Effect of Cu powder addition on thermoelectric properties of Cu/TiO_{2-x} composite

Y. Lu[1*], K. Sagara[2], Y. Matsuda[2], L. Hao[2], Y. R. Jin[3] and H. Yoshida[4]

[1]Graduate School & Faculty of Engineering, Chiba University, 1-33, Yayoi-cho, Inage-ku, Chiba, Japan
*luyun@faculty.chiba-u.jp,
http://apei.tu.chiba-u.jp/Luyun-HP.html

[2]Graduate school, Chiba University, 1-33, Yayoi-cho, Inage-ku, Chiba, Japan
[3] School of Materials Science and Engineering, Xihua University, 610039 Chengdu, Sichuan, P.R. China
[4]Chiba Industrial Technology Research Institute, 889 Kasori-cho, Wakaba-ku, Chiba, Japan

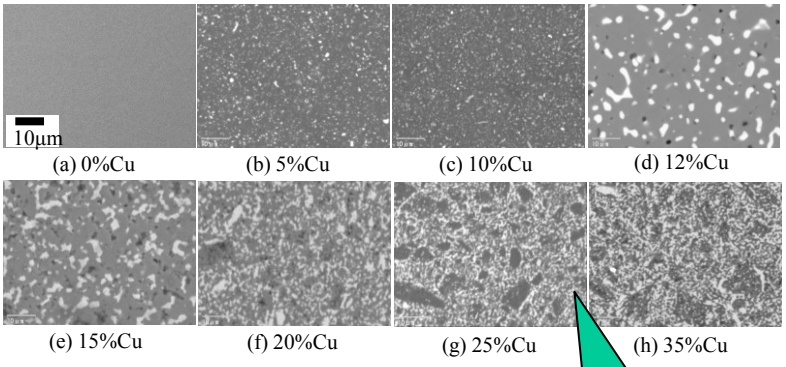
Aim: Cu powder addition → Cu/TiO_{2-x} composite → Composite effects → High thermoelectric properties

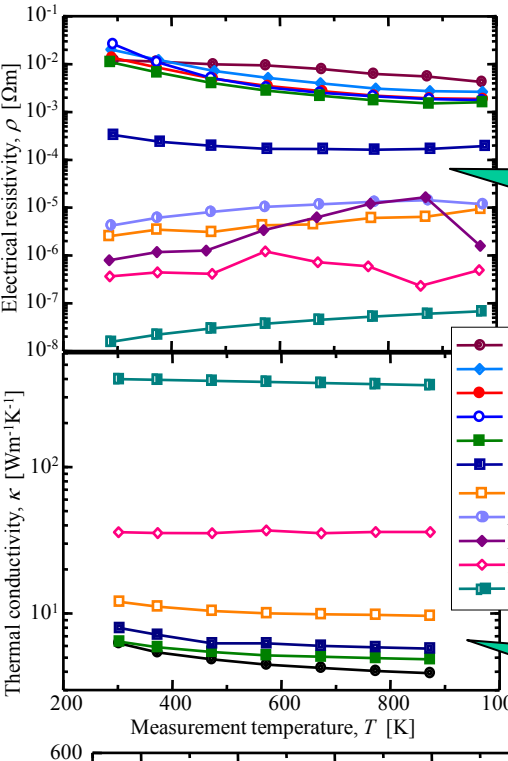
Experiment: Cu/TiO_{2-x} composite through adding Cu powder into nonstoichiometric titanium dioxide TiO_{2-x} was fabricated by spark plasma sintering (SPS). The composition and crystal forms of the composite were examined. The thermoelectric properties of the composite were also investigated. Rule of mixture (ROM) and effective medium theory (GET) were introduced to discuss the influence of the composite effects on the thermoelectric properties.

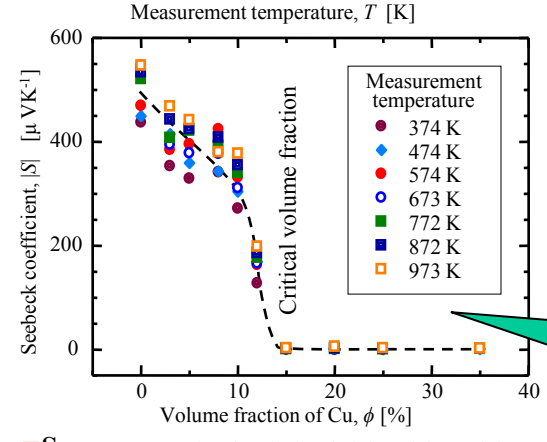
■ Dimensionless figure of merit: $ZT = S^2 \rho^{-1} \kappa^{-1} T$

