Nanoarchitecting to induce flexibility in $Ca_3Co_4O_9$ thin films for thermoelectric applications

LINKÖPINGS UNIVERSITET

Biplab Paul[1,*], Jun Lu[1], Per Eklund[1]

[1]Thin Film Physics Division, Linköping University, SE-581 83 Linköping, Sweden

*bippa@ifm.liu.se

Aim: The growth of flexible $Ca_3Co_4O_9$ thin films with better mechanical flexibility, while sustaining high thermoelctric efficiency comparable to that of its prisitine bulk values.

❑ Motivation behind this study

Organic materials

- Flexible
- Low output power density
- Unstable

Inorganic materials

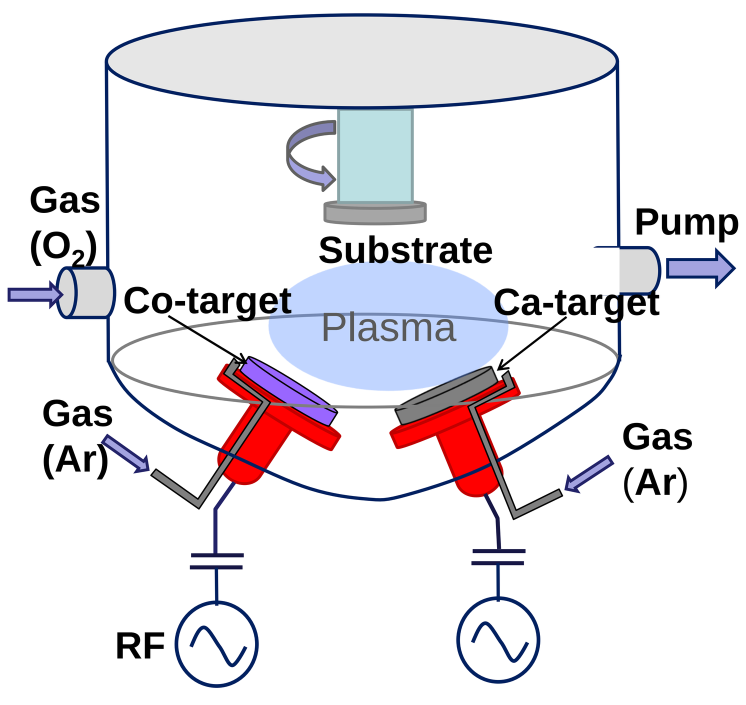
- Stable
- High output power density
- Rigid and brittle

Future demand

- Stability
- High output power density
- Flexibility

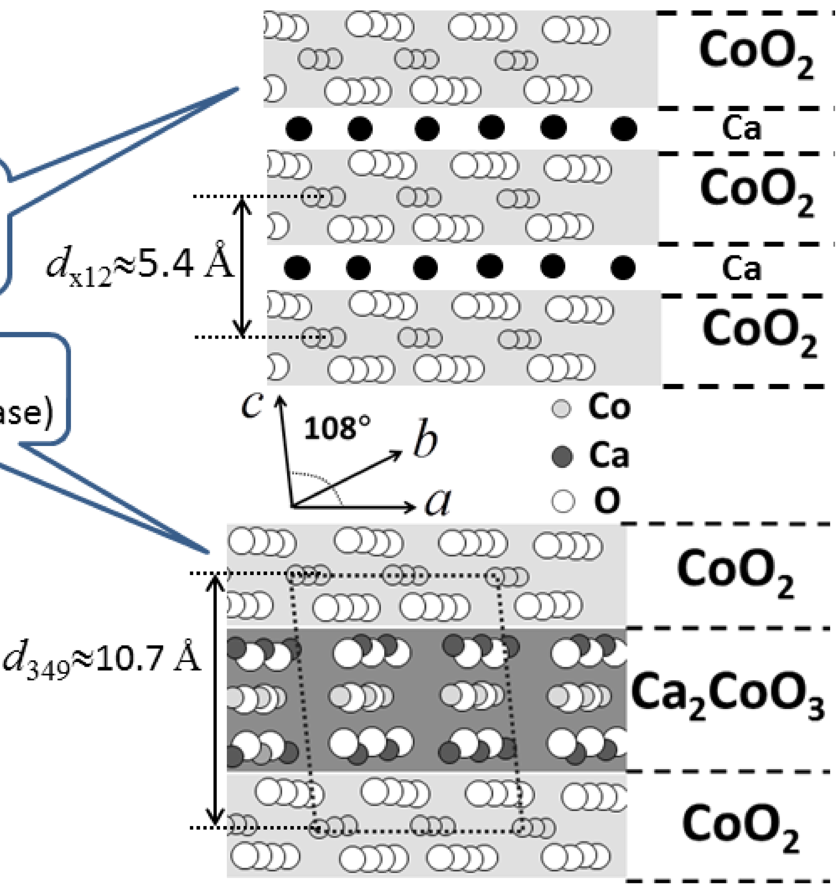
❑ CaO-CoO film deposited by rf- magnetron reactive cosputtering

