Gallium Oxide Nanostructures for High Temperature Sensors

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Outline

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- Research Objectives
- Experiments
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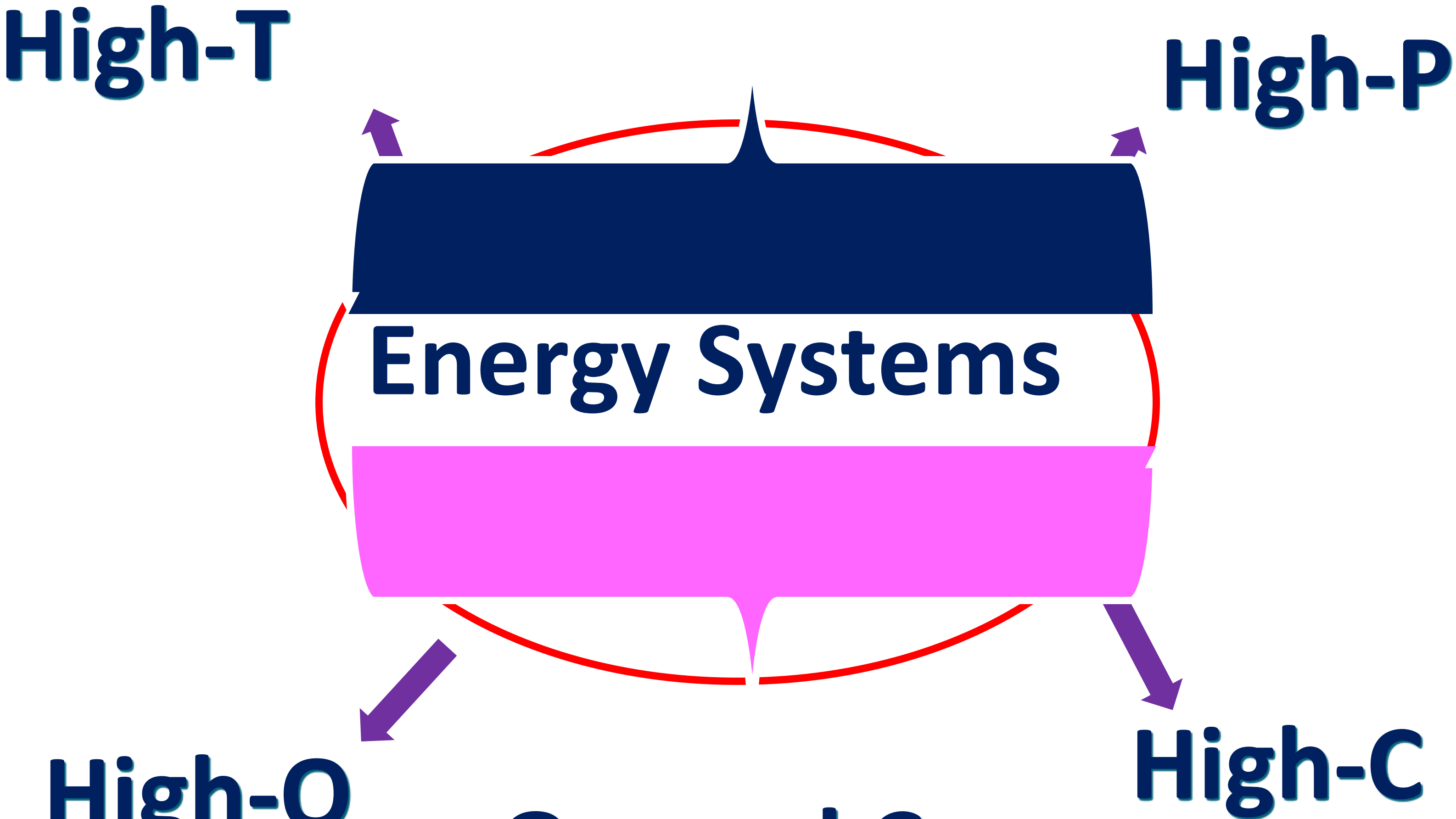
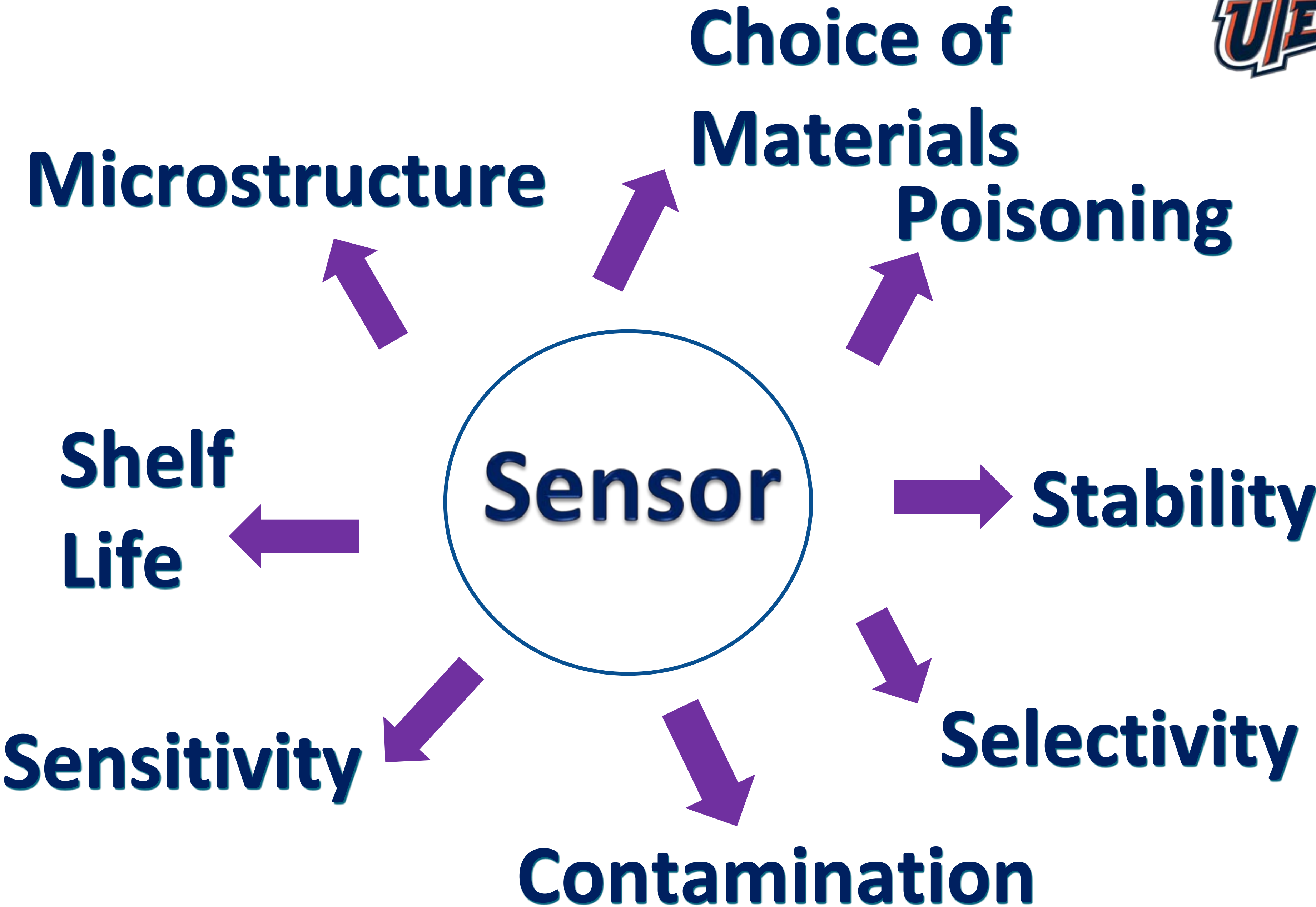
  - Characterization
- Results and Discussion
  - Ga_2O_3 Thin Films (Physical Methods)
  - Ga_2O_3 Nano-Particles and Nano-Wires (Chemical Methods)
- Summary & Future Work

