Fabrication and testing of compact thermoelectric module based on ZnO and $Ca_3Co_4O_9$ thin films

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Compact thin film modules (5 legs of n-type: $Al_{0.02}Zn_{0.98}O$, AZO; 5 legs of p-type: $Ca_3Co_4O_9$) were fabricated on Al_2O_3, $SrTiO_3$ (STO) single crystal and fused silica substrates by pulsed laser deposition (PLD).

Two targets (AZO and $Ca_3Co_4O_9$) were set in the PLD chamber. At first, laser was focused on AZO target and n-type (AZO) legs were deposited on 10 mm X 10 mm uncut substrates by superimposing a custom Ni mask (Micron Co. Ltd, Osaka) using the following conditions: energy density of about 4.2 J/cm^2; deposition period of 30 min; T_{dep} 400 °C on Al_2O_3, T_{dep} 300 °C on STO and Silica; oxygen pressure of 200 mTorr; laser pulse frequency 10 Hz; substrate–target distance about 35 mm; rotation speed of the target 30 % rpm. Then, $Ca_3Co_4O_9$ target was moved under the laser beam and ablated to fabricate p-legs after shifting the custom Ni mask. Conditions used for $Ca_3Co_4O_9$ legs were same as for AZO legs except for lower energy density (about 1.1J/cm^2) and higher T_{dep} (700 °C on Al_2O_3 and Silica, T_{dep} 650 °C on STO). Gold electrodes were sputtered at room temperature after completion of PLD routes in order to achieve the electrical connection of the n-p couples. Typical picture of AZO/$Ca_3Co_4O_9$ module is shown in Fig. 1.

Performance of modules was evaluated using ad-hoc customized system where the module was set vertically. The largest output power was obtained on Al_2O_3 with ΔT = 230 °C (T_{hot} = 300°C): P_{max} =29.9 pW (Fig. 2). This result is encouraging for the practical applications of thermoelectric oxide thin films, looking forward to the fabrication of modules on flexible substrates for ubiquitous harvesting of the waste heat.

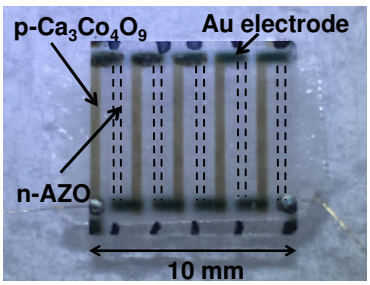

Fig. 1 – Typical AZO/$Ca_3Co_4O_9$ module。 Position of transparent AZO legs is indicated by dotted lines.

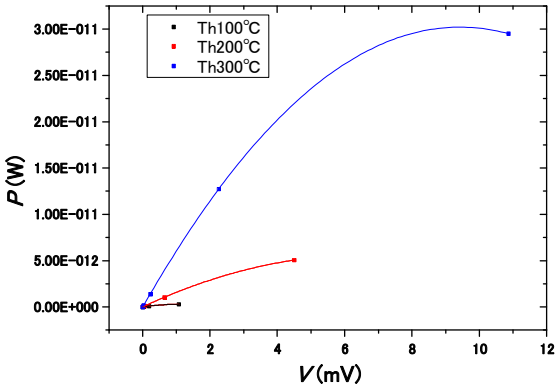

Fig. 2 Power of thin film module deposited on Al_2O_3 (T_{hot} = 100, 200 and 300°C)