Electron and heat transports of oxygen deficient WO$_x$ (2.83 < $x$ < 3) epitaxial films

Tungsten oxide (WO$_x$) has been studied as an active layer of electrochromic devices such as anti-glare mirror and smart window because its color can be controlled electrochemically at room temperature. Although various crystal structures are known in oxygen deficient WO$_x$, called Magnéli phase such as WO$_{2.9}$, WO$_{2.82}$ and WO$_{2.72}$, the electron and heat transports are not clearly understood yet because of the lack of the study on the epitaxial WO$_x$. Here we report electron and heat transports of oxygen deficient WO$_x$ (2.83 < $x$ < 3) epitaxial films at room temperature. We fabricated WO$_x$ films on (001) LaAlO$_3$ substrate with various $x$ ranging from 2.835 to 2.977 by the pulsed laser deposition technique under controlled oxygen atmosphere. Figures (a) – (c) summarize the electrical conductivity, thermopower, and thermal conductivity of the resultant WO$_x$ epitaxial films. Those of amorphous WO$_x$ films are also plotted for comparison.\[1\] Both electrical conductivity and thermal conductivity of the epitaxial films dramatically increases when $x$ decreases from 2.98 to 2.95 whereas the absolute value of thermopower decreases from 550 to 30 $\mu$V K$^{-1}$, indicating drastic increase of the carrier concentration. However, these properties do not change a lot when $x$ < 2.95, probably due to that structural phase transition occurs around $x \sim$2.95. We believe these systematic electron and heat transport data of oxygen deficient WO$_x$ epitaxial films would be useful to develop WO$_x$-based devices.