Physical properties of Sn and Cr doped β-Ga_2O_3 nanostructures

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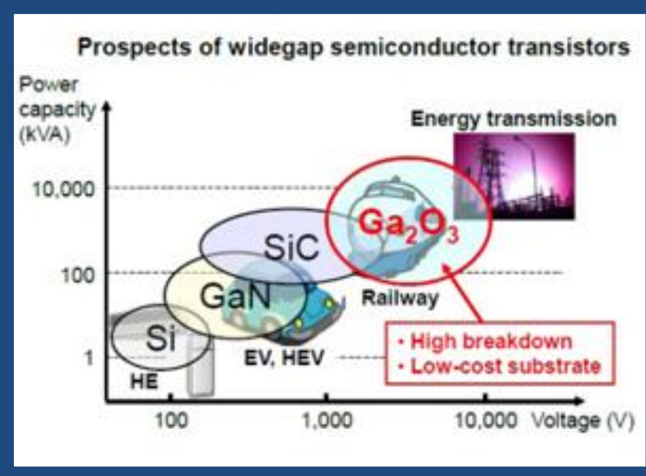
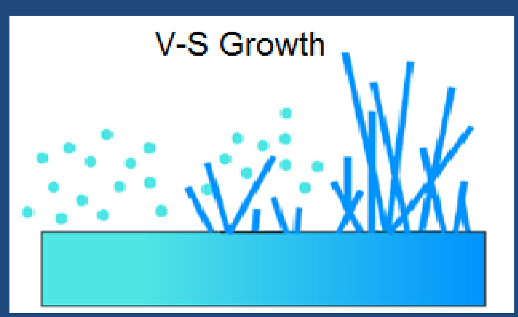
Motivation

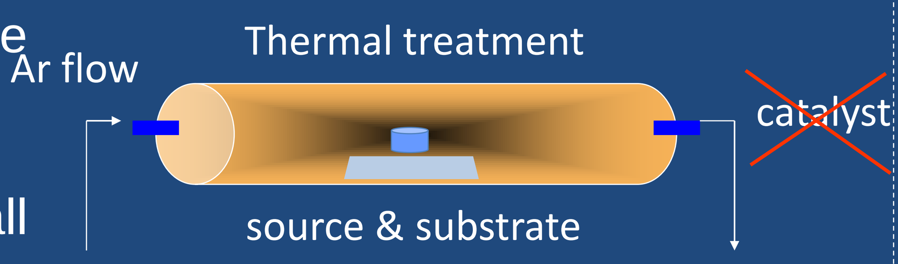
- β-Ga_2O_3 is a wide band-gap (4.9 eV) transparent conductive oxide which has attracted much attention due to its optoelectronic properties. Its current applications in the nanoscale range from deep-UV photodetectors to NW-based FETs [1].
- Suitable doping of Ga_2O_3 nanostructures affects both their morphology and their electronic and optical properties, hence widening their potential applications.
- In this work, Sn and Cr doped β-Ga_2O_3 micro- and nanostructures are obtained and their physical properties are studied. The incorporation of these impurities does not only produce doped nanostructures with enhanced optical and electronic properties, but also mixed SnO_2/Ga_2O_3 heterojunctions.



Synthesis method

- Catalyst-free physical (Vapor-Solid) growth process under Ar flow.
- Ga_2O_3 pellet → source and substrate. Metallic gallium is placed on top of the pellet.
- Sn and/or Cr powder is added and all is placed on an oven.
- After several hours at 1100-1500ºC → Thousands of nanostructures are formed.





Undoped β-Ga_2O_3

	Si	β-Ga_2O_3
E_g (eV)	1.1	**4.8 – 4.9**
μ (cm^2/Vs)	1400	300
E_b (MV/cm)	0.3	**8**
Baliga's FOM	1	**3400**

- Its transparency on the VIS-NUV range and extremely high breakdown field makes Ga_2O_3 attractive in optics and high power electronics.
- Undoped Ga_2O_3 luminescence (blue-UV range) is due to radiative recombinations from energy levels originated in oxygen vacancies and Si impurities [1]. *Figure 1* shows a CL spectra acquired at a Ga_2O_3 nanostructure.

