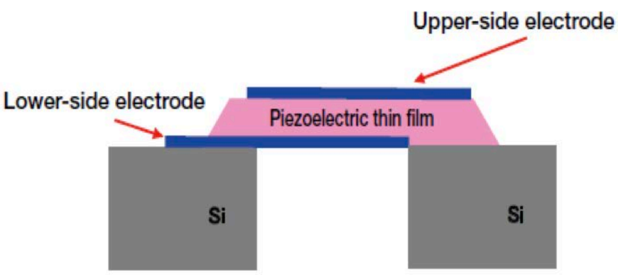
STRESS IMPROVEMENT FOR FBAR ELECTRODES ON CLUSTERLINE® 200 II

Evatec Scientist, **Dr. Andrea Mazzalai**, explains how know how in deposition of Molybdenum and Ruthenium electrodes with controlled stress now compliments processes for AlScN deposition to bring solutions for full thin film stack production for high performance FBARS on CLUSTERLINE® 200 II.

Within the the development of 5th generation wireless systems (5G) the quest for high performance duplexers is driving the development of the latest FBAR devices with resonant frequencies of several GHz. At this range, relatively small in-wafer deviations of the membrane bow can lead to substantial frequency shifts as well as significant variations of the coupling coefficient. For this reason, the strict requirements in terms of stress uniformity are no longer confined to the piezoelectric layer, but are becoming more and more important also for the electrodes.



The FBAR electrode material has to show a good balance between low specific resistivity and high acoustic impedance in order to minimise the resistive losses and to maximise the fraction of mechanical energy confined in the piezoelectric layer. The large majority of designs therefore employ Molybdenum (Mo); but recently Ruthenium (Ru) is also gaining more and more popularity.

We have therefore concentrated our efforts on bringing our Mo and Ru process solutions towards the same outstanding stress control and uniformity levels as we achieve for $Al_{1-x}Sc_xN$.

Our accumulated know-how and experience from developing the piezo-layers themselves represented a valuable base on which we could further design specific process kits for the deposition of Mo and Ru with enhanced stress uniformities on our CLUSTERLINE® 200 II.

Figures 1 and 2 illustrate the significant improvements achieved especially towards the edge of the wafers. With the our latest technology we are now able to offer production solutions for Mo with ±100MPa and Ru with ±150MPa stress range down to 7mm of edge exclusion. This now comes along with thickness uniformities better than 1.5% (1σ) for Mo and 1% (1σ) for Ru.

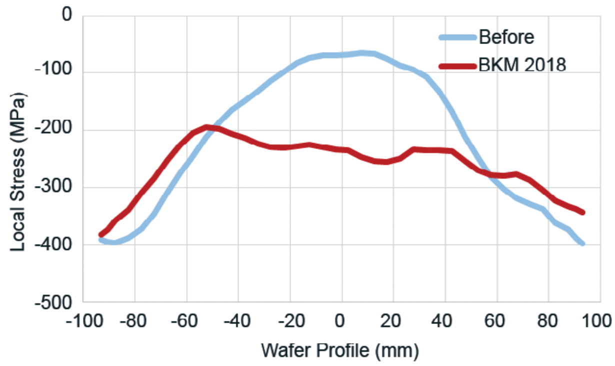


Figure 1. Mo stress uniformity

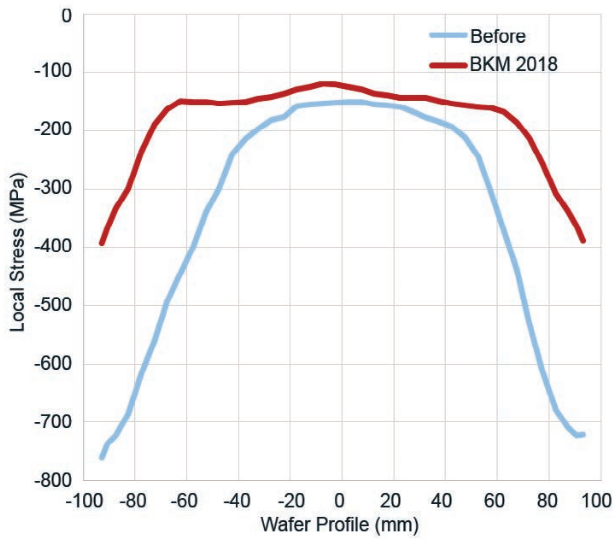


Figure 2. Ru stress uniformity

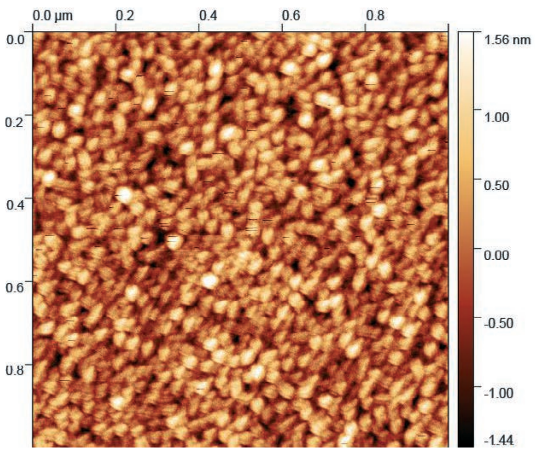


Figure 3. AFM scan of 300nm thick Mo bottom electrode grown on AlN seed layer.

Excellent stress and thickness uniformity are not the only features needed in the manufacturing of high performing FBARs: the bottom electrode also serves indeed as a template for the nucleation and growth of the fiber-textured piezoelectric layer on top. In order to achieve highest coupling coefficients and maximal yield, its grains have to grow with the narrowest alignment and the surface must be defect-free. A narrow FWHM of the bottom electrode rocking curve and a low surface roughness in as-deposited electrodes are therefore prerequisite for a good piezoelectric performance.

With the dedicated process kit we can now deposit Mo electrodes that combine the aforementioned stress and thickness uniformities with rocking curve peaks as narrow as 1.6° for a thickness of 300nm and an average roughness Ra of 0.4nm when deposited onto an AlN seed layer. This is the key to excellent crystallinity of the subsequent $Al_{1-x}Sc_xN$ piezoelectric layer!

In combination with the excellent performance of the $Al_{1-x}Sc_xN$ thin film deposition, we can now offer a complete production solution for the full film stack of high performing FBARs. I hope that this short example of our efforts in understanding and mastering the entire chain from vacuum systems to the material science represents an example of Evatec's focus on PVD of advanced functional materials.

A closer look at the edge exclusion

The market is flooded by numerous values of stress uniformities these days. These indications can only be understood when quoted in conjunction with an edge exclusion value in mm. Many companies for example claim superior stress uniformities but they are often measured out to an exclusion of about 20mm. A short lesson in geometry reveals the importance of precise measurement as far out to the wafer edge as possible: on a 200mm wafer the addition to the useful surface of the annulus defined by 80mm and 93mm radii (20mm and 7mm respectively) represents an increase of the yield of 33%! Equally, the measurement method used should also be declared. This is due to the fact, that the values towards the edges are often extrapolated following fitting procedures which might differ significantly. We therefore recommend that you always check for the measurement conditions, or better compare two wafers from different vendors on the very same instrument.