Introduction

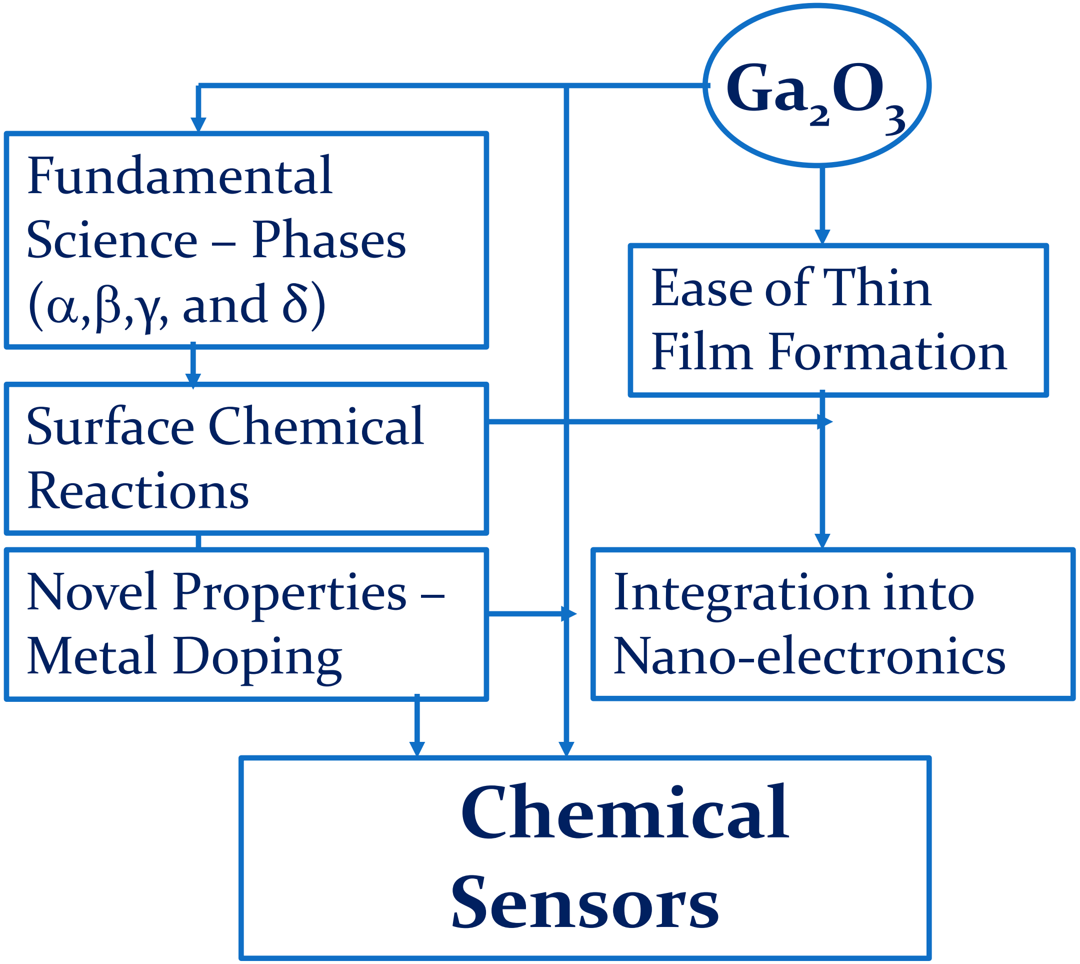
T,P Tolerance



Ox. and Cr. Resistance


Choice of
Materials
Microstructure
Poisoning
Shelf
Life
Sensor
Stability
Sensitivity
Selectivity
Contamination

Gallium Oxide (Ga_2O_3)



♦Wide band gap (>5 eV) semiconductor
*High thermal and chemical stability (T_m: 1725 ^oC)
*Due to a high melting point and stable structure, it is one of the most suitable materials for high temperature gas sensing.

Sensing Mechanism

At T>700 ^{o}C, defects → equilibrium with surrounding atmosphere → n type conductivity → depends on oxygen partial pressure

$$\sigma = \sum_i P_{O_2} \exp\left(\frac{-E_A}{k_B T}\right)$$

- Electrical conductivity → σ
- Activation energy → E_A
- Oxygen partial pressure → P_{O_2}
- Boltzmann constant → k_B
- Temperature → T

At T< 700 ^{o}C, Ga-oxide exhibits sensitivity to reducing gases (CO, H_2)

Objectives and Goals

Objective 1: To fabricate high-quality pure and doped Ga_2O_3-based materials and optimize conditions to produce unique architectures and morphology at the nano scale

Objective 2: Derive the structure-property relationships at the nanoscale dimensions and demonstrate enhanced high-temperature oxygen sensing and stability

Objective 3: To promote research and education in the area of sensors and controls

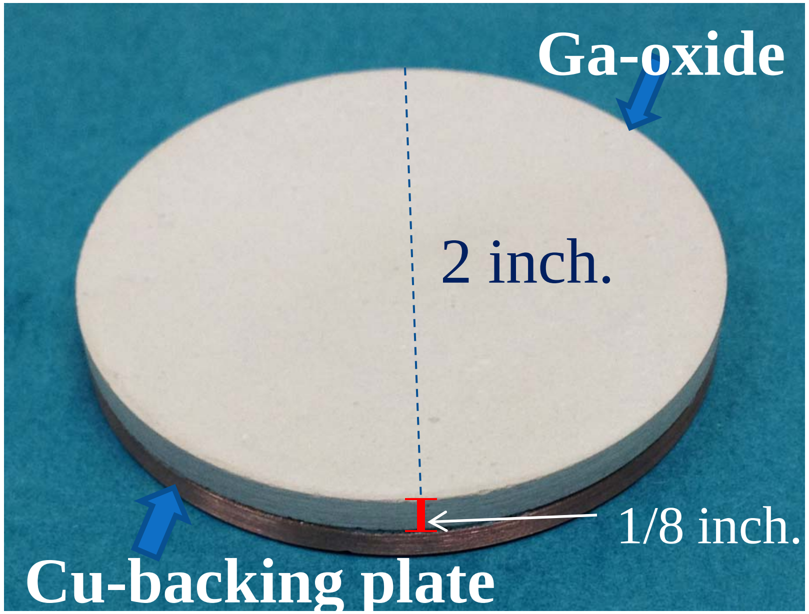
Goal: Develop the high temperature oxygen sensors (employing Ga_2O_3-based nanostructures)

Experiments

Materials

<u>Target (for Deposition)</u>

Ga_2O_3



<u>Substrate(s)</u>:

- Si(100)
- Alumina

<u>Powder (for Milling)</u>

GaN

Fabrication – Thin Films

- RF magnetron sputtering
- Deposition Conditions

Fixed:

- Base pressure ~10^{-6} Torr

- Power: 100 W

- Target-Substrate distance: 7 cm

- Sputtering gas: Argon

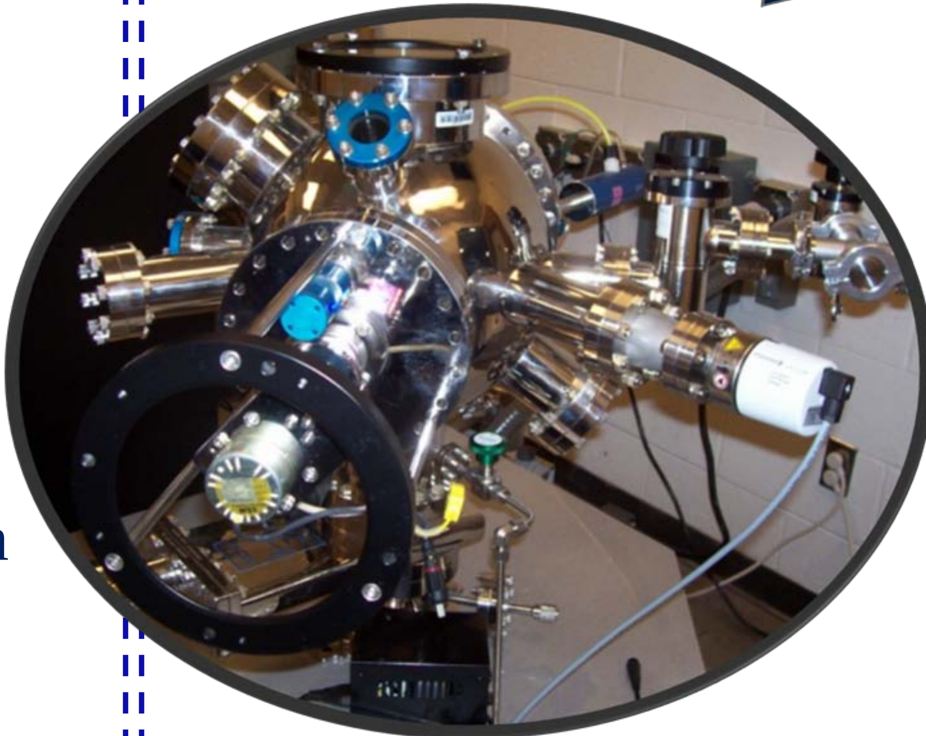
Variables:

<u>Sample set 1</u>:

