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Extremely Highly Textured MgO [111] Crystalline Films on Soda-Lime Glass by E-Beam.

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Abstract (less than 200 words):
Textured or crystalline Magnesium Oxide films on soda-lime glass has been a subject of investigation by many researchers in recent times due to the applications of such films in the semiconductor industry. Here we report for the first time highly textured MgO [111] films -- similar to that of single crystalline -- on ordinary soda-lime glass via a new electron-beam deposition method. The grain sizes, up to 1 μm, are much larger than the largest previously reported ~0.1 μm by the Sol-Gel method. Such films will have a wide range of applications in various industries, specifically they can be used as a buffer layer for deposition of large grained to single crystal semiconductor films such as silicon on soda-lime glass thus allowing for a game-changing major breakthrough in the solar and display industries.

Keywords
Highly Textured MgO [111] films; thin-film silicon on glass; MgO photovoltaics; MgO displays.
1.1

Introduction:

Large grain magnesium oxide films on inexpensive substrates have long been known to be an attractive material for several reasons: 1) they can serve as a protective layer on glass plasma display panels 2) they can serve as an intermediate buffer layer between a semiconductor substrate such as silicon or gallium arsenide and a ferroelectric film in oxide based devices on semiconductors. In more recent times, it has been suggested by several research groups that MgO be used as a buffer layer on which to deposit semiconductor films for photovoltaic applications. It is known that Ion Beam Assisted Deposition (IBAD) can be used successfully to grow crystallographically aligned biaxially textured MgO on glass. MgO develops biaxial texture within about 10 nm of IBAD growth which is a cost effective attribute. Yet, IBAD remains expensive in comparison to an ISD e-beam approach, which allows for growth at 20-100 A/sec – even faster than IBAD – on randomly oriented metal substrates. One group has reported textured MgO films on soda-lime glass using electron beam evaporation but not ISD. Several groups have reported textured MgO on soda-lime glass by ISD MgO [111] oriented film has been reported on a silicon substrate but using the sol-gel method and on soda-lime glass using Atomic Layer Epitaxy and Aerosol Assisted Metalorganic Chemical Vapor Deposition. The latter group reported MgO grain sizes between 35nm and 50nm for the [111] oriented film. Here for the first time we report extremely highly textured MgO [111] films on soda-lime glass using the cost effective e-beam evaporation technique which is a breakthrough allowing and opening the door for the future development of large grained to single crystal semiconductor thin film deposition on ordinary soda-lime glass for inexpensive energy efficient photovoltaic, display and other nanoelectronic and photonic applications. Moreover, the high optical transparency of MgO buffer on glass retains the optical properties of glass yet provides a template for controlling grain orientation and morphology for semiconductor device engineering.

2.1

Materials and Methods

The MgO films were deposited using an e-beam evaporation system. For the 7μm MgO deposition a 3.2mm thick regular soda lime glass (basically window glass), manufactured by Taiwan Glass in Taiwan, was used. Two samples were prepared using this method. The first sample was deposited at 450°C and the second at 550°C, both temperatures below the softening point of ordinary soda-lime glass. The MgO was deposited in a “Blue Wave Semiconductors” vacuum system by an electron beam evaporation system with the capability of holding the substrate – in this case soda-lime glass – at a specific growth temperature necessary to control growth kinetics. The evaporation source was highly dense MgO crystals. The source to substrate distance was between 6 to 9 inches. The deposition rate was monitored by quartz crystal thickness monitor. Base pressure in the vacuum chamber was achieved to be better than 10^-7 Torr. After deposition samples
were cooled at 30C/min rate. Samples were characterized by X-ray Diffraction, and Scanning Electron Microscopy (SEM).

3.1

Theory/calculation

N/A

4.1

Results

5.1

Figures 1 and 2 show x-ray diffraction patterns of the two samples. X-ray diffraction patterns of both samples clearly showed highly oriented MgO films along the preferred [111] direction. (See figures 1 