STUDY OF PLASMONIC NANOPARTICLES IN OXIDE THIN FILMS FOR SENSING APPLICATIONS

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Motivation

ZnO is known for its wide bandgap and high exciton binding energy, and it is widely used in **sensors and transparent electronics**.

CuO, with its narrow bandgap and p-type behavior, is a promising candidate for visible light absorption and applications like **photovoltaics and gas sensing**.

Au nanoparticles (Au NPs) have distinct optical properties due to their ability to sustain **localized surface plasmon resonances (LSPR)**, which make them valuable candidates for applications in sensing, imaging, and energy harvesting. **Integrating these plasmonic nanoparticles into oxide thin films** allows for the combination of their functionalities, enhancing their performance.

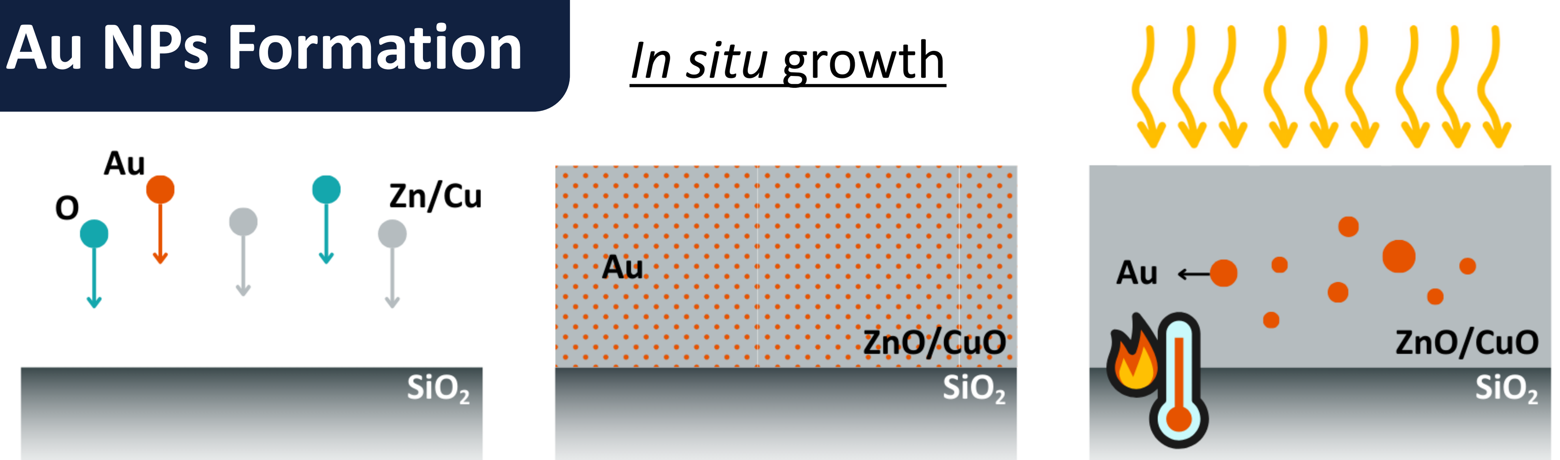
Ion implantation can be used as a NP formation method that offers **precise control over NP depth profile and concentration** by modulating the ion energy and implantation fluence.
It is **ideal for multifunctioning devices** since it allows for the combination of different ions.

Objectives

1. **Create Au NPs by ion implantation** in ZnO and CuO thin films**;**
2. **Compare two methods of NP formation**: *in situ* growth and ion implantation;
3. **Study the plasmonic temperature sensing potential** of Au-ZnO and Au-CuO composites.