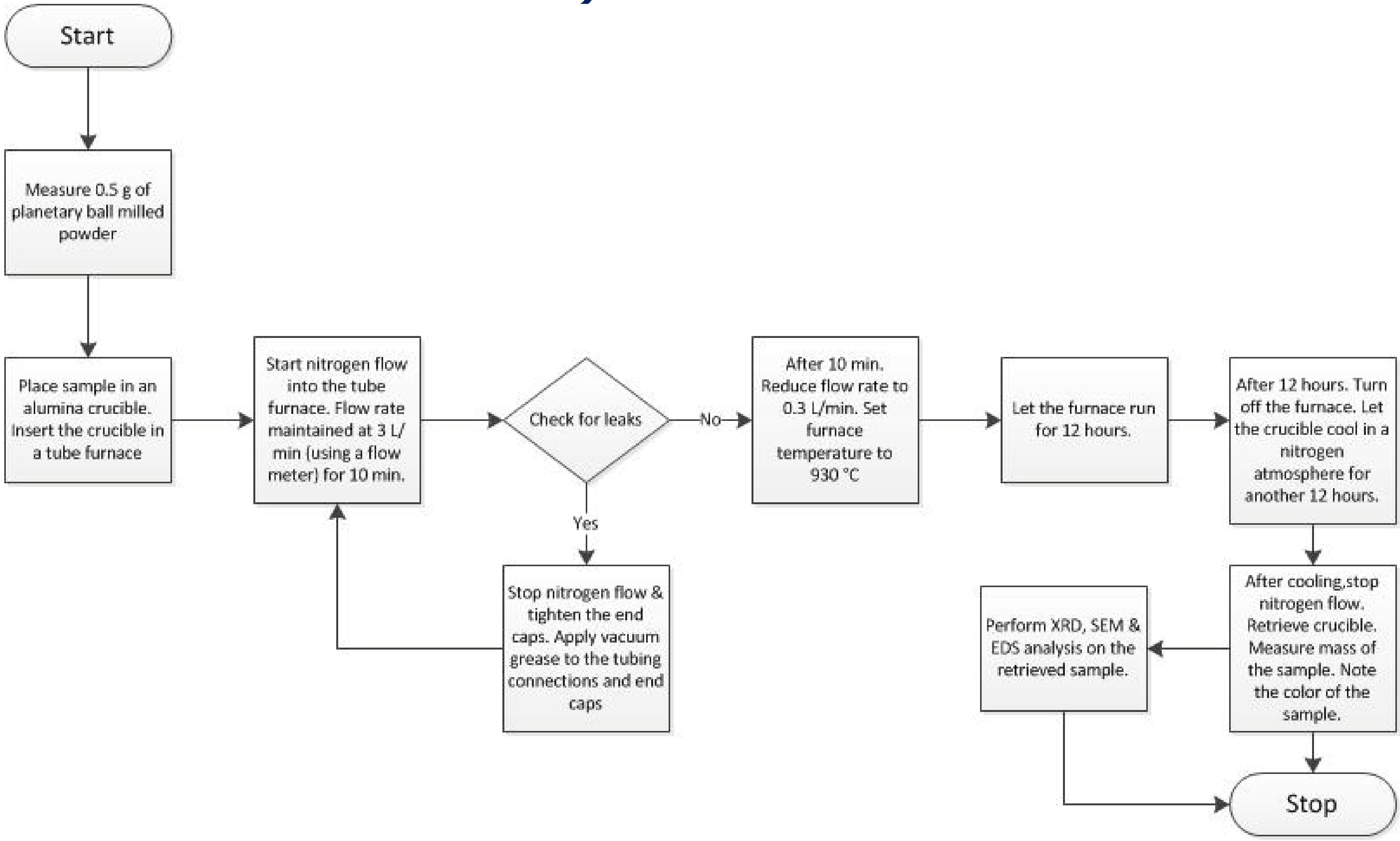
Substrate temperature: RT to 800 °C

<u>Sample set 2</u>:

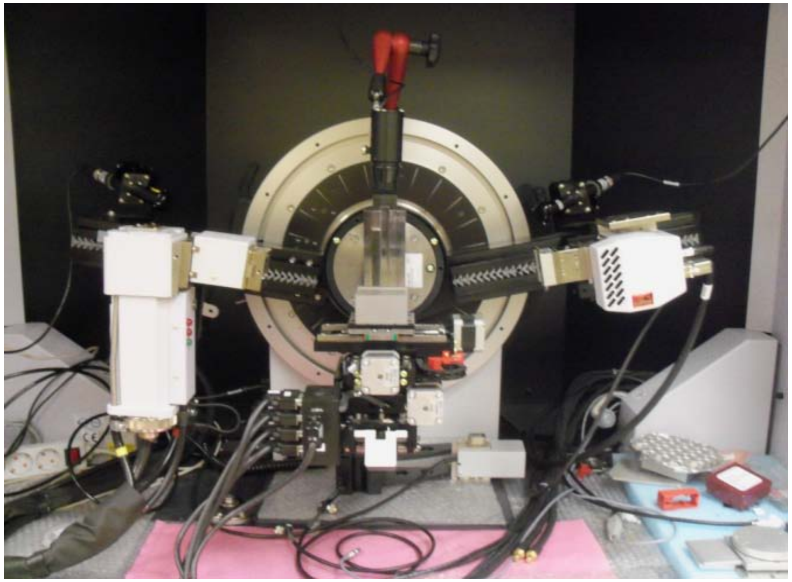
Deposition time or thickness:



