# Transport Properties of $MgB_2$ Thin Films Grown by Hybrid Physical Chemical Vapor Deposition Method

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We prepared four different $MgB_2$ films on $Al_2O_3$ by hybrid physical chemical vapor deposition method with thicknesses ranging from 0.65 μm to 1.2 μm. X-ray diffraction patterns confirm that all the $MgB_2$ thin films are c-axis oriented perpendicular to $Al_2O_3$ substrates. The superconducting onset temperature of $MgB_2$ films were between 39.31K and 40.72K. The residual resistivity ratio of the $MgB_2$ films were between 3.13 and 37.3. We measured the angle dependence of critical current density ($J_c$) and resistivity, and determined the upper critical field ($H_{c2}$) from the temperature dependence of the resistivity curves. The anisotropy ratios defined as the ratio of the $H_{c2}$ parallel to the *ab*-plane to $H_{c2}$ perpendicular to the *ab*-plane were in the range of 1.59 to 7.03 and were increased as the temperature was decreased. Some samples showed an increase of $J_c$ and decrease of resistivity when a magnetic field in applied parallel to the *c*-axis. We interpret this angle dependence in terms of enhanced flux pinning due to columnar growth of $MgB_2$ along the *c*-axis.

Keywords : $MgB_2$, thin film , HPCVD