Au NPs Formation

In situ growth



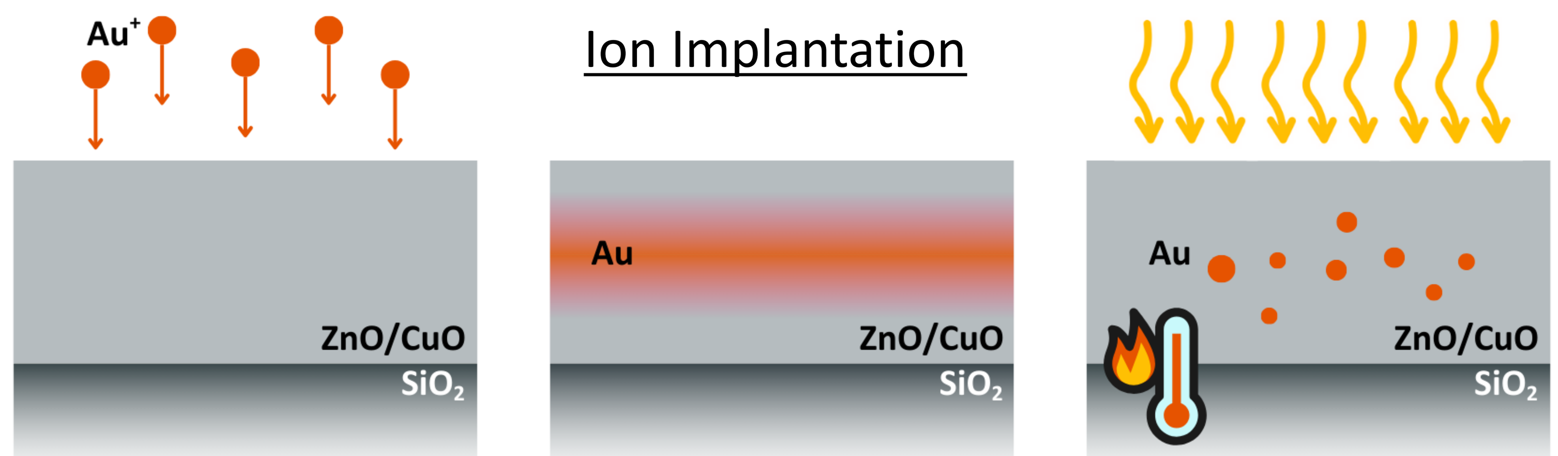
DC sputtering using oxide target + Au pellets

Thermal annealing in air

Temperature: 750 °C for ZnO and 800 °C for CuO

Offers uniform distribution of nanoparticles inside the film

Ion Implantation



DC sputtered oxide thin films are implanted with Au

Energy: 120 keV for ZnO and 150 keV for CuO

Fluence: 1×10^{16} ions/cm^2

Thermal annealing in air

Temperature: 500 °C for ZnO and 700 °C for CuO

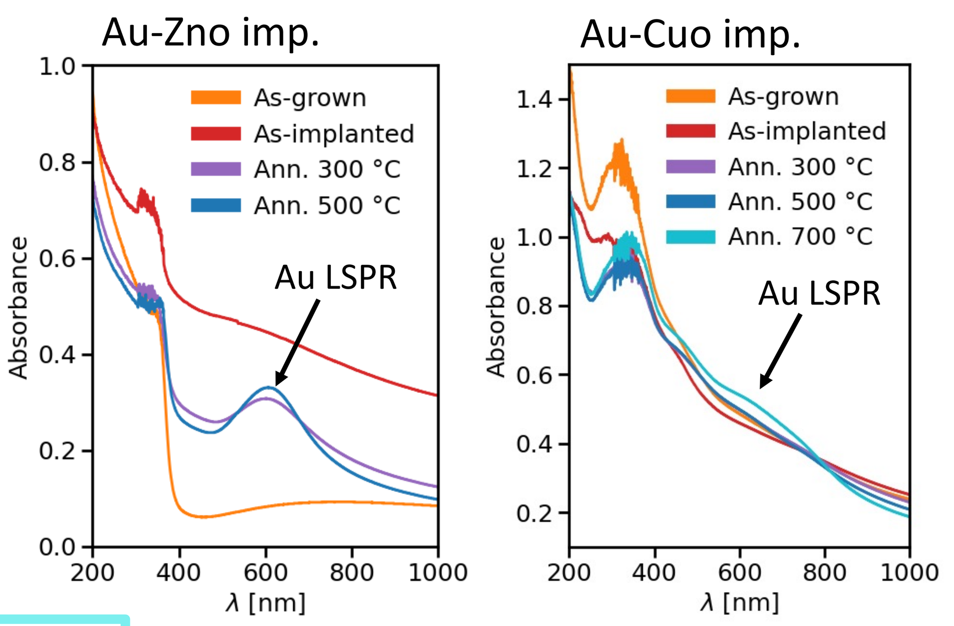
Offers precise control over nanoparticle depth profile

Characterization

Absorbance at RT

What are we looking for?