❑ As-deposited CaO-CoO film reactively annealed to form final phase of $Ca_3Co_4O_9$



1. $CoO + O_2 \Rightarrow Co_3O_4$ (11-phase) (34-phase)
2. $Co_3O_4 + CaO \Rightarrow Ca_xCoO_2$ (x12-phase)
3. $Ca_xCoO_2 + CaO \Rightarrow Ca_3Co_4O_9$ (349-phase)

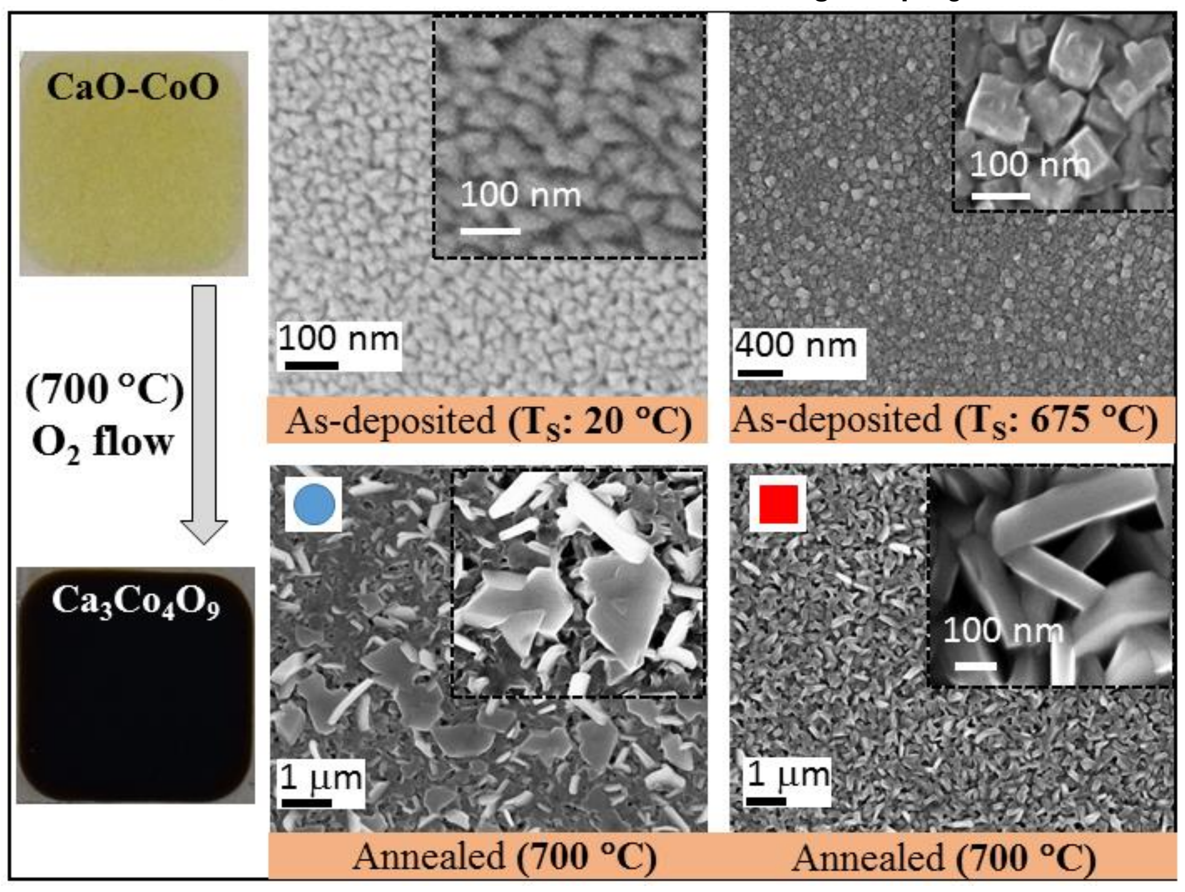
Three stage phase transformation occur during annealing



Advantage of mica as substrate

- Mica can sustain high deposition temperature of 675 °C.
- Mica can serve as flexible substrate.
- Thin film can be transferred onto other flexible platform from mica substrate.

