

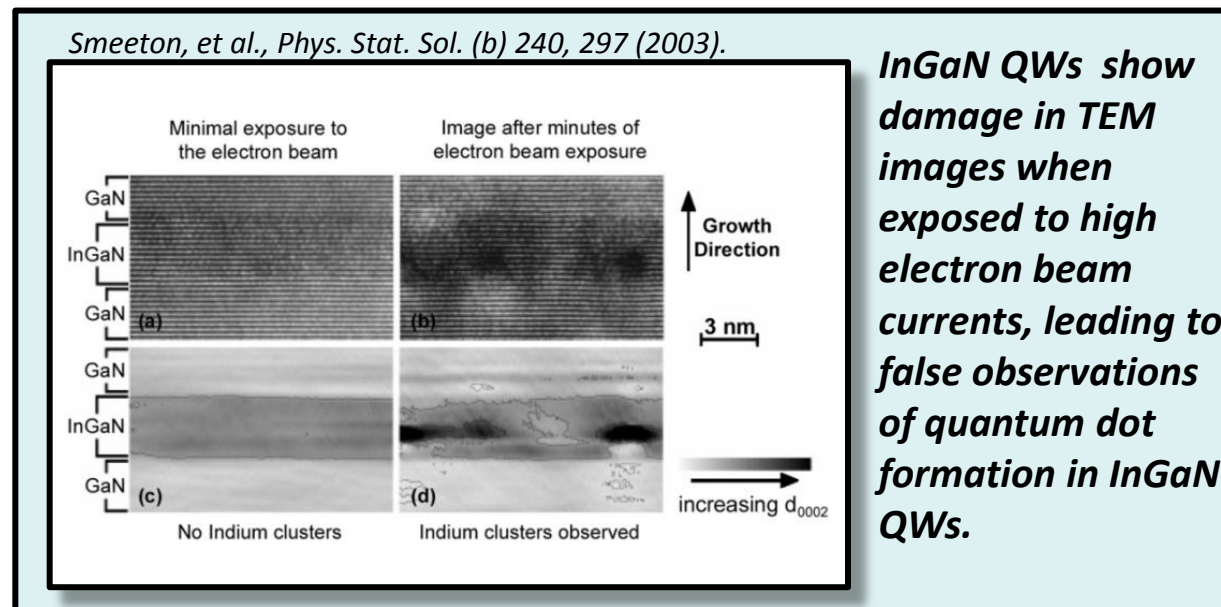
# Thermal Stability of Thin InGaN Films

D. D. Koleske, G. Thaler\*, S. R. Lee, K. H. A. Bogart, and M. H. Crawford

## Motivation and Background for InGaN Decomposition Studies

**Motivation:** Since InGaN quantum wells (QWs) are grown at lower temperatures and the surrounding GaN barrier layers are grown at higher temperatures, there is concern that the InGaN QWs may undergo some degree of decomposition during the growth process.

**Background:** There has been little work on this topic. InGaN decomposition has been studied primarily by TEM and XRD with little optical characterization. InGaN was found to decompose to indium and gallium metal.