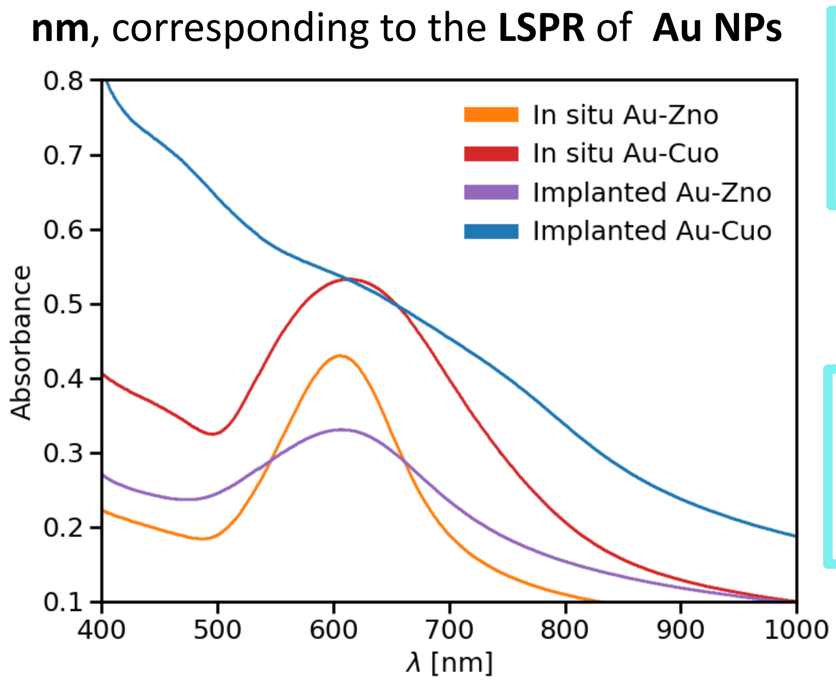
LSPR manifests as an **absorption band** in the spectra



Thermal annealing **promoted the formation of Au NPs**

LSPR absorption band becomes more defined with increasing annealing temperature in implanted samples

The **absorption spectra** of the samples revealed an absorption band at **550–700 nm**, corresponding to the **LSPR** of **Au NPs**



Why is LSPR stronger in *in situ* grown samples?