❑ Tailoring of nanoarchitecture of $Ca_3Co_4O_9$ film



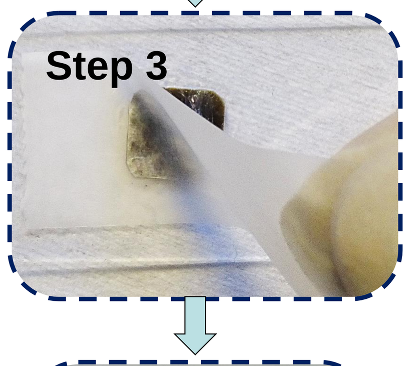
- Architecture of the film depends on the nanostructural evolution during thermally induced phase transformation during annealing.
- The pattern of nanostructural evolution depends on the relative arrangements of CaO and CoO phases in the as-deposited films, which is controlled by deposition temperature.

❑ Flexible $Ca_3Co_4O_9$ thin film

➢ ***Different steps for developing flexible film from sample (T_S: 675 °C)***

Step 1: Film is attached to a glass slide by wax

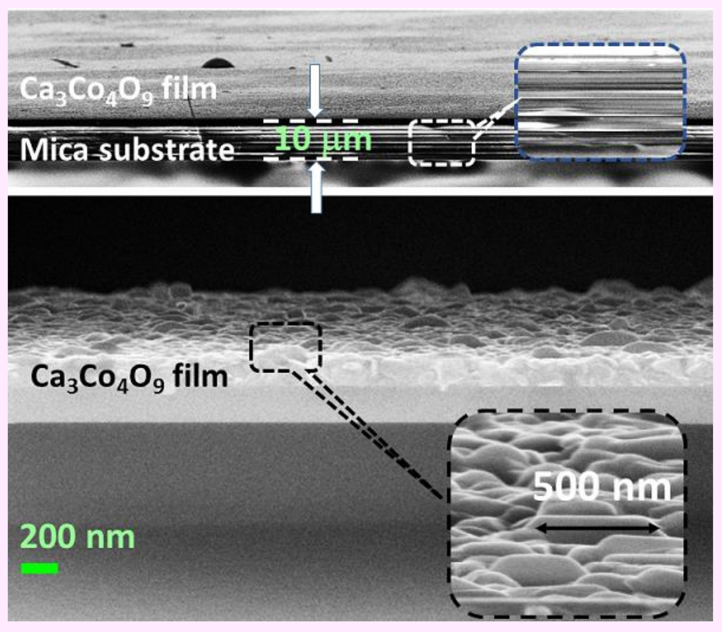
***Step 2*:** Substrate thickness is reduced to 100 µm.



***Step 3*:** Thickness is reduced to 10 µm.

***Step 4*:** Immersed in acetone for 12 h to desolve wax.

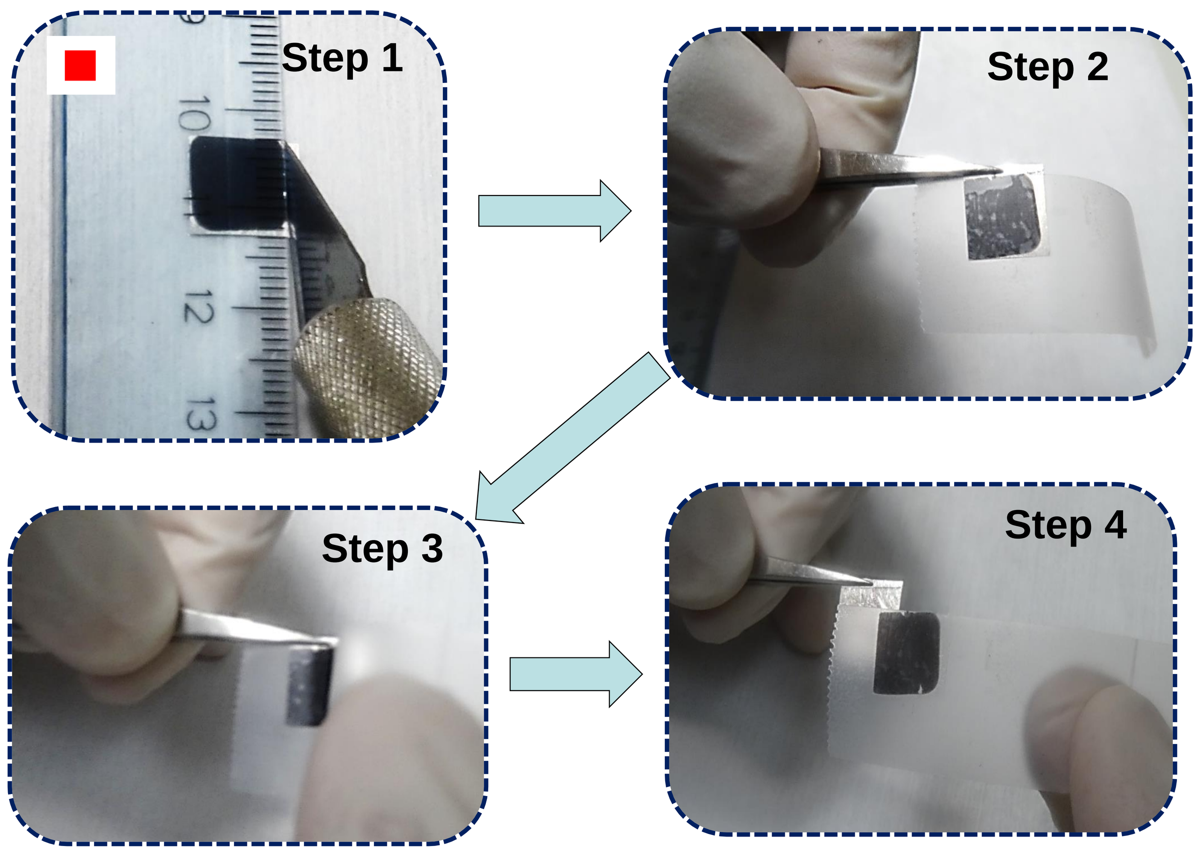
➢ ***Cross section SEM image of the flexible film***