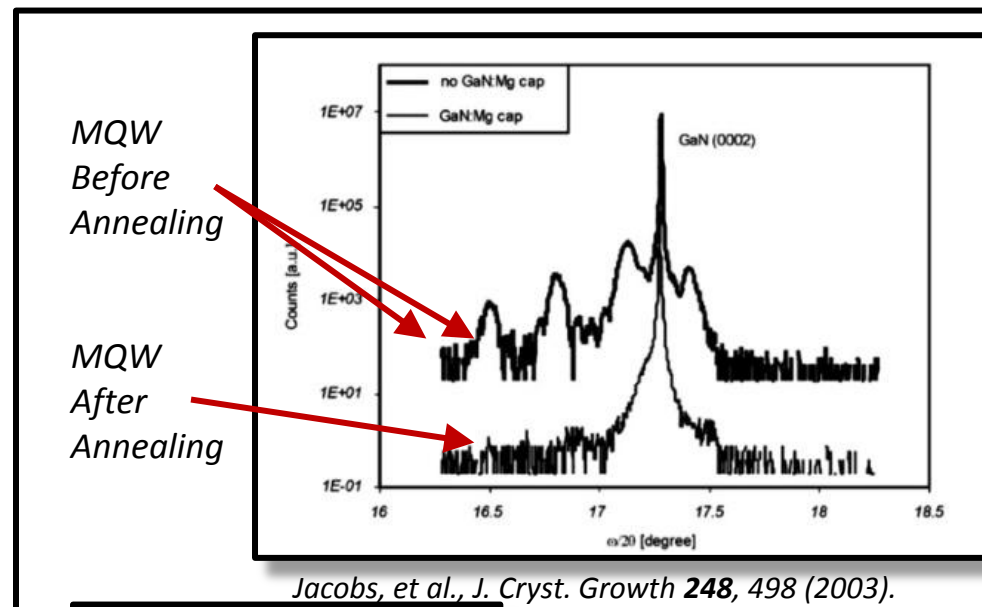
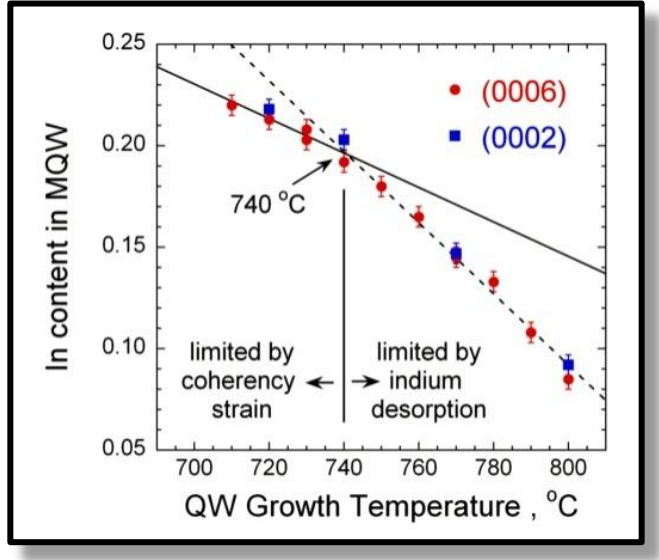


InGaN QWs show damage in TEM images when exposed to high electron beam currents, leading to false observations of quantum dot formation in InGaN QWs.

**Kinetic factors that limit indium incorporation on c-plane GaN are known.**

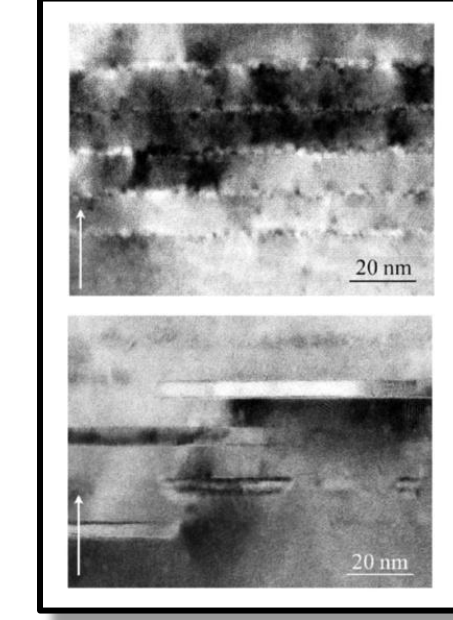
- Limited by:
- 1). Coherency strain
  - 2). Indium desorption
  - 3). Metallic indium

Koleske and Creighton, unpublished.



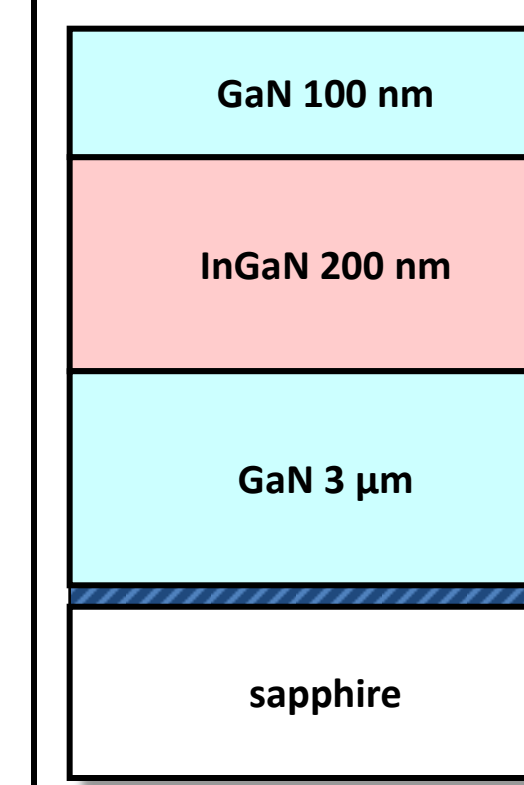
7% indium concentration QWs before annealing. **No damage.**

