Chapter 6

RF Bulk Acoustic Wave Resonators and Filters

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Small sized, highly selective solidly mounted bulk acoustic wave (BAW) band pass filters are of great interest for mobile and wireless systems operating in the frequency range of 0.8 GHz up to more than 10 GHz. Applications for BAW filters include front-end filters for USPCS, UMTS, GSM, bluetooth and other standards. BAW filters can be fabricated on silicon or glass wafers using standard semiconductor production techniques. On-wafer packaging techniques allow to fabricate small, flip chip mountable BAW filter devices suited for System in Package (SiP) solutions.

The chapter explains the how BAW filters work, compares their performance with competing filter technologies (e.g. surface acoustic wave filters), describes the technique Philips uses to realize BAW filters and reviews briefly alternative technical approaches. BAW filters are based on electro-acoustic high Q resonators, which exploit the thickness extensional mode of a thin, highly oriented, piezoelectric AlN or ZnO film. One section of the chapter is devoted to the growth of piezoelectric AlN films, which have to be grown with the polar c-axis, oriented perpendicular to the substrate. It is shown that both the sputter deposition process and using a textured, well oriented electrode support excellent c-axis oriented growth of the AlN films. An example is the growth of AlN (0002) on Pt (111) oriented electrodes where we find an epitaxial relation. The growth mechanism of AlN films, which grow highly oriented as well on amorphous and smooth surfaces like SiO2 and the thickness dependence of their orientation is discussed. We show that AlN (0002) orientation is directly correlated with the electromechanical coupling coefficient k_t of the films and therefore with the filter bandwidth.

The following section describes the modeling techniques we use to describe the filter and resonator response. A combination of a 1 dimensional analytical electro-acoustic model together with an electromagnetic model reveals optimal agreement between measurement and simulation. It is shown that the small details of the resonator
and filter curves can be used to extract relevant material data. Embedding the electro-acoustic model into a commercial circuit simulator offers an excellent method for the designer to predict filter performance. The limits of this 1-D model are discussed briefly referring the reader to a more rigorous 2-D treatment of BAW resonators, which would allow to explain major acoustic loss mechanisms. Finally a few examples of filters operating in the range between 2 and 8 GHz are shown.