Nano- Particles, Wires and Belts

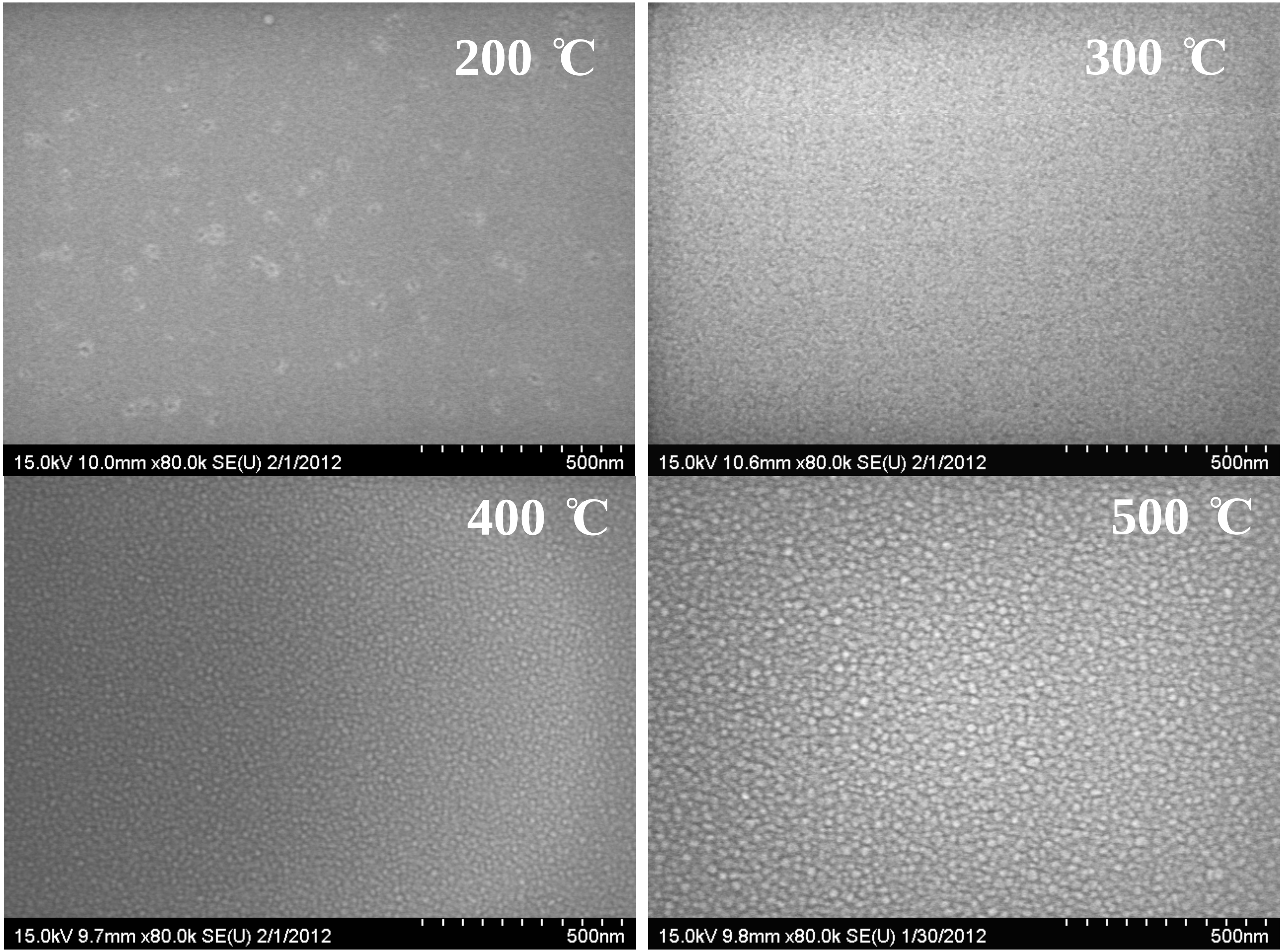


Characterization



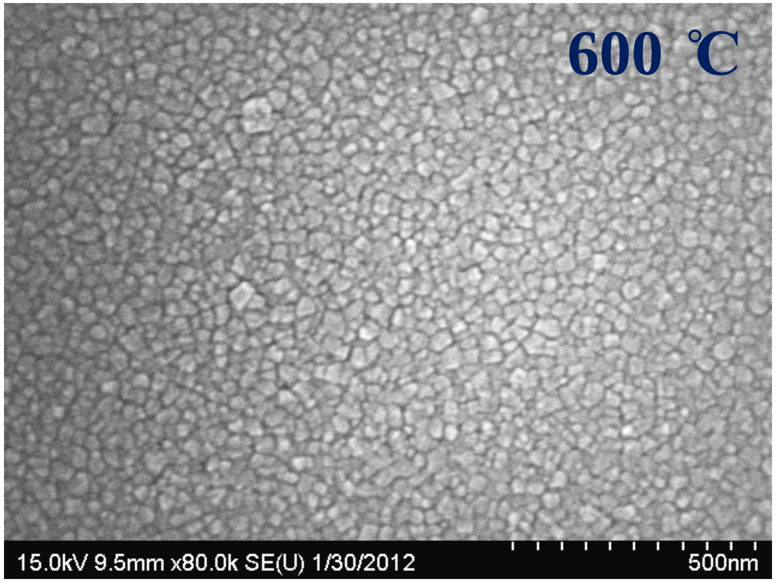
Results and Analysis

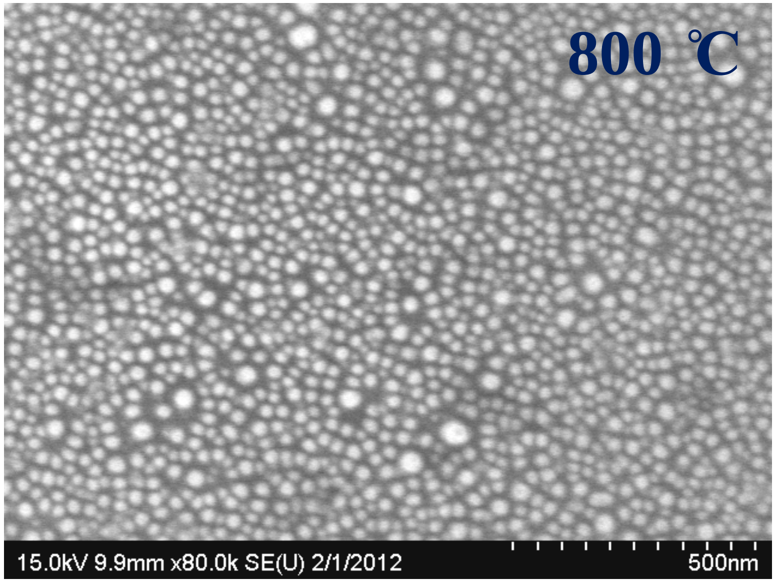
Surface Morphology - SEM



$t_{dep.}$= 30 min.

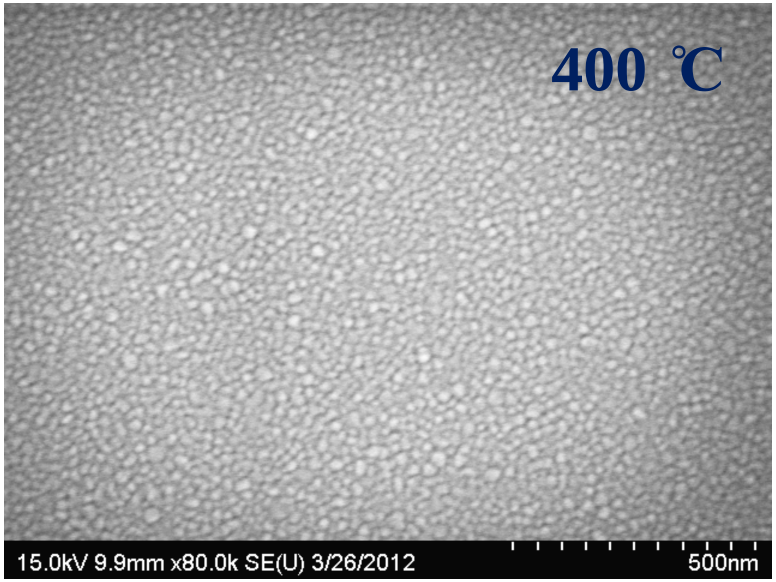
Surface Morphology - SEM

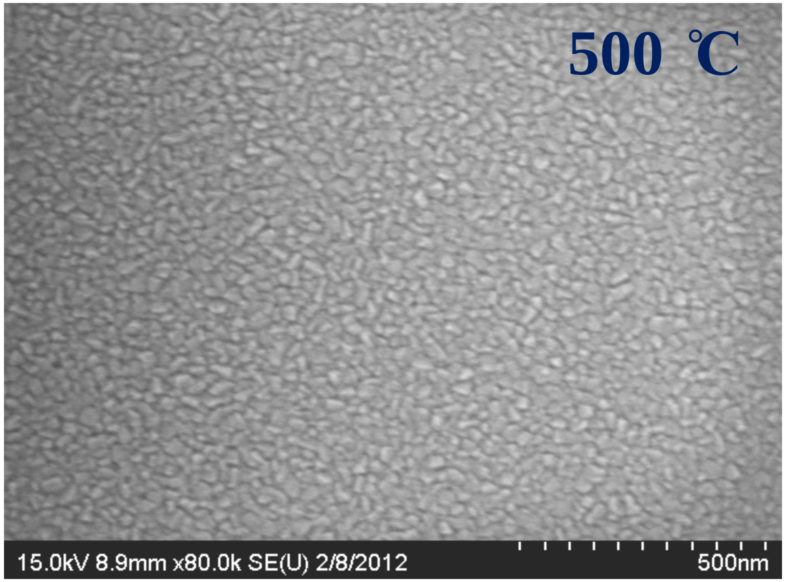


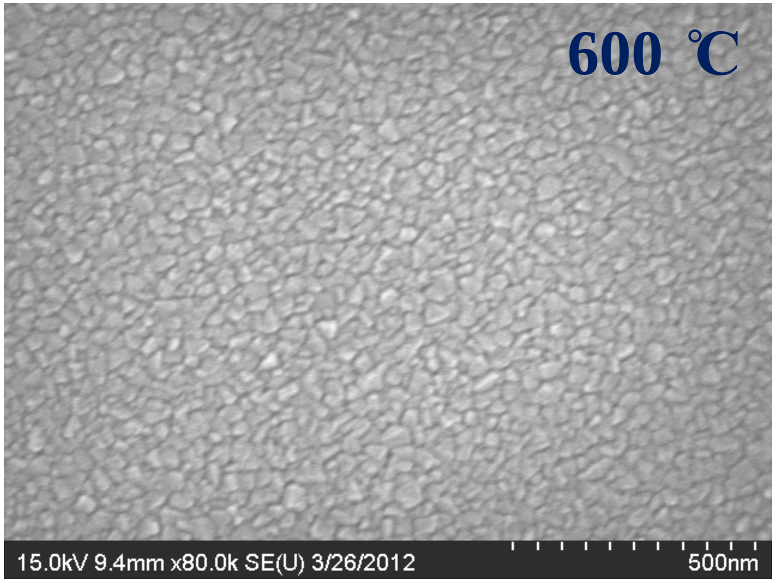


$t_{dep.}$= 30 min.

Morphology – Thickness







$t_{dep.}$=
60 min.