14% indium concentration QWs after annealing. **InGaN QWs are decomposed**



## Thermal Stability of Thin InGaN films on GaN

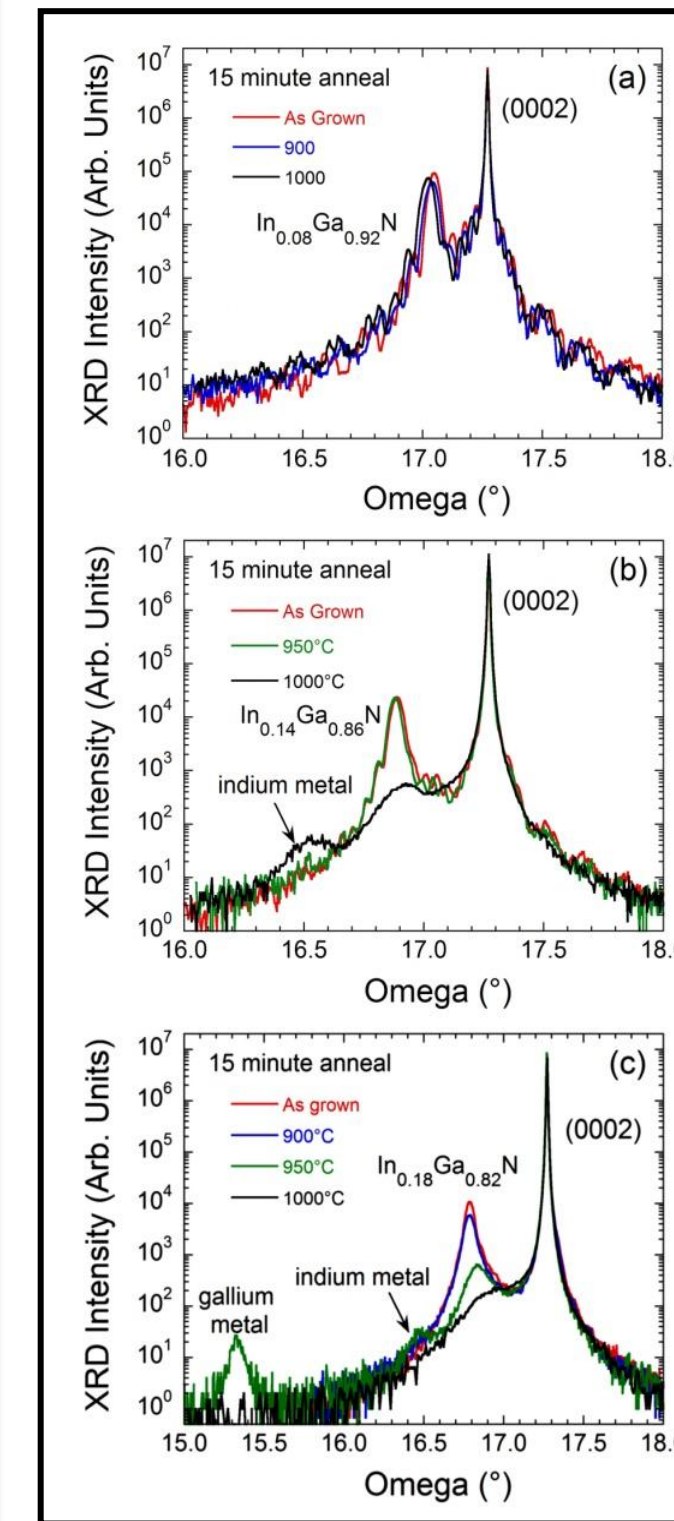
### Sample structure



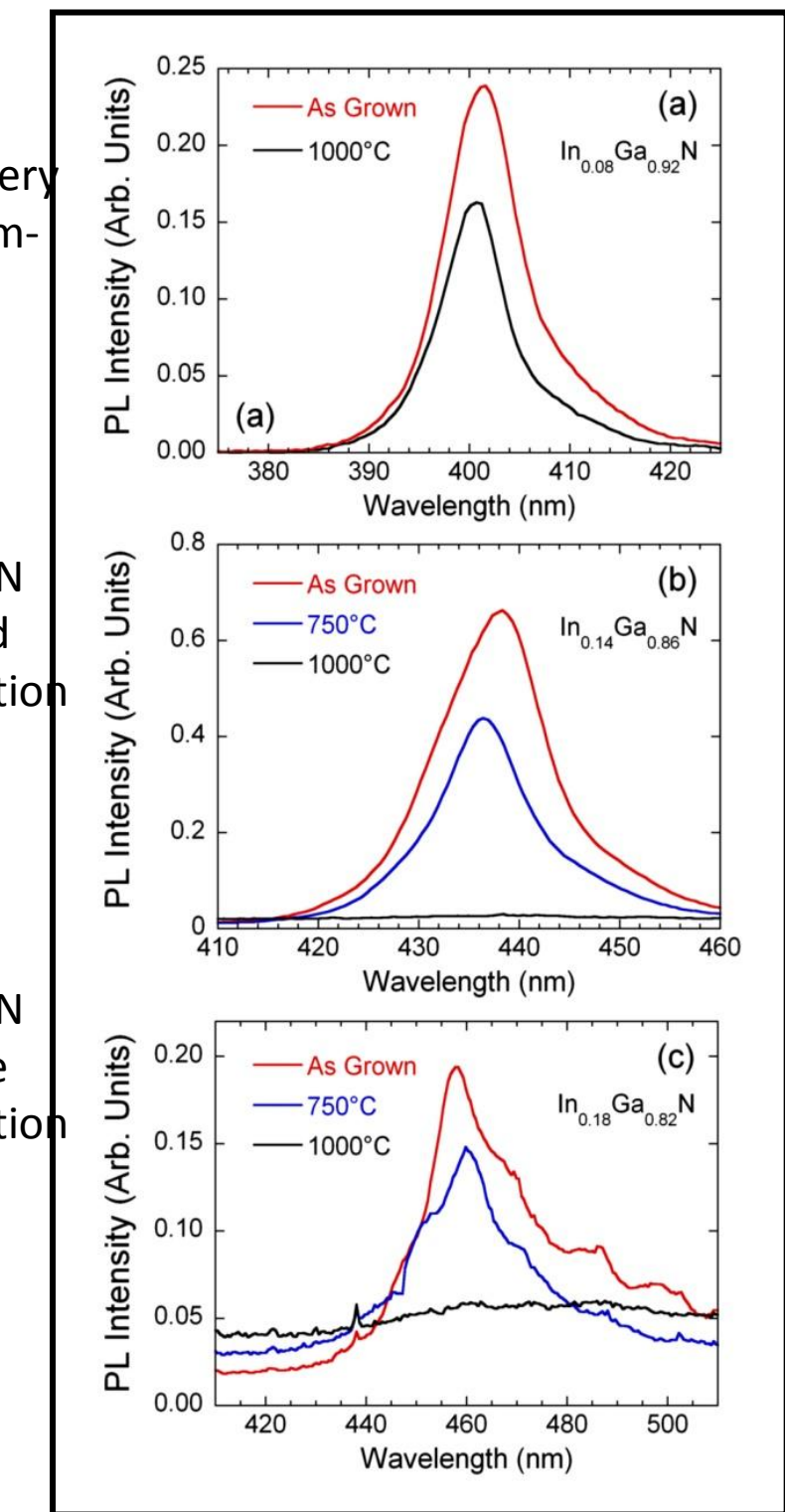
### InGaN annealing conditions

- 1). Use ¼ wafer
- 2). Anneal in N<sub>2</sub>
- 3). Anneal at a single temperature from 600 to 1000 °C
- 4). For times ranging from 15 to 60 min.

