non-superconducting behavior. The room-temperature Raman spectrum of Eu^{3+} sample exhibits four phonon peaks at about 263, 300, 435, and 648 cm^{-1}. With increasing the ion radius r_R, these Raman lines shift toward lower frequencies and their linewidths broaden, indicative of strong distortions of lattice structure. Infrared and optical reflectance spectra of these samples have also been measured over a wide frequency range (50 - 52000 cm^{-1}) and at temperatures between 10 and 340 K. The room-temperature far-infrared conductivity of Nd^{3+} sample shows the lines at 347, 587, and 648 cm^{-1}, which all shift toward lower frequencies with decreasing temperature, suggesting a strong spin-phonon coupling in this material. In the superconducting state, a partial sum-rule evaluation of the effective number of carriers from the optical conductivity indicates that the value of London penetration depth of $RuSr_2EuCu_2O_8$ is about 2380 nm.