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Towards realization of bipolar devices based on In_2O_3: Epitaxy of Be doped InAs on In_2O_3

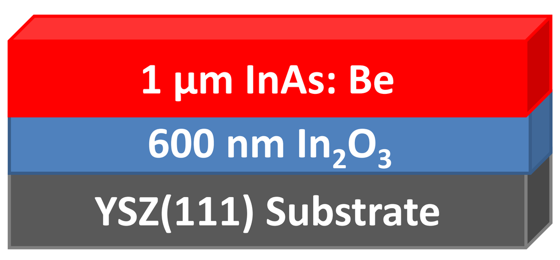
Fariba Hatami and W. Ted Masselink
Inst. für Physik, Humboldt-Universität zu Berlin, Newtonstrasse 15, 12489 Berlin, Germany
Martin Schmidbauer
Leibniz-Institut für Kristallzüchtung, Berlin, Germany
Patrick Vogt and Oliver Bierwagen
Paul-Drude-Inst. für Festkörperelektronik, Berlin, Germany

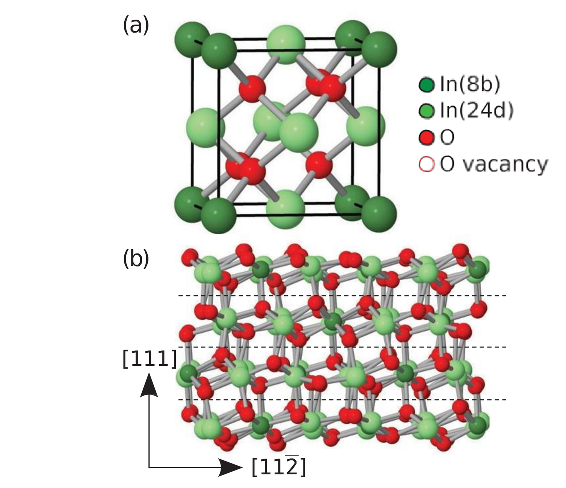
In_2O_3 is an important transparent semiconducting oxide and has a great potential for applications in transparent microelectronics, optoelectronics, and short wavelength photonics. In_2O_3 exists only as n-type material. Even nominally undoped In_2O_3 is n type. This characteristic limits applications based on In_2O_3 to unipolar devices. A hybrid structure based on p-doped III-V semiconductors and In_2O_3 opens the possibility of bipolar devices. We describe the growth of Be doped InAs on YSZ(111) and on In_2O_3(111) using gas-source molecular-beam epitaxy. The films were grown at different growth conditions and temperatures. According to the x-ray analysis, all samples have the zinc-blend crystal structure; with increasing growth temperature, the InAs films tend to grow monocrystalline.

Materials and Growth

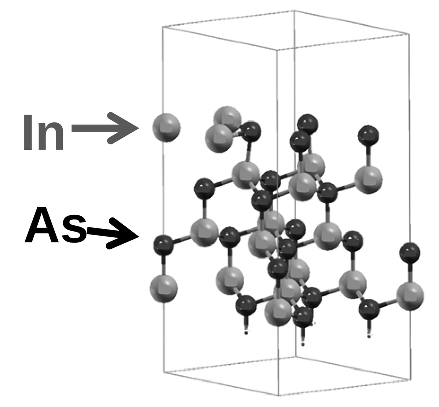
Structures were grown using gas-source MBE (AsH_3, solid In, Be, and thermally cracked Sb) on either (111)-oriented Y-stabilized ZrO_2 (YSZ) wafers, or epitaxial In_2O_3 film grown on YSZ(111). The effect of the background hydrogen atmosphere on the layer quality was investigated by comparing of three groups of structures. (a) InAs:Be on In_2O_3/YSZ, (b) InAs:Be on YSZ, (c) InSb on YSZ and InSb on In_2O_3.

<u>Lattice parameters</u>
YSZ: cubic fcc Fluorite, $2a_{YSZ}$=10.250 Å (Zr:Y=91:9)
In_2O_3: cubic bcc, $2a_{In2O3}$=10.117 Å
InAs: zinc blend, a_{InAs}= 6.058 Å
InSb: zinc blend, a_{InSb}= 6.479 Å





bcc-In_2O_3 bixbyite structure: (a) Ideal undistorted parent crystal structure; (b) side view of the (111) surface (Sadefev et al. APL 101,17102).



Side view of the reconstructed InAs (111)A—(2 × 2) surface (Eremeev et al. Semic. 46, 49).