**XRD**  $\omega/2\theta$  scans of the (0002) diffraction peak



**PL** intensity measured using a 325 nm HeCd laser



8% InGaN very little decomposition

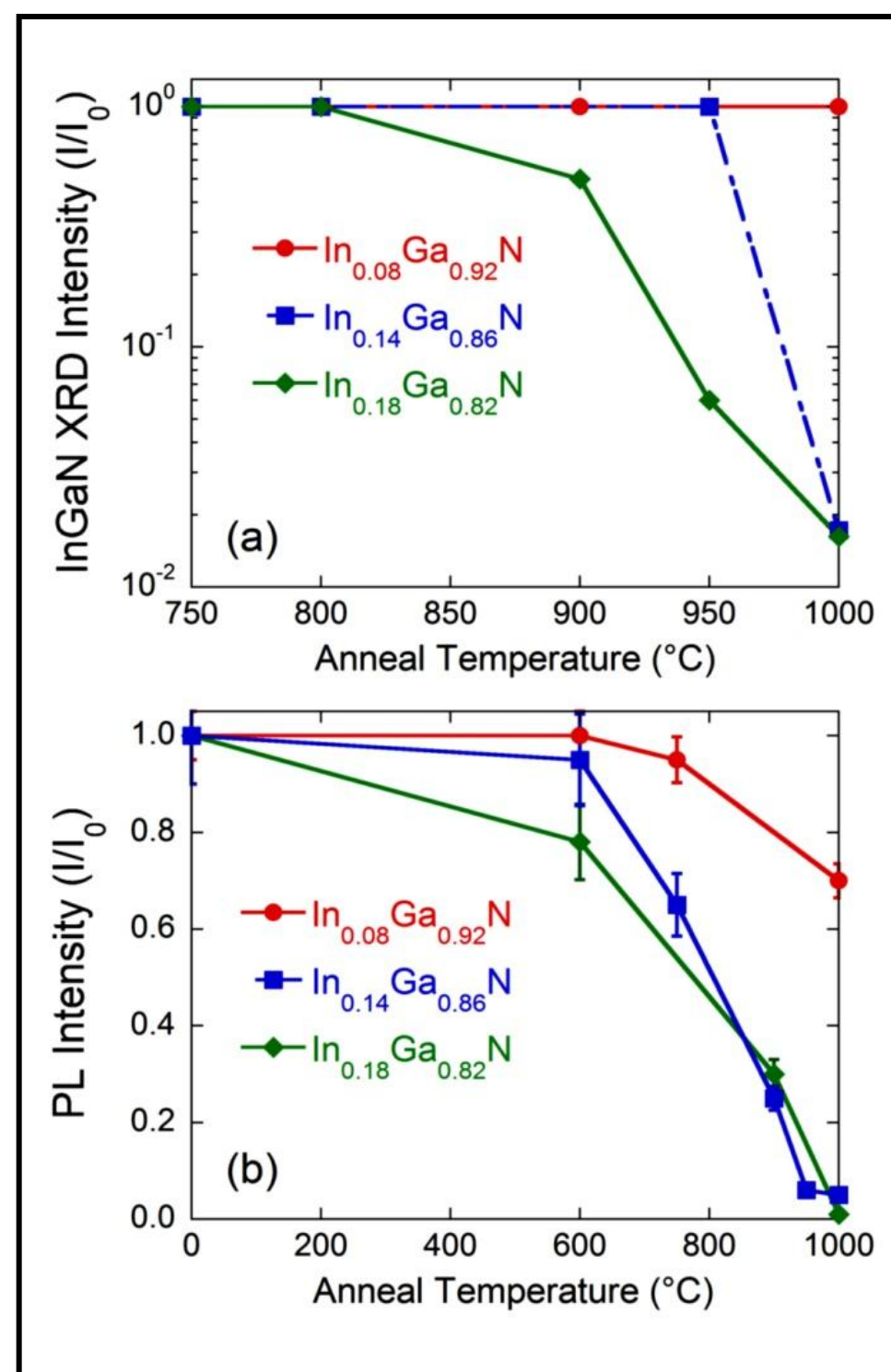
14% InGaN increased decomposition

18% InGaN extensive decomposition

In XRD scans, observe metallic indium and gallium

## Summary of measured XRD and PL intensities for annealing studies

Isochronal anneals at 15 min.