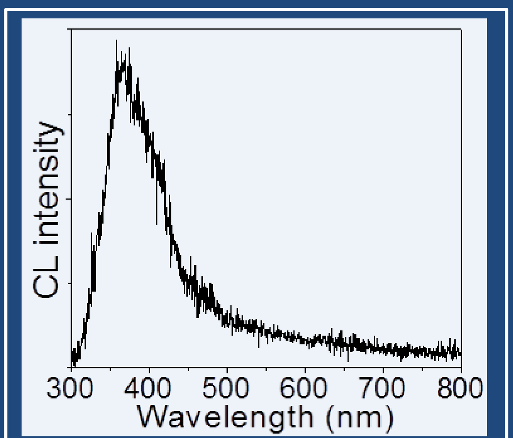


Figure 1

Sn doped β-Ga_2O_3 – reshape and decoration

Sn doping → branched Ga_2O_3 nanowires. (*Fig.2a*). SnO_2 also decorates some of the nanostructures (*Figs. 2b* and *2d*) [2]. *Figures 2c* and *2e* show their EDX spectra. Gallium X-Ray photons are shown in red, tin in green.

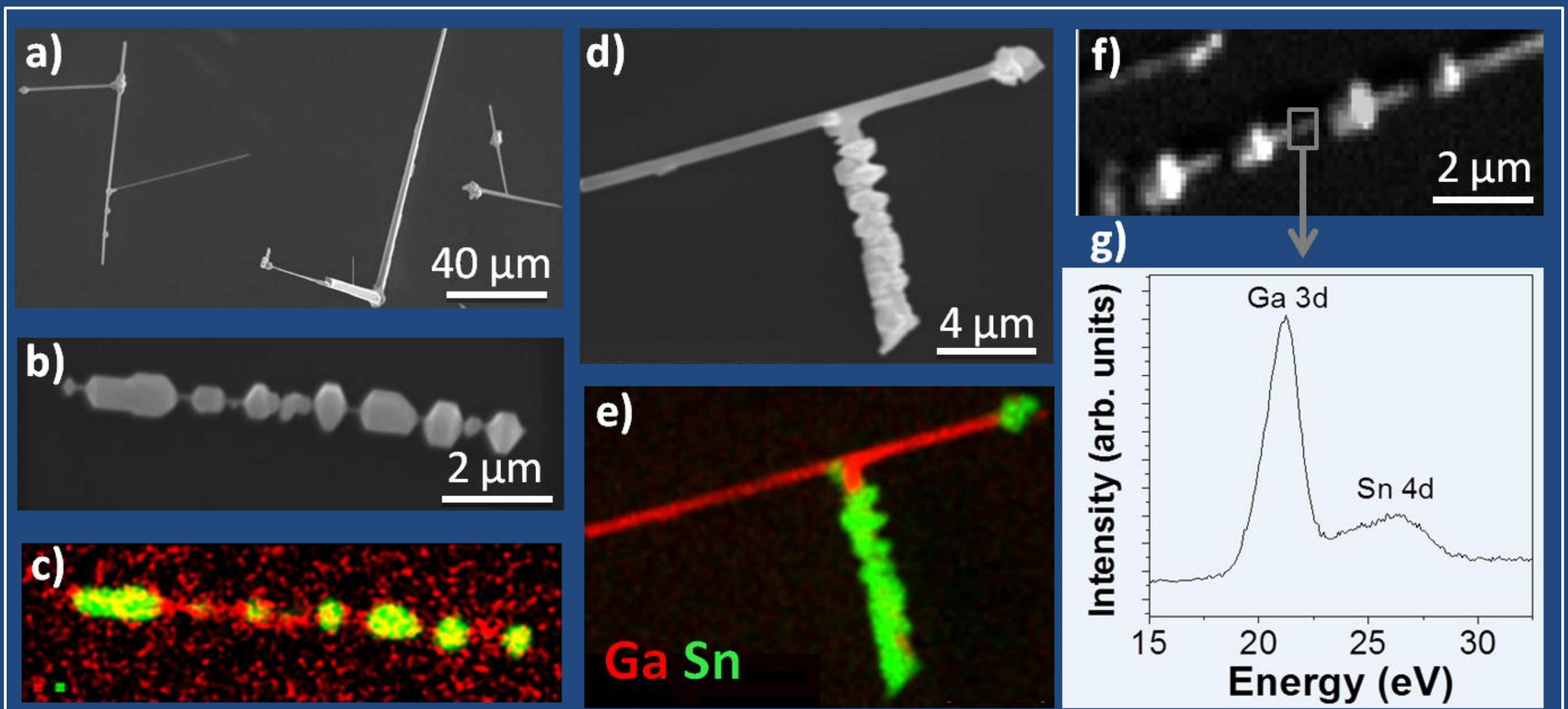
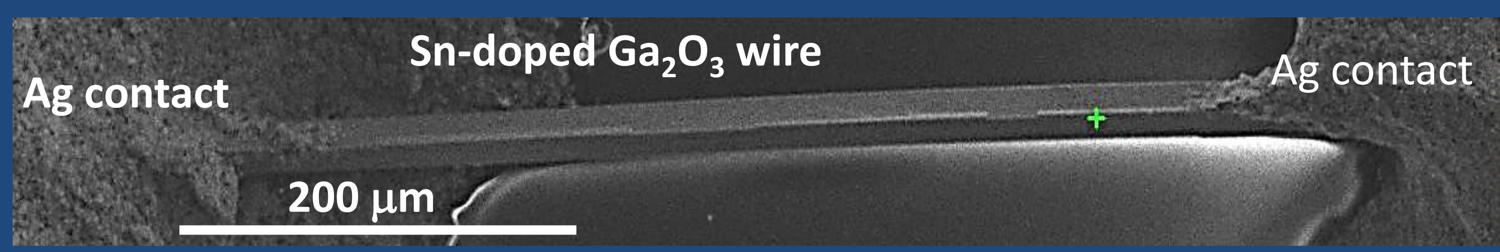