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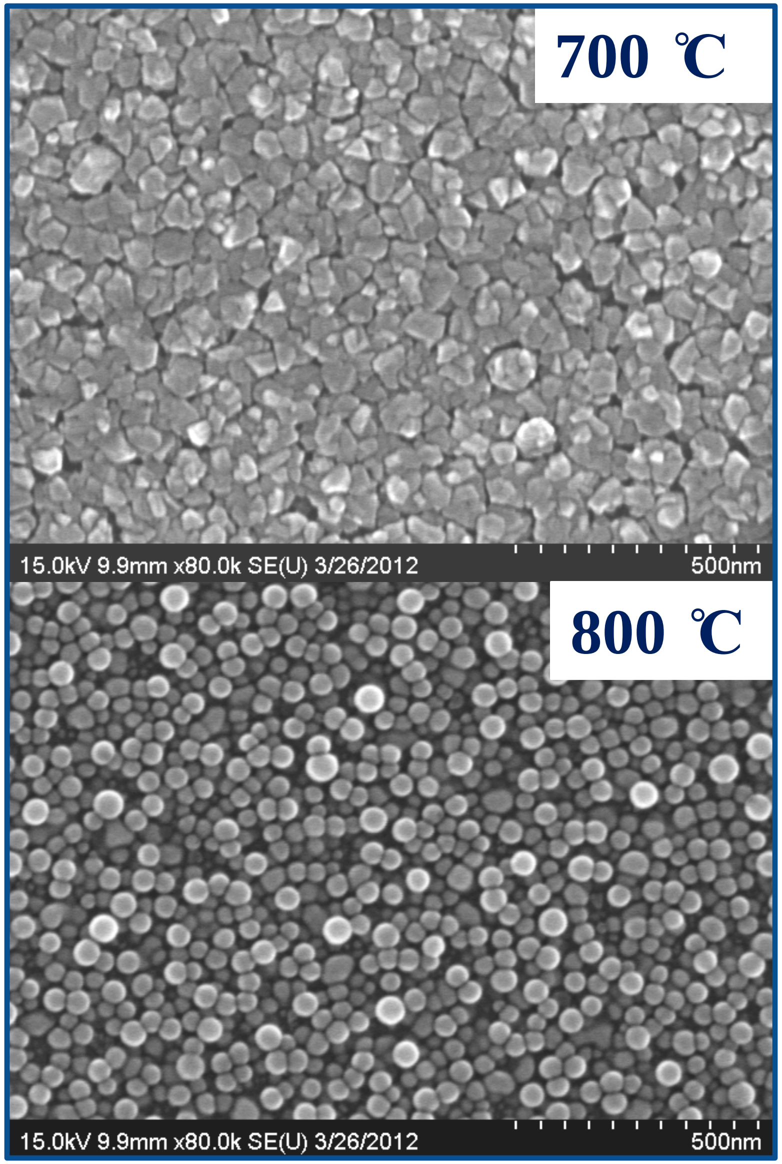
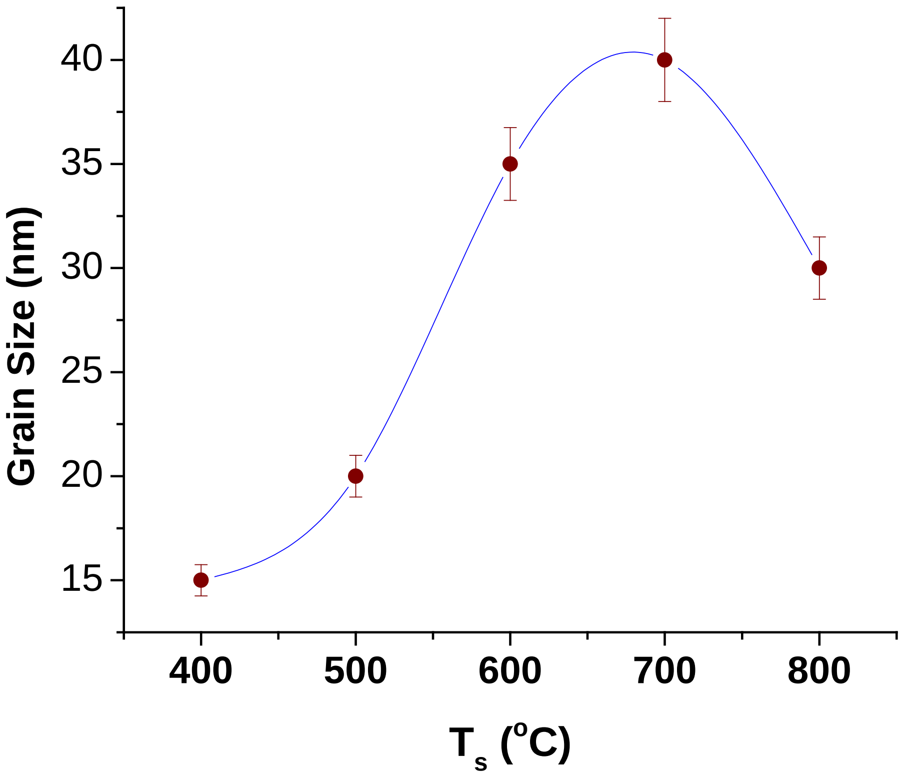
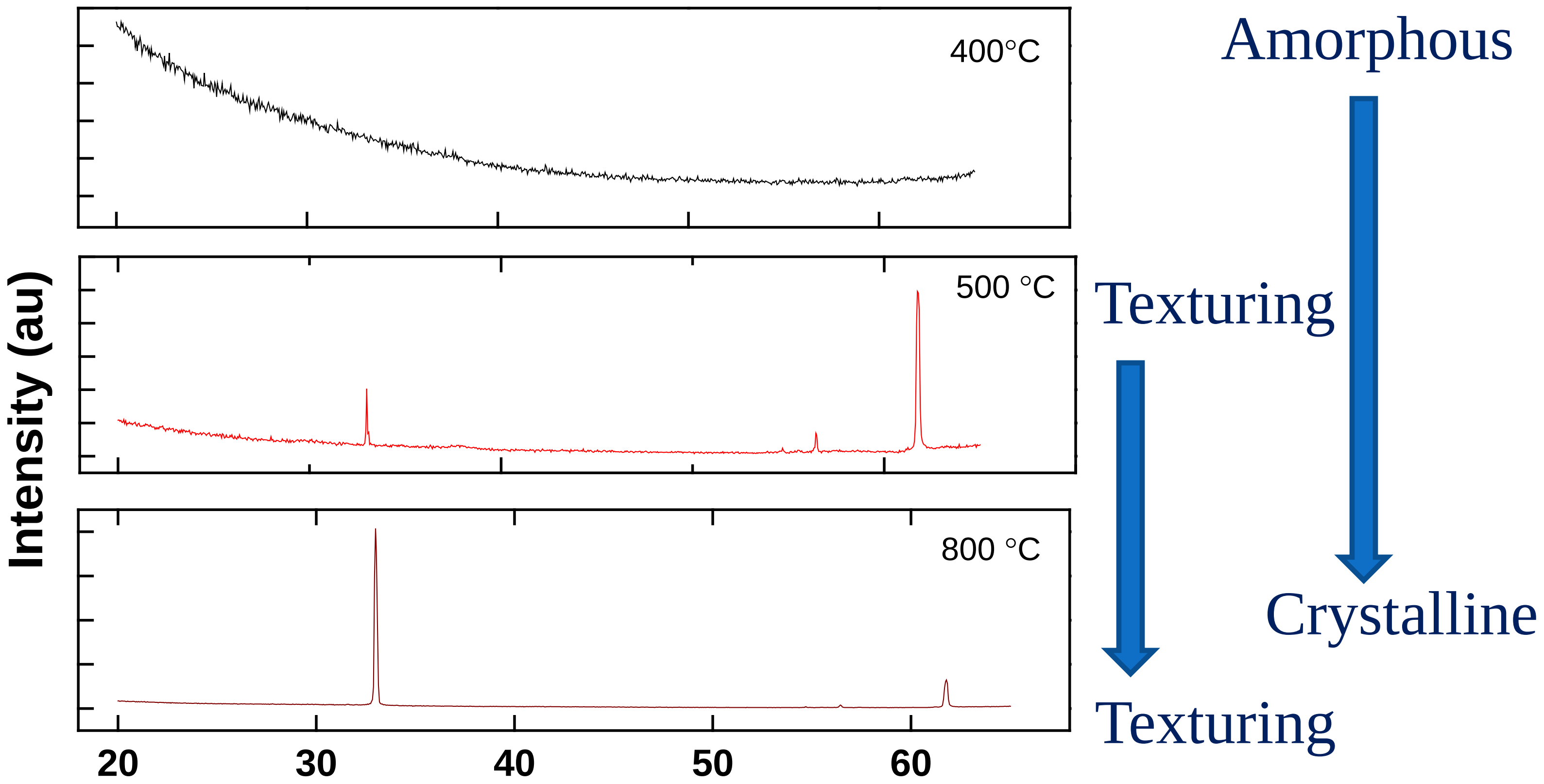

700 ℃
15.0kV 9.9mm x80.0k SE(U) 3/26/2012
500nm
800 ℃
15.0kV 9.9mm x80.0k SE(U) 3/26/2012
500nm