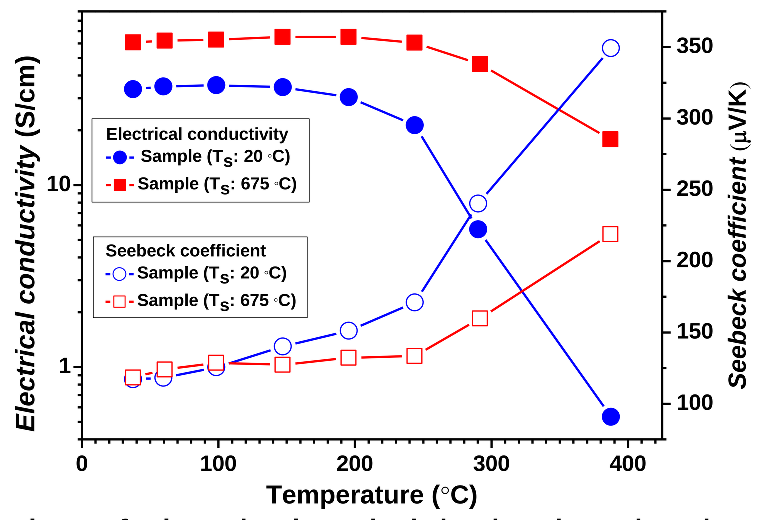
- Vertical alignment of the grains improve the mechanical flexibility of the film.
- Substrate thickness being 10 µm the film is easily bendable.

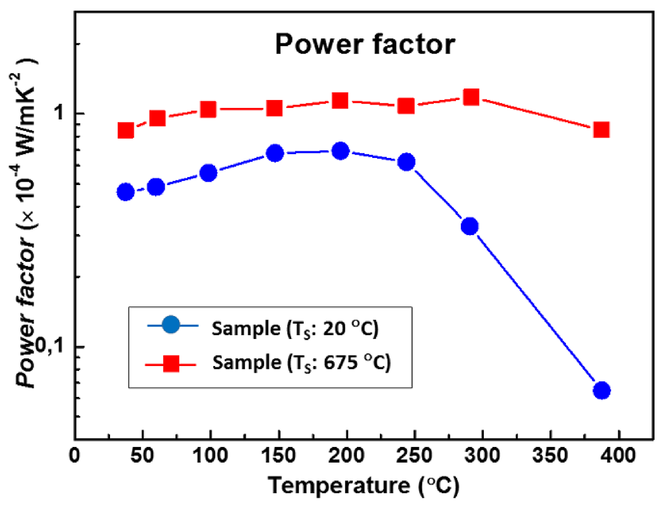
❑ Transfer of $Ca_3Co_4O_9$ film onto other flexible platform

- The film is transferred onto the adhesive tape following the steps shown below.



❑ Thermoelectric properties





- Best value of electrical resistivity is obatained as16. 46 mΩ.cm near room temperature from sample (T_S: 675 °C).
- Power factor above 1×10^{-4} $Wm^{-1}K^{-2}$ is achieved from the same sample.

Conclusion:

- A nanorachitecting approach has been demonstrated to induce flexibility in $Ca_3Co_4O_9$.
- Mica acts as flexible substrate.
- Maximum power factor ~1.2×10^{-4} $Wm^{-1}K^{-2}$ near 300 °C.

Reference

- **B. Paul**, J. L. Schroeder, S. Kerdsongpanya, N. V. Nong, N. Schell, D. Ostach, J. Lu, J. Birch, P. Eklund, *Advanced Electronic Materials* **1**, 1400022 (2015).

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Vetenskapsrådet

Swedish Foundation for Strategic Research