Higher Au amount
In situ: ~5×10^{16} ions/cm^2
vs
Imp: ~1×10^{16} ions/cm^2

Higher imp. fluences can sputter the thin film

+

Higher annealing T
In situ: 750 / 800 °C
vs
Imp: 500 / 700 °C

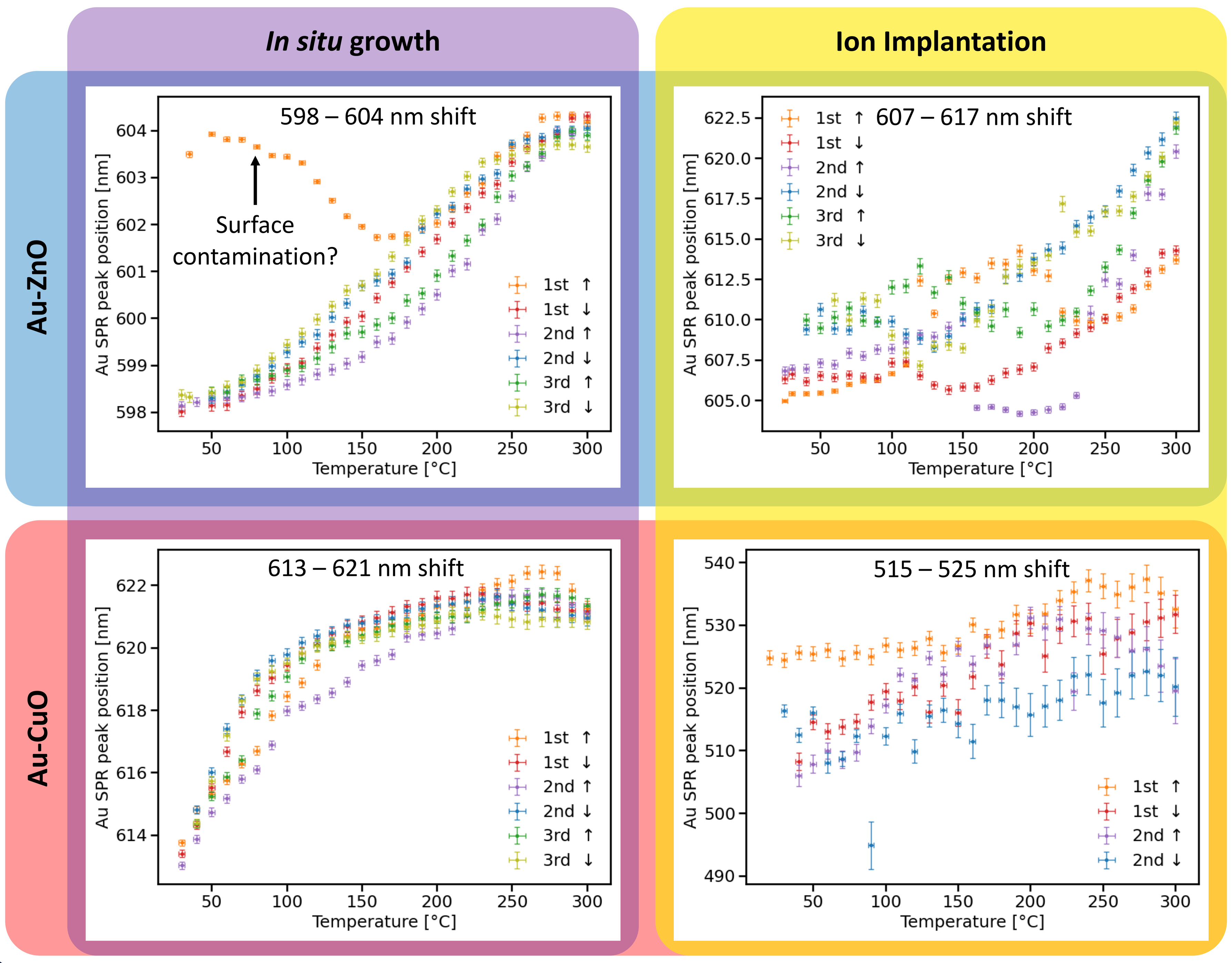
Higher annealing T can cause Au diffusion

Results

Evaluation of Temperature Sensing Potential

How was the study conducted?

1. **Heated the samples** from room temperature up to 300 °C
2. **Measured the optical transmission** while heating up (↑) and cooling down (↓) for multiple cycles
3. **Analyzed the spectra** by fitting gaussian on the absorption band range to obtain the LSPR peak position



Red-shift of the Au LSPR peak with increasing temperature

In agreement with the Drude model and Mie theory predictions

Shift attributed to
electron–phonon scattering
+
thermal expansion of Au NPs
+
changes in the dielectric properties of the matrix

Possible surface contamination on *in situ* grown Au-ZnO deviates LSPR before the evaporation of adsorbed species!

Potential for substance detection

Conclusions

- **Formed Au NPs in ZnO and CuO by ion implantation**, enabling a comparison with the *in situ* growth method;
- **Thermal annealing improved the plasmonic behaviour of the implanted samples**, as the LSPR band became more defined;
- **LSPR was stronger on *in situ* grown samples than on implanted samples**, likely due to differences in Au quantity and thermal treatment;
- **The LSPR absorbance band red-shifted with increasing temperature** for all samples, which is is agreement with theoretical predictions;
- ***In situ* grown Au-ZnO could be a candidate for substance detection**, as possible surface contamination deviated the LSPR peak position.

All studied nanocomposites showed potential for temperature sensing

***In situ* grown Au–ZnO had the most linear LSPR peak shift**

Future work
Experiment with higher implantation fluences and higher annealing temperatures for better comparison of NP formations methods

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