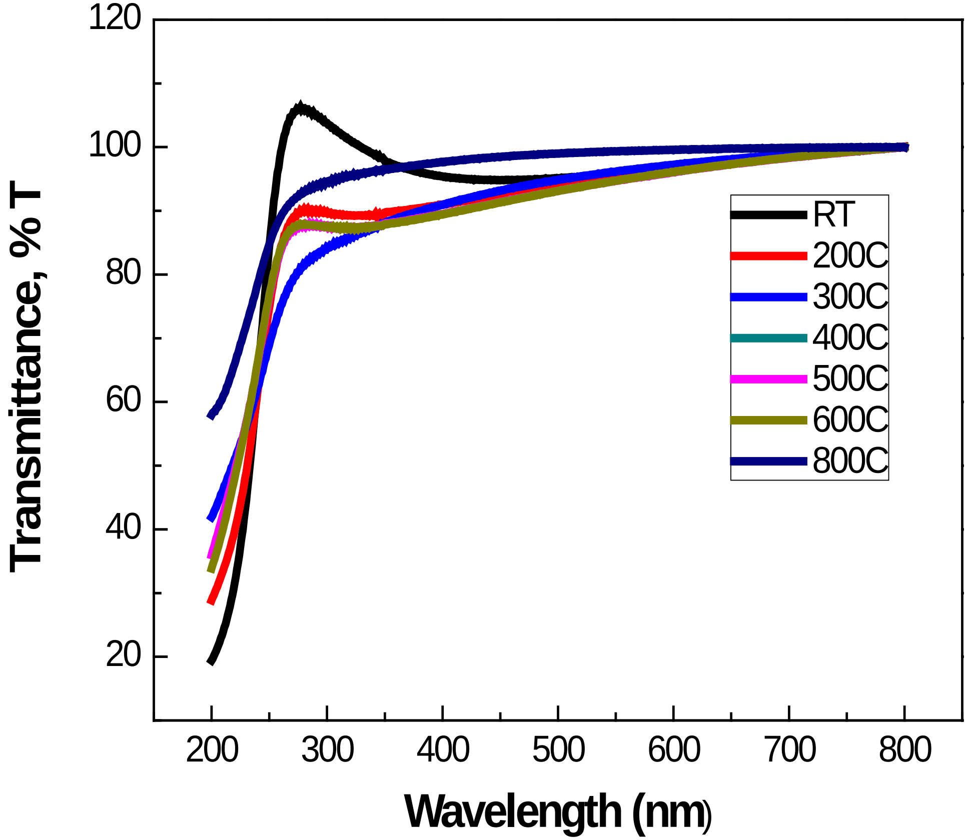
Grain Size

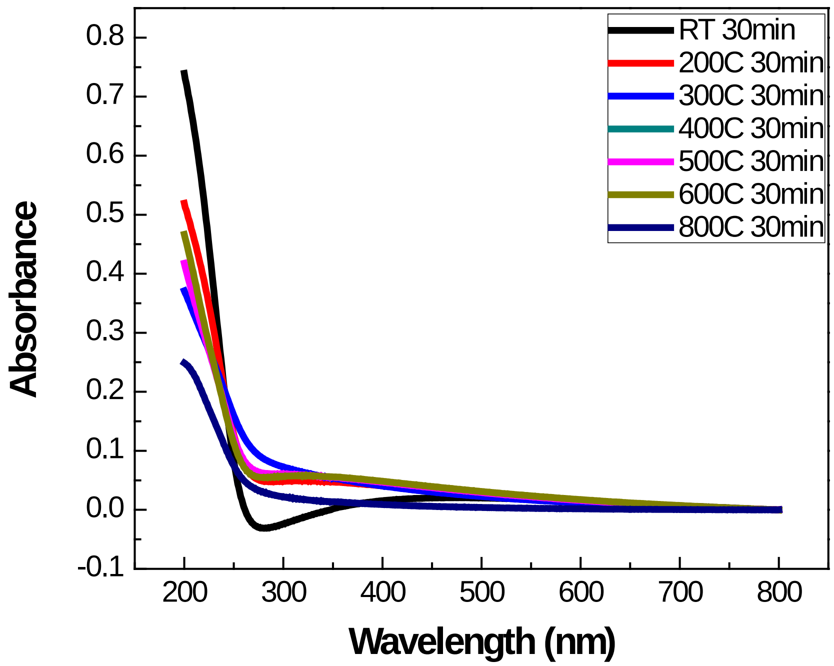


Crystal Structure – GIXRD



Optical Properties

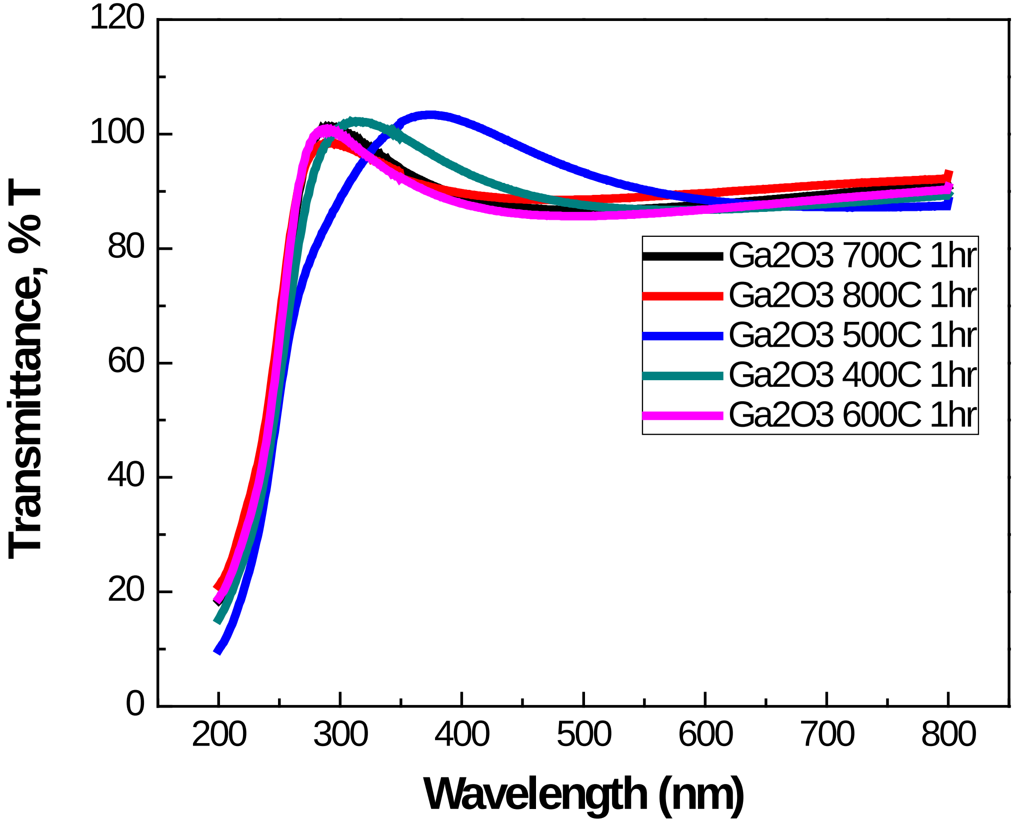


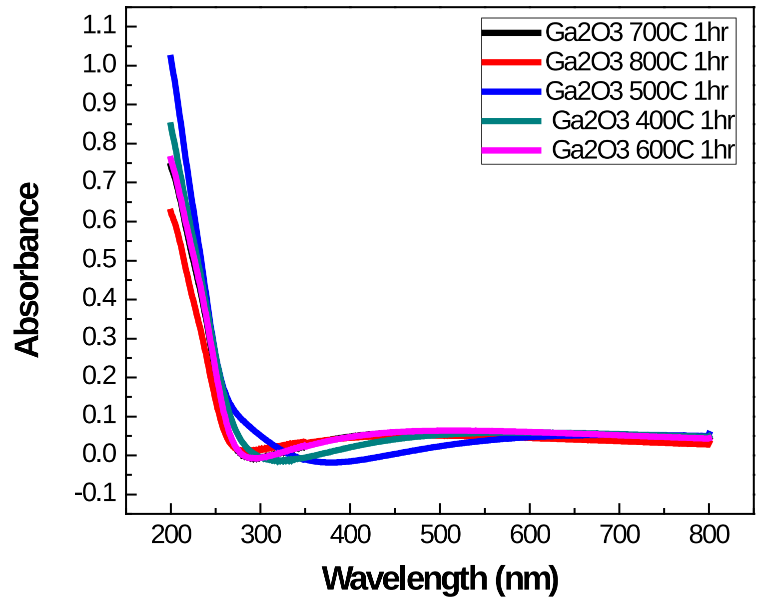


$t_{dep.}$=
30 min.