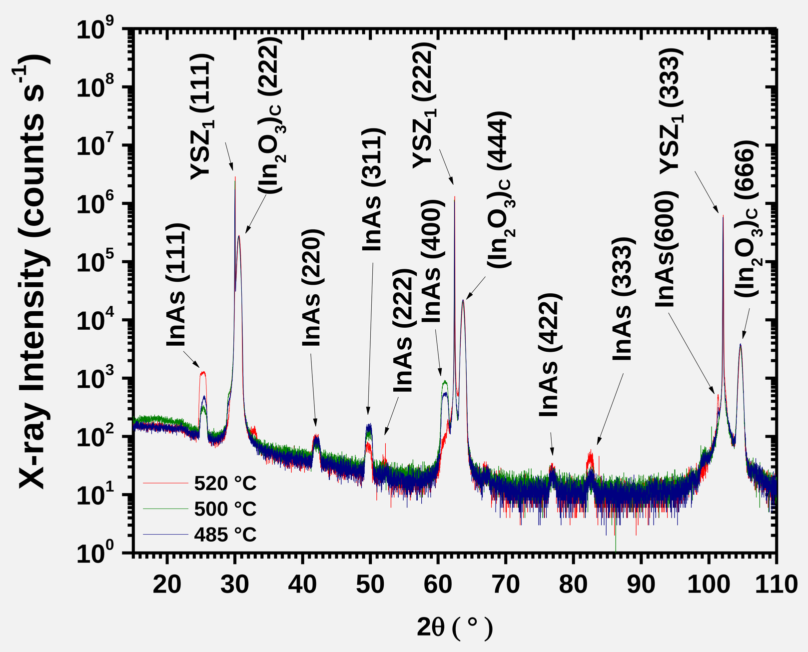
Overview of samples

InAs:Be on In_2O_3/YSZ (111)
T_{growth}
300 °C
450 °C
485 °C
500 °C
520 °C

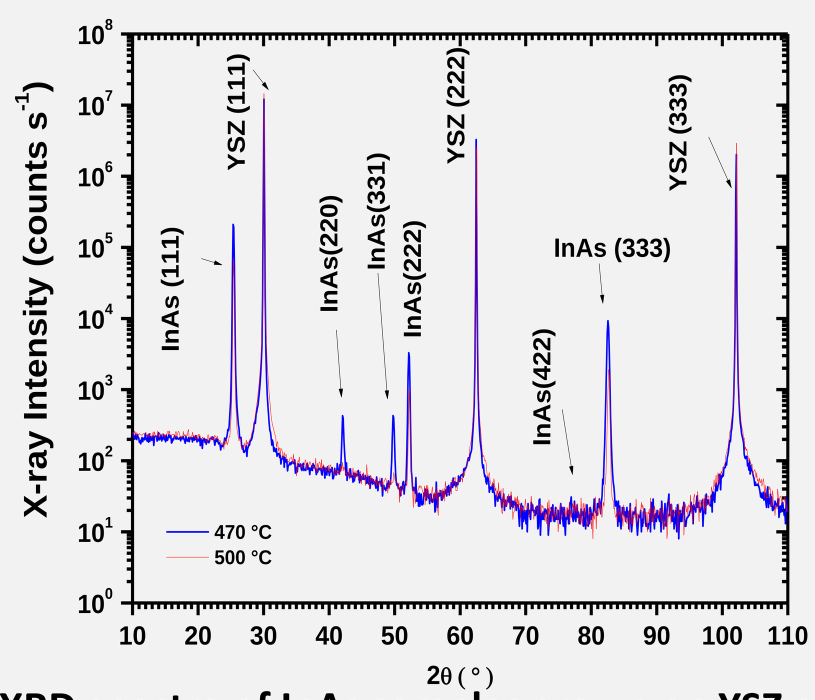
InAs:Be on YSZ (111)
T_{growth}
400 °C
450 °C
485 °C

InSb , T_{growth}=400 °C
Substrate
YSZ (111)
In2O3/YSZ (111)