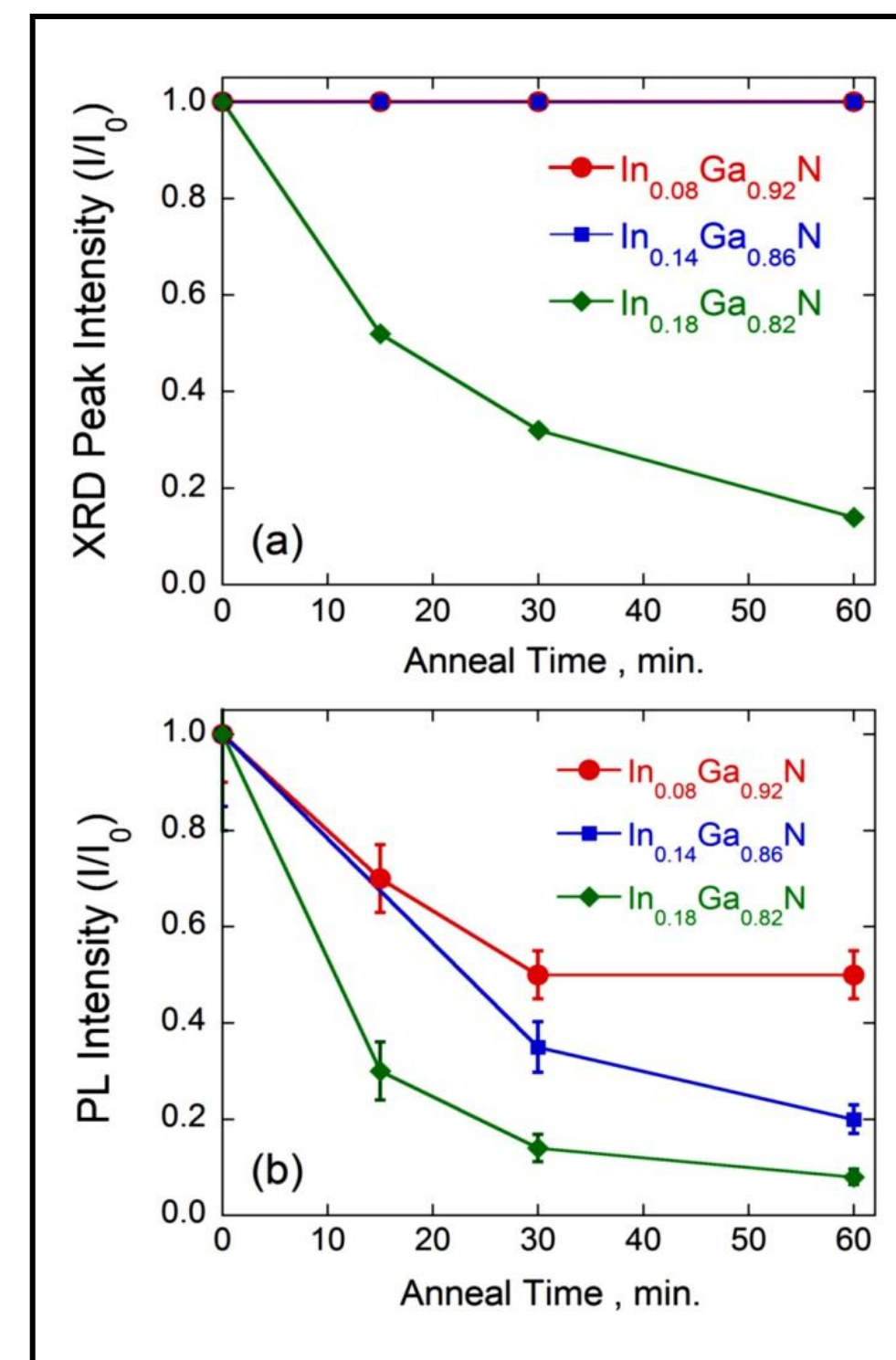
← Onset of InGaN decomposition observed with XRD at 900 °C.

As indium concentration increases the degree of decomposition increases.