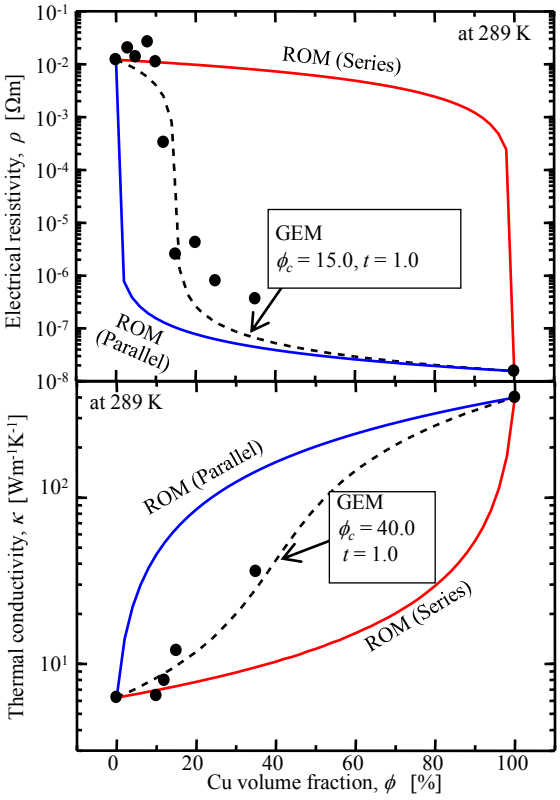
■ Parallel ROM: $\sigma_m = \phi\sigma_h + (1-\phi)\sigma_l$ ■ Series ROM: $\frac{1}{\sigma_m} = \phi\frac{1}{\sigma_h} + (1-\phi)\frac{1}{\sigma_l}$

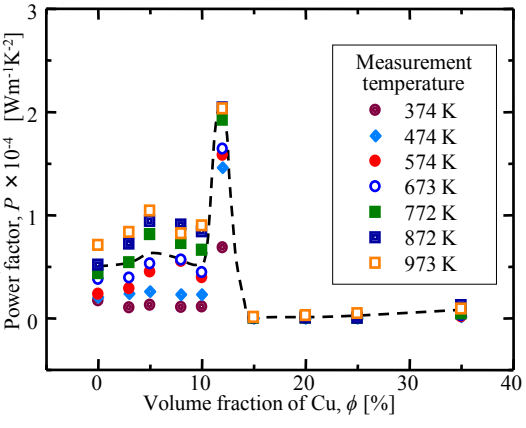
■ GEM: $\frac{(1-\phi)(\sigma_l^{1/t}-\sigma_m^{1/t})}{\sigma_l^{1/t}+[(1-\phi_c)/\phi_c]\sigma_l^{1/t}} + \frac{\phi(\sigma_h^{1/t}-\sigma_m^{1/t})}{\sigma_h^{1/t}+[(1-\phi_c)/\phi_c]\sigma_h^{1/t}} = 0$

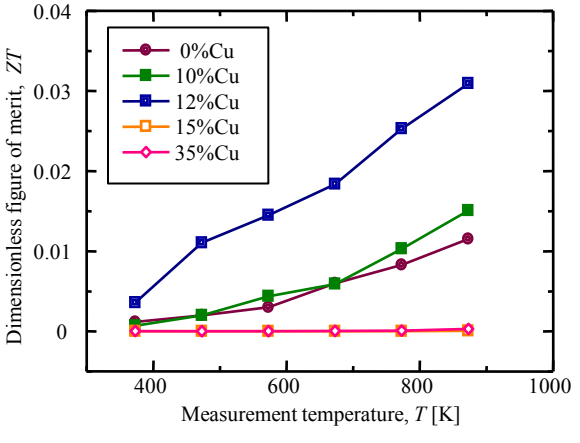












Cu/TiO_{2-x} composite

Semiconductor ↓Cu% Metallic

Parallel ROM ↑ ρ, κ GEM ↓ Series ROM

$\kappa(TiO_{2-x})$ ↓Cu% κ(Cu)

12%Cu ↓ P_{max}, ZT_{max}

$S(TiO_{2-x})$ ↓Cu% S(Cu)

Summary: The electrical resistivity of the Cu/TiO_{2-x} composites was decreased and the thermal conductivity was increased with the volume fraction increase of Cu powder addition. The critical volume fractions of Cu powder addition for the electrical resistivity and the thermal conductivity of the composite showed evident different. The thermoelectric properties and the transition of the composites from semiconductor to metal can be controlled by adjusting the volume fraction of Cu powder addition. Seebeck coefficient also had a critical volume fraction of Cu powder addition. Thermoelectric performance can be improved by adjusting the balance among electrical resistivity, thermal conductivity and Seebeck coefficient with the composite effects.