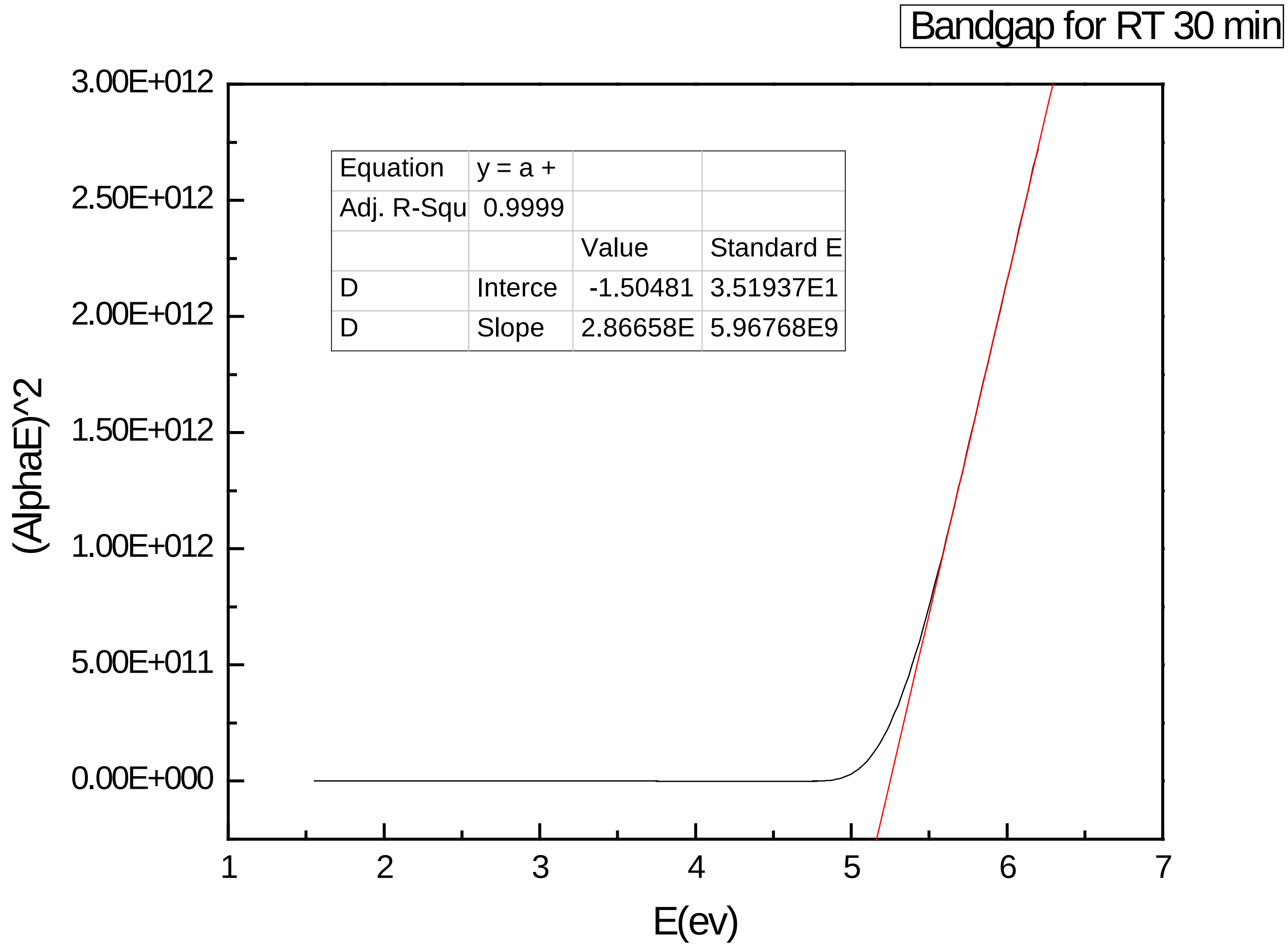
Optical Properties

$t_{dep.}$=
60 min.



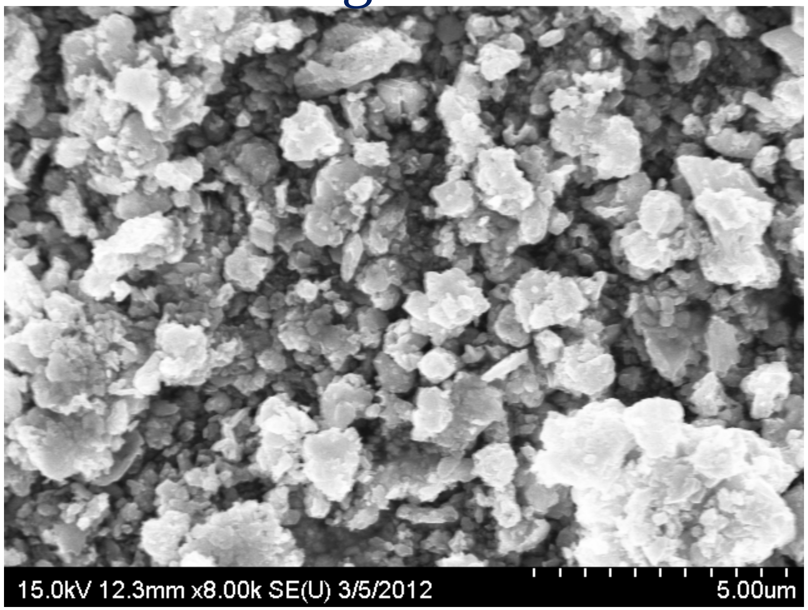


Optical Properties

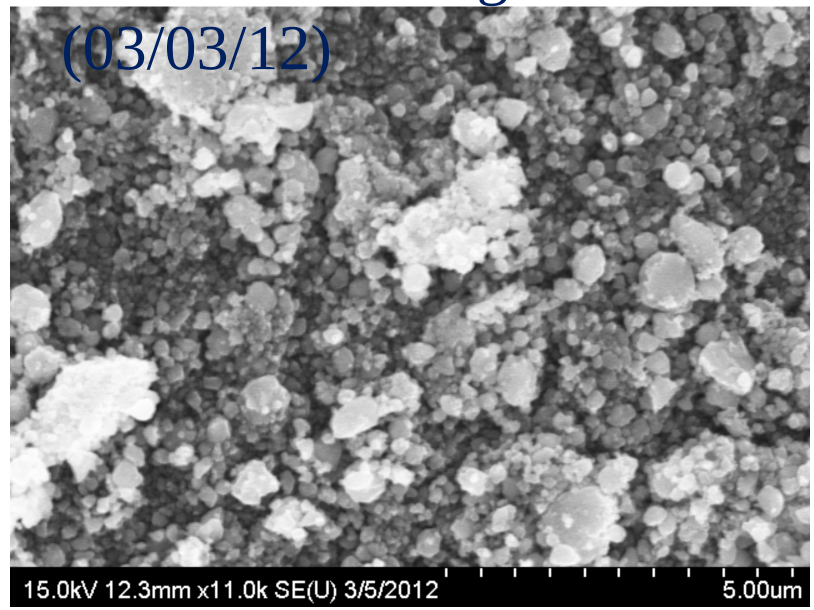


Ball Milling Synthesis

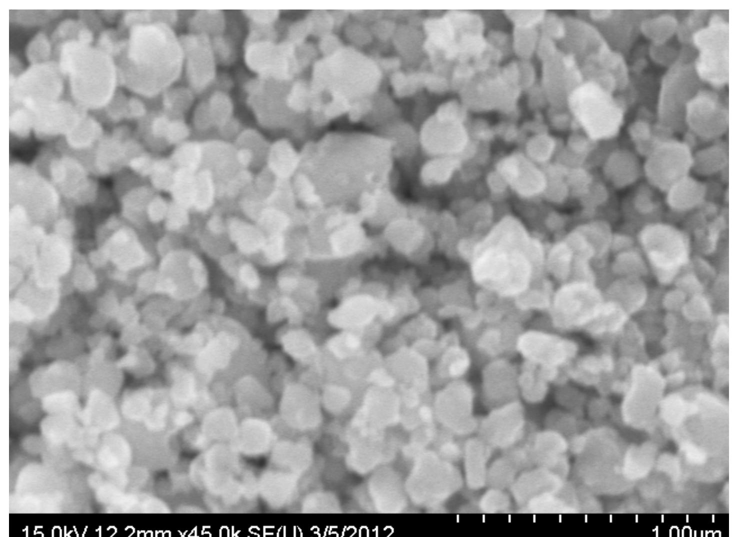
GaN Original Powder



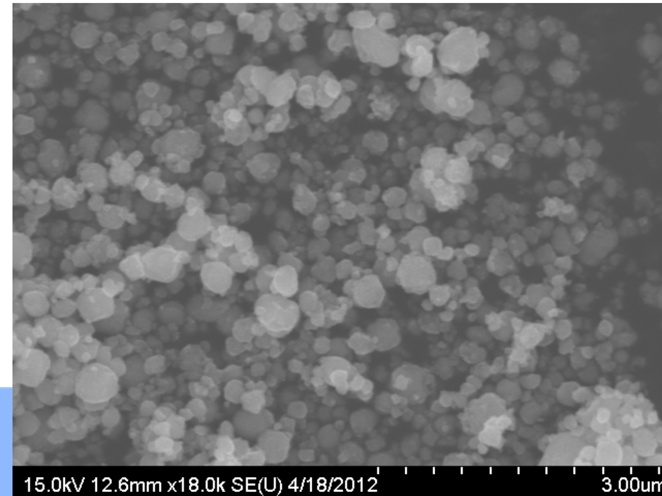
After ball milling (03/03/12)

