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High Throughput Magnetron Sputtering of Tilted c-Axis AlN Films for Biosensing Applications

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Summary:

A new two-step approach for high throughput magnetron sputtering of tilted c-axis aluminum nitride will be presented. This includes a slower growth of AlN in a tilted magnetron arrangement followed by a faster AlN deposition in a standard face-to-face sputtering arrangement.

Keywords: AlN; Tilted c-axis; Biosensors; Magnetron Sputtering

Motivation

Over the last decade, there has been an increasing development of biosensing applications using resonant vibrating bulk piezo devices, such as aluminum nitride, due to its excellent sensitivity and fast response [1]. The change in resonant frequency can be easily detected and is sensitive down to concentrations of <0.1 ng of molecules of interest. While standard resonators with vertical c-axis orientation suffer from significant attenuation in liquid, shear mode oscillators are advantageous.

We present the development of a magnetron sputtering process for the growth of polycrystalline aluminum nitride films with a defined oriented, tilted c-axis of the AlN grains. The high-vacuum tool employs an in-line principle with quasi-continuous substrate movement during deposition (Figure 1). Multiple wafers can be placed face down on a carrier tray as they move over the linear magnetron sputter sources.

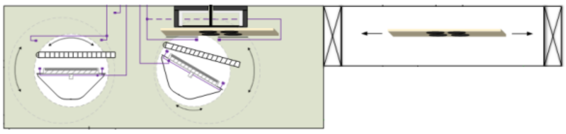

Fig. 1. Schematic illustration of the main components of the inline sputter tool scia Magna 200 Inline *with bulk and seed station (left) and load-lock (right), carrier tray for 4 wafers.*

Simulation

A particle-in-cell (PIC) simulation was used to define specific components and arrangements, in particular the tilt and orientation of the magnetron at the so-called seed sputtering station. At this position, a particle flux extracted from the sputter source with a wide angular distribution is parallelized by means of a collimator. The cell size and mechanical dimensions of the collimator are varied in order to achieve the highest flux at the substrate position while maintaining a well-defined growth of tilted grains with a small angular spread. Simulation results are presented (Figure 2). Nevertheless, the flux of sputtered particles through such a collimator is much lower than for an unrestricted sputtering arrangement. Therefore, the developed tool is equipped with a second sputtering station, the so-called bulk station, for subsequent fast growth by standard magnetron arrangement face to face with the substrate, which ensures a much higher rate than within the seed station.

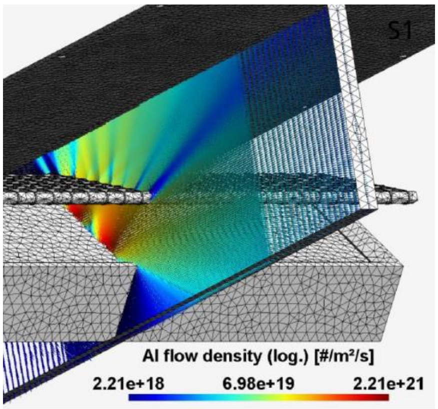

Fig. 2. Simulation result for a specific magnetron-collimator-substrate arrangement

Experimental

The quality of the grown films, in particular the crystal grain size and orientation, is investigated by XRD measurements such as theta-2-theta scans, rocking curves and pole figures.

We have found that an initial film thickness of about one hundred nanometers can be sufficient to act as a seed. The "seeded" tilted orientation is maintained for a few microns of film growth to the desired thickness. This two-step approach allows the inline processes to be much better coordinated, without the throughput being limited by one of the steps. The influence of the initial substrate roughness is also known to be an important parameter for the seed of the tilted grains. Angles of tilt of >31° from the substrate normal have been achieved (Fig. 3).

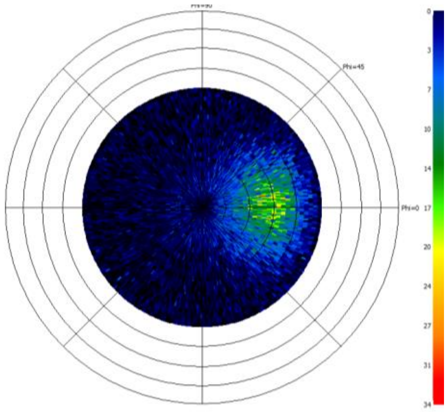

Fig. 3. Pole figure for an AlN film with 31° c-axis tilt represented by the (002) reflex

Outlook

Future developments will aim at a controlled switching of the tilt orientation after a certain film thickness as well as a change of the polarisation direction of the piezo crystallites.

References

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