← Onset of InGaN decomposition observed with PL at 600 °C.

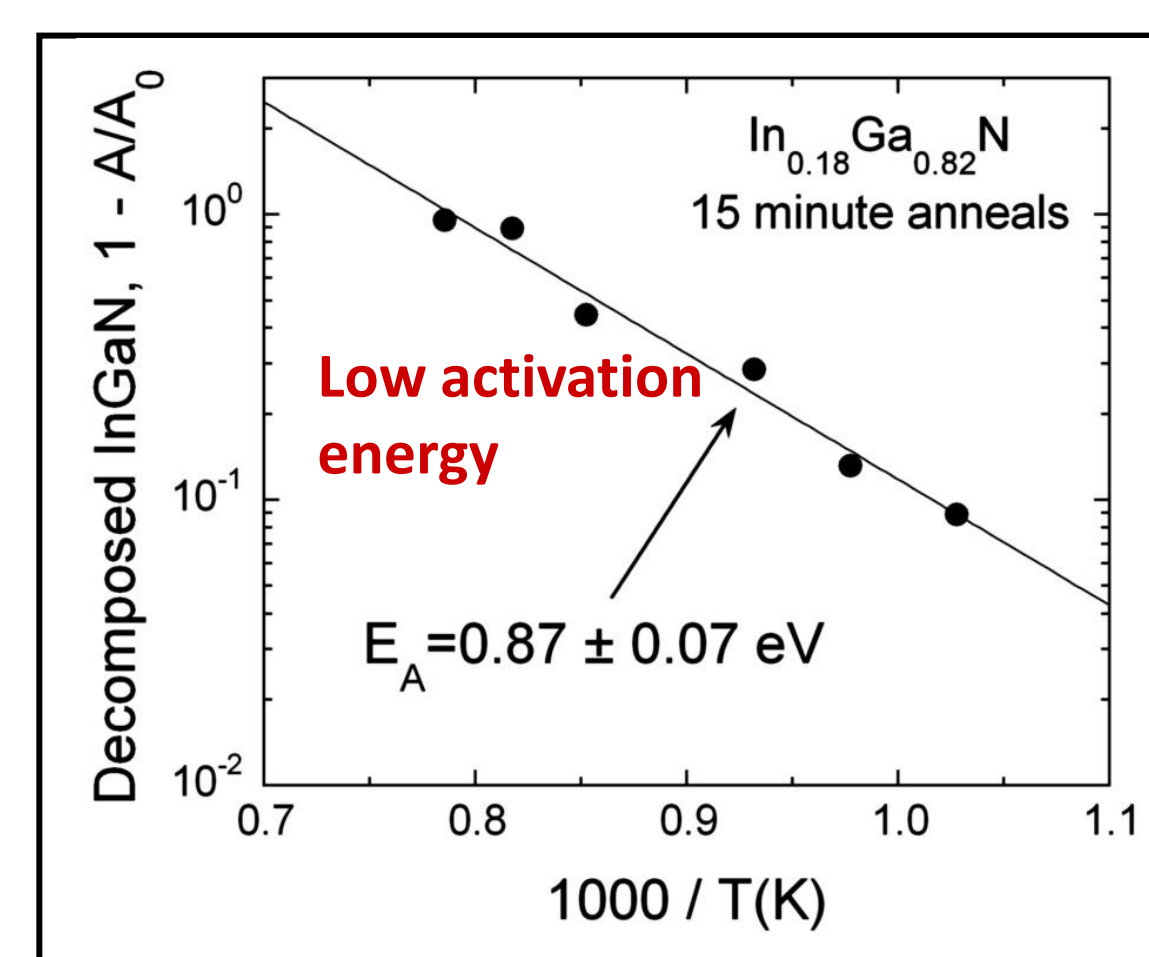
Onset of InGaN decomposition first observed by PL followed by XRD