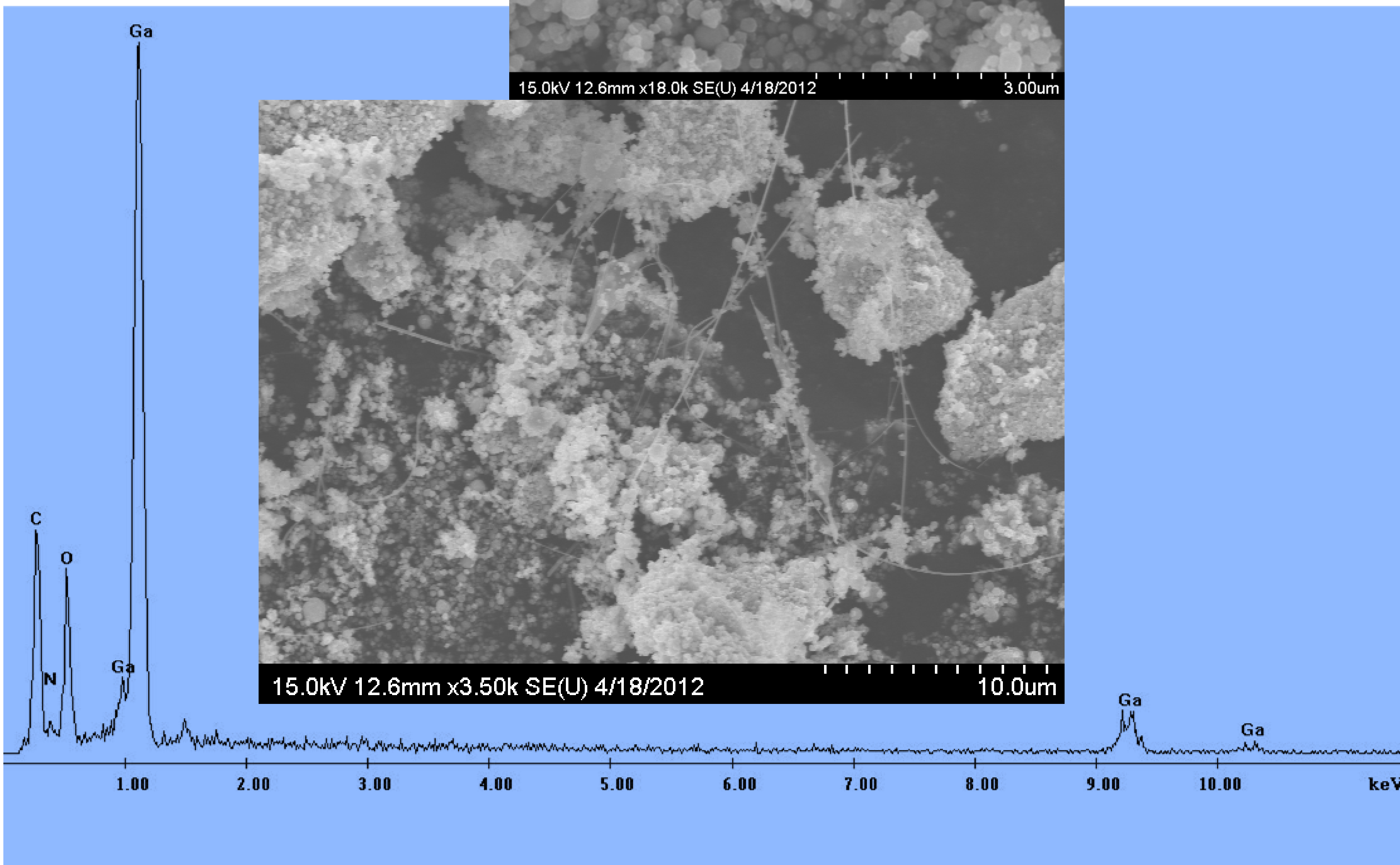


Nano Particles !!!



Chemical -EDS

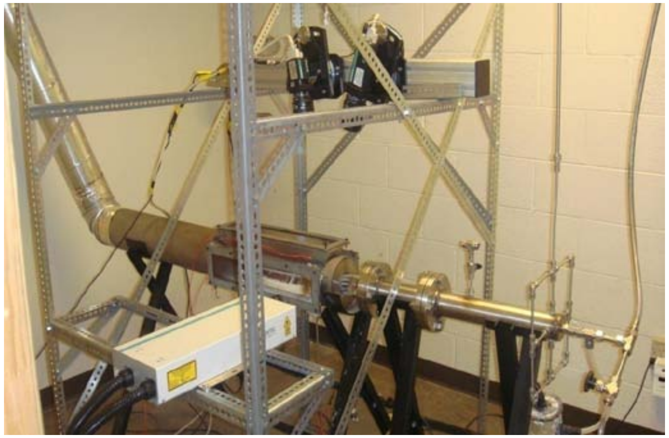


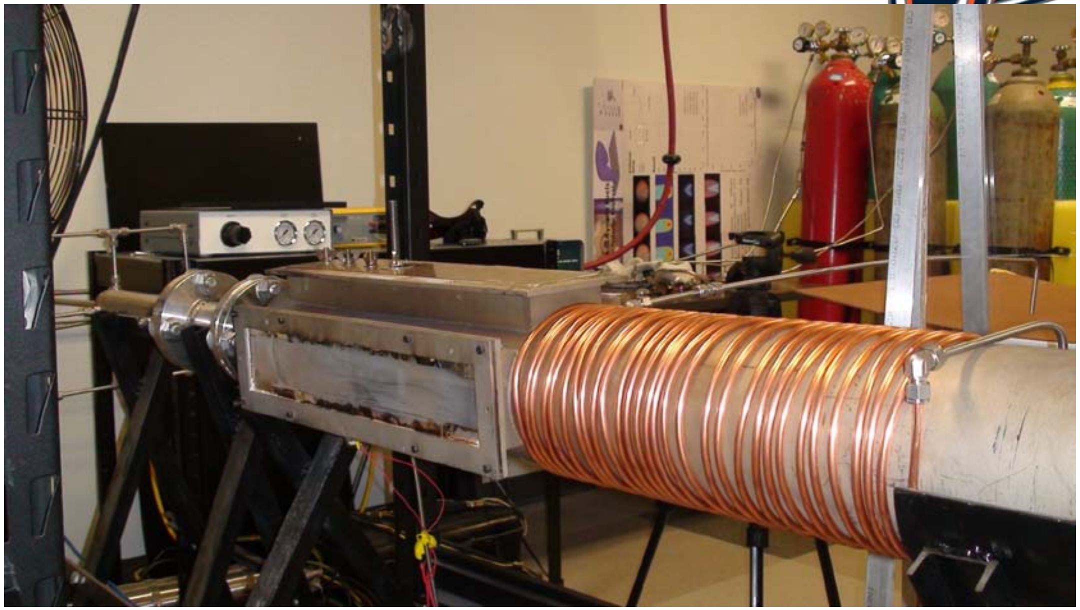


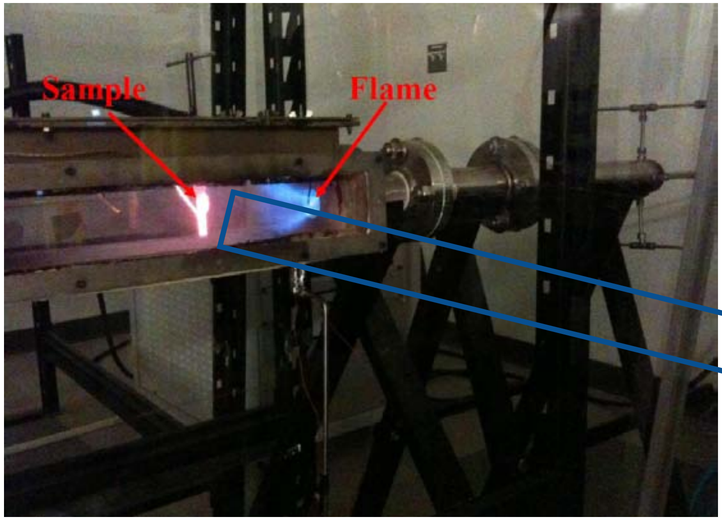
Summary

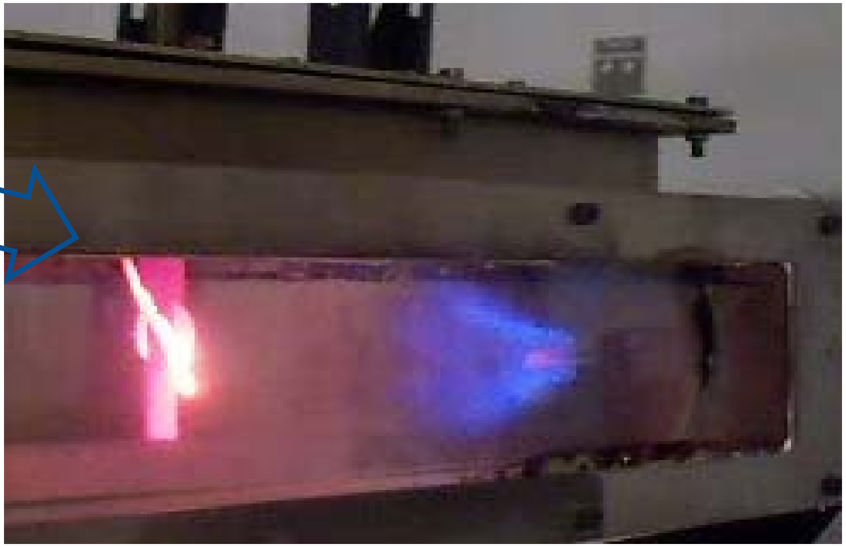
- Ga-oxide thin films, nano-particles and nano-belts were synthesized
- The effect of temperature is remarkable in deciding the structure and morphology of Ga-oxide films
- Preliminary results obtained on the optical properties are encouraging

Future Work









Acknowledgements

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THANK YOU!