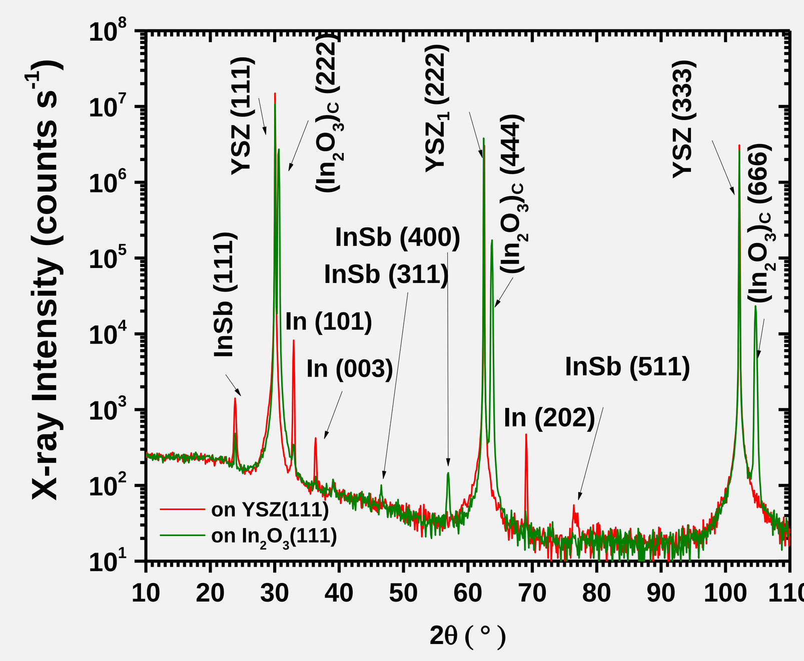
Structural Properties



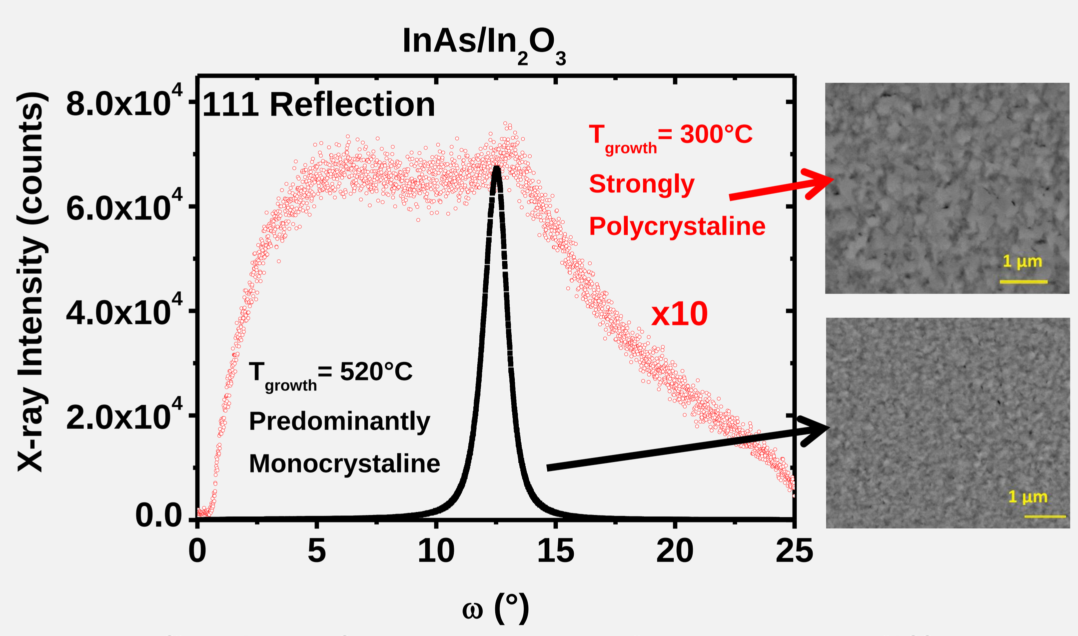
XRD spectra of InAs/In_2O_3/YSZ samples grown at 485, 500, and 520 °C.



XRD spectra of InAs samples grown on YSZ at 470°C and 500°C.



XRD spectra of InSb/In_2O_3/YSZ and InSb/YSZ grown at 400 °C.



111 reflection of two InAs samples grown at different temperatures together with their plan-view SEM images.

References

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- Walsh et al. Phys. Rev. B 83, 161202(R) (2011)
- Kajikawa et al. Thin Solid Films 519, 136 (2010)
- Sadefev et al. APL 101,17102 (2012)
- Eremeev et al. Semic. 46, 49 (2011)

Contact: hatami@physik.hu-berlin.de

Conclusion

- ✓ For samples grown between 300 and 520 °C, the InAs(111) quality improves with increasing growth temperature.
- ✓ InAs films grown on In_2O_3/YSZ at 300 °C are highly polycrystalline, whereas the layer grown at 520 °C is predominantly monocrystalline.
- ✓ InAs films grown directly on YSZ show better crystal quality than do InAs/In_2O_3. At T_{growth}=500 °C, InAs grows monocrystalline on YSZ.
- ✓ Epitaxy of the InSb layers grown with thermally cracked Sb are similar to the InAs layers grown using AsH_3 source.
- ✓ The free carrier type for samples grown using similar Be incorporation changes with increasing temperature, from n type (T_{growth}= 300 °C) to p type (T_{growth}= 500 °C). This difference is most likely due to improvement of the crystal quality, similar to homoepitaxial InAs.