Figure 2

•*Figure 2f* → X-Ray Photoelectron Spectroscopy (XPS) map from a skewer-like structure, similar to the one shown in *Figs. 2b-2c.*

•Area inside grey square → Local XPS spectrum (*Fig.* 2g). Sn 4d line → surface of the Ga_2O_3 nanowire is Sn-rich [3].

Sn doped β-Ga_2O_3 – increased conductivity



•As shown above, individual Sn doped Ga_2O_3 microwires have been contacted

•Figure 3 → I-V curve for one of these structures (Schottky type).

•Ohmic range →ρ is obtained.

•By further analysis → Sn concentration, mobility… can be estimated.

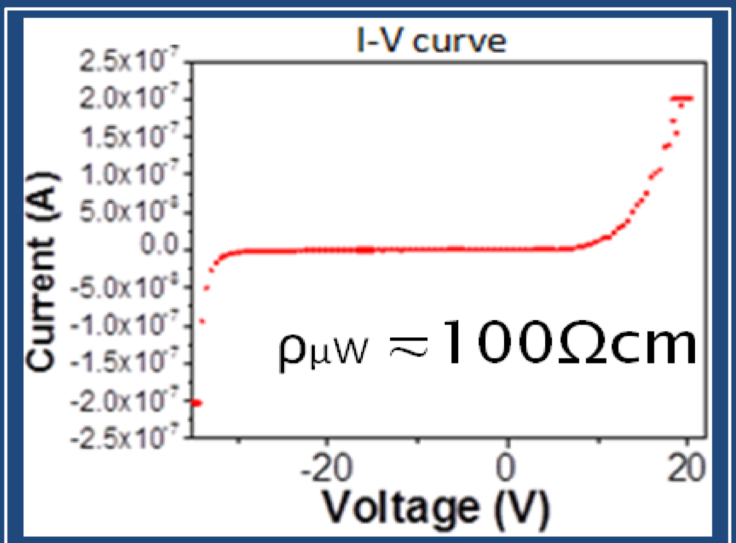


Figure 3

Sn and Cr doped β-Ga_2O_3 – heterojunctions

Sn and Cr co-doping generates crossed–wire heterojunctions, as shown in *Fig. 4* [3]. *Figures 4c-4d* show monochromatic CL maps: Ga_2O_3 axis = blue-UV luminescence + SnO_2 crossed-wires = orange luminescence.