Isothermal anneals at 900 °C



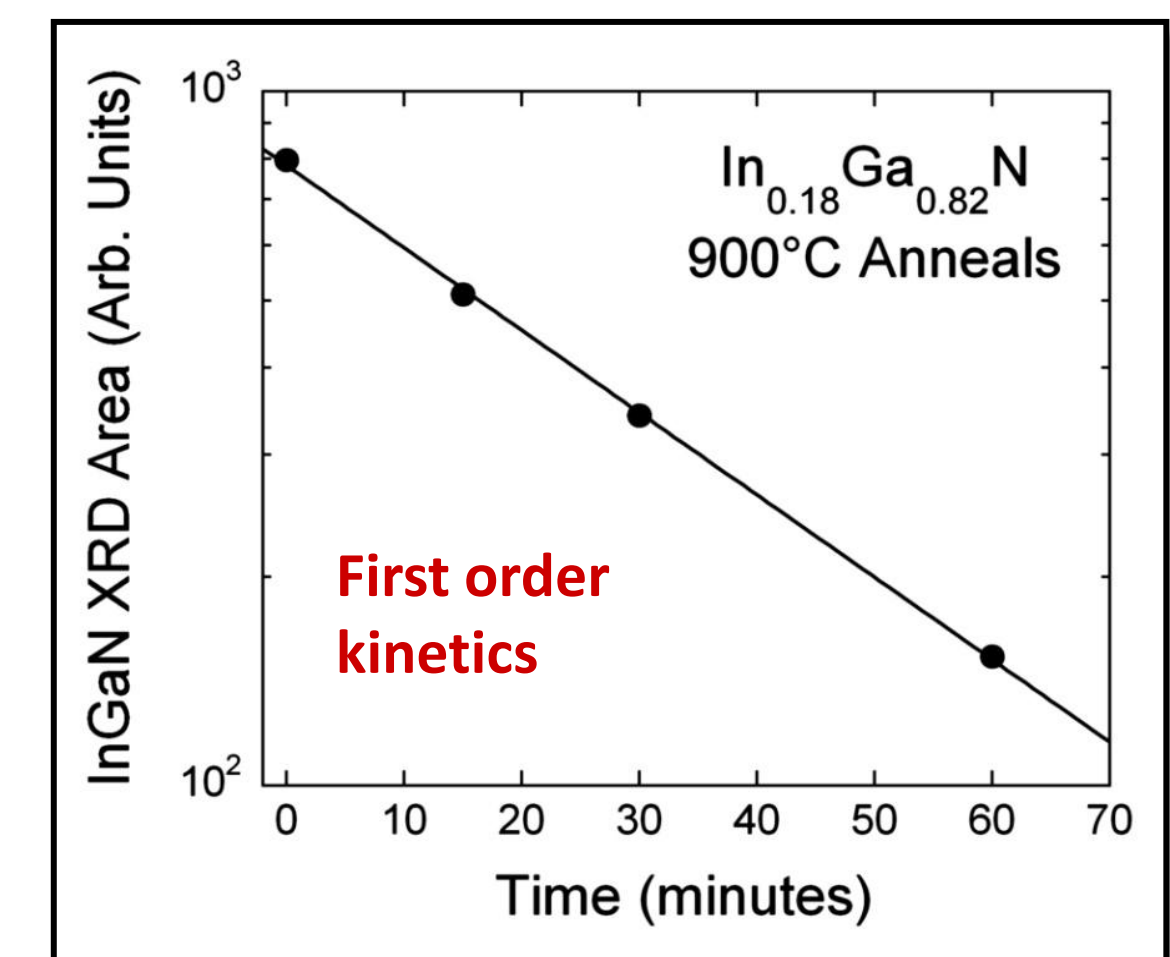
## InGaN Decomposition Kinetics and Summary

Arrhenius plot of InGaN Decomposition



Low activation energy suggests simple In-N bond cleavage as the rate limiting step.

Time dependence of InGaN Decomposition



Pseudo-first order kinetics also suggests a simple In-N bond cleavage.

### Summary:

- 1). Higher indium concentration InGaN decomposes at lower temperatures than previously thought.
- 2). PL intensity decreases first observed at 600 °C, possible increase in non-radiative defects.
- 3). Later stages of InGaN decomposition observed in XRD.  $2\text{InGaN} \rightarrow 2\text{In(m)} + 2\text{Ga(m)} + \text{N}_2$

\*G. Thaler was a Sandia Postdoc from Sept. 2006 to Oct. 2008. He is currently at Lasertel in Tucson, AZ 85743

Sandia National Laboratories is a multi-program laboratory operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin company, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

