EAG Laboratories

Assessing Local Polarity in III-Nitrides Using AC-STEM

Different signals obtained through AC-STEM can provide direct observation of local polarity switching.

Introduction

Crystal polarity plays a significant role in materials properties. Controlling polarity in III-nitride semiconductors provides access to tailoring electronic or optoelectronic behavior. In many situations, it is important to monitor and control polarity locally to achieve intended electrical behavior; for example, devices that utilize lateral polar junctions. However, assessing local polarity requires extremely high spatial resolution and can be challenging from conventional imaging approaches. In this application note, we show how different signals obtained through aberration-corrected scanning transmission electron microscopy (AC-STEM) can provide direct observation of local polarity switching.

Discussion

Figure 1 shows an example of an Al-polar AlN film grown on a sapphire substrate with an N-polar AlN buffer layer. The intensity in this high-angle annular dark-field (HAADF) scales roughly with atomic number where the larger bright spots correspond to Al atom columns (red in the model) and the smaller dimmer spots correspond to N atom columns (purple in the model). You can clearly see the bottom of the image is N-polar (N is above the Al) while the top is Al-polar (Al is above the N). However, for materials with a larger difference in atomic number between the metal and N species, it becomes very difficult to simply use HAADF images to assess polarity.

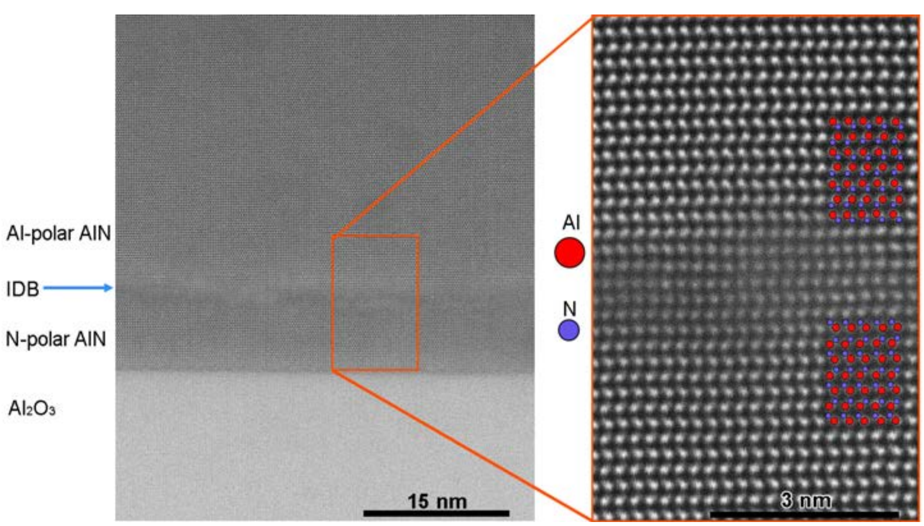

Figure 1: Al-polar AlN film grown on a sapphire substrate using a N-polar AlN buffer layer. The left image shows the overview of the structure with the inversion boundary noted by the 'IDB' text and blue line. The right shows the atomic resolution HAADF image with atom column schematic overlaid on the image.

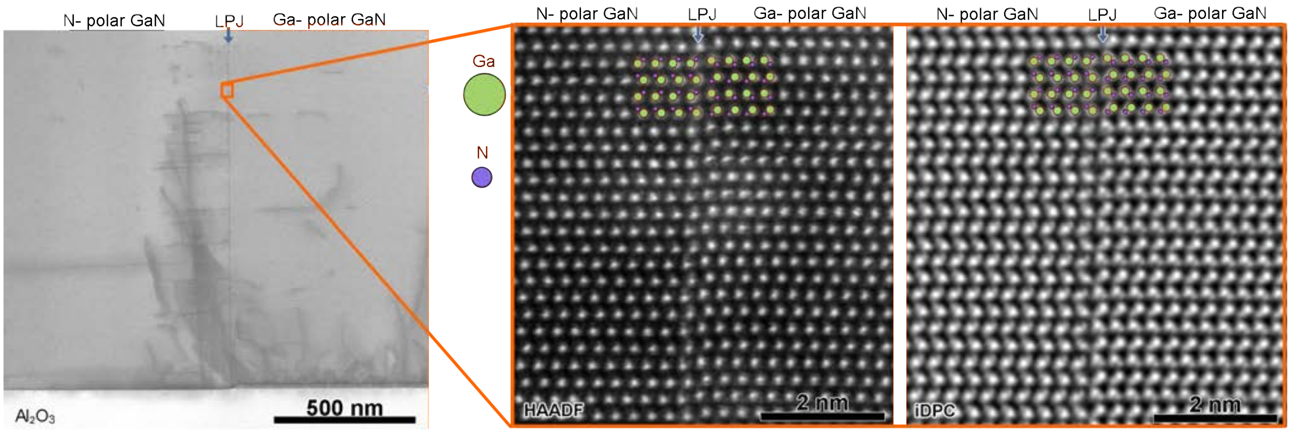

Figure 2: A LPJ GaN sample with the overview shown on the left side. The IDB is indicated by the blue arrow. The two images on the right outlined in orange show the high magnification atomic resolution image from the LPJ.

Figure 2 shows a lateral polar junction (LPJ) in GaN. For this sample, there is boundary that runs vertically in the sample, indicated by the blue arrow, where the sample switches between Ga-polar and N-polar. In the HAADF image, only the Ga columns are observable, making polarity assessment ambiguous. However, by employing integrated differential phase contrast (iDPC) imaging, both heavy (Ga) and light (N) atom columns appear very clearly and the complete structure at the LPJ is clearly observable.

Conclusion

Through the combination of HAADF and iDPC imaging techniques, it is possible to assess the local polarity throughout different locations in a large variety of III-nitrides. For situations where there is a large difference in atomic number between the elements present and HAADF falls short, iDPC imaging provides an excellent alternative approach. Although the image quality can look exceptional for iDPC, the microscope experimental set up is much more demanding, time consuming, and prone to artifacts. Further, the sample should be as thin as possible – ideally under 20 nm for the best results. Alternatively, ADF, ABF, or STEM-BF are much less demanding and could provide local polarity information though the contrast is not as good as iDPC. Through selecting the appropriate technique, we can help identify local polarity for a broad range of sample types. Contact us today to learn more about this application.