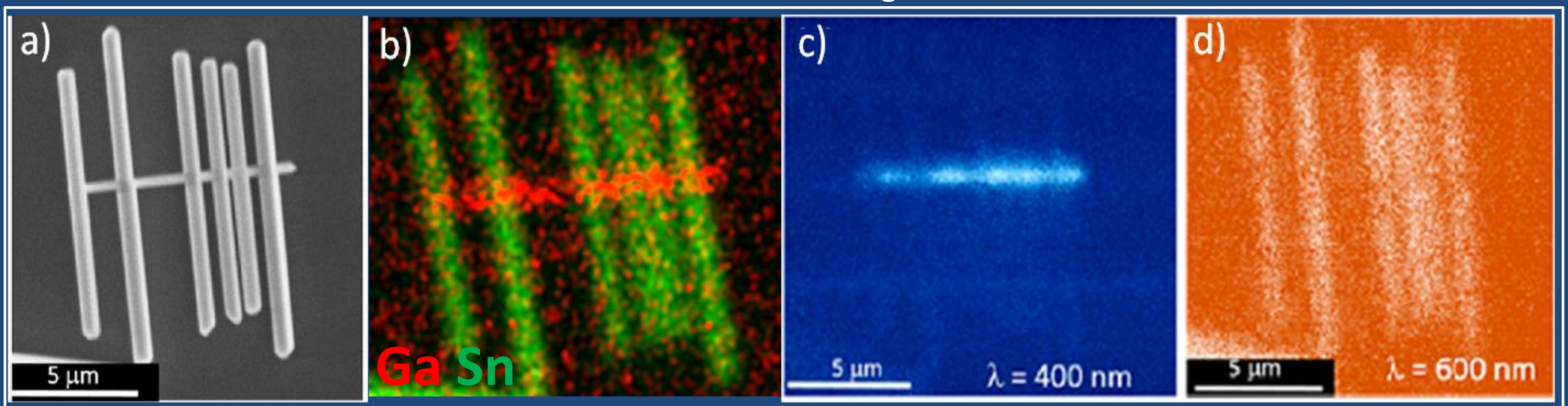


Figure 4

Cr doped β-Ga_2O_3 – red luminescence + resonances

•*Figure 5a* → Cr doped Ga_2O_3 microwire. Cr doping induces intense red-IR luminescence, which is guided through the microwire to the other end.

•*Figure 5b* → Photoluminescence spectrum of the microwire, showing optical resonances. Several micro- and nanowires have been analyzed; all contain Fabry-Pérot resonances (*Fig. 5c*) [4].

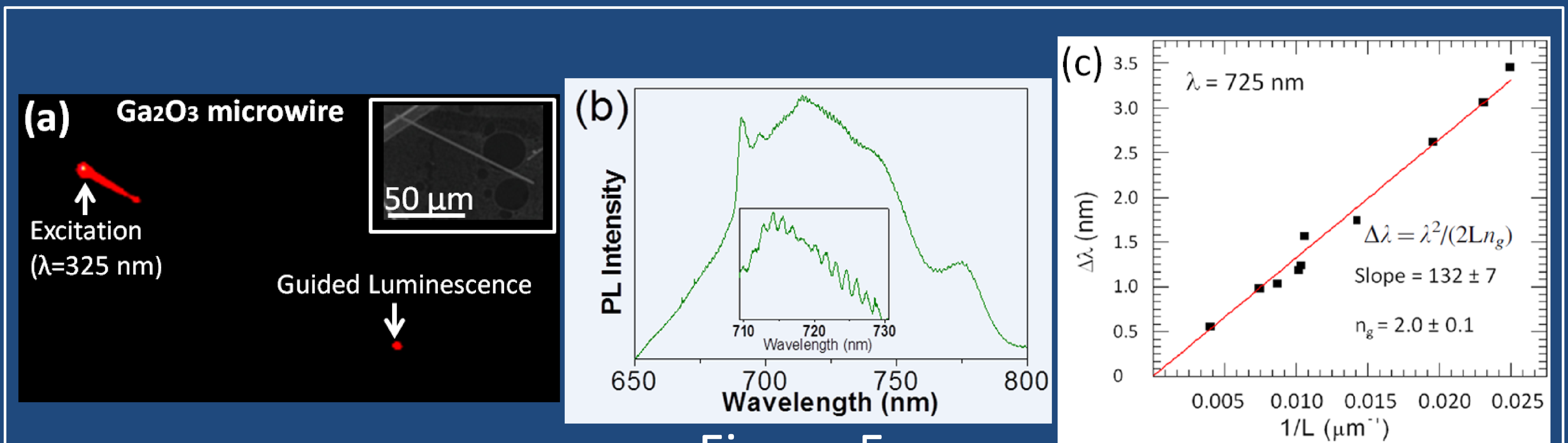


Figure 5

References

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[3] Alonso-Orts, M., Sánchez, A. M., Hindmarsh, S. A., López, I., Nogales, E., Piqueras, J., & Méndez, B. (2016). Nano letters, 17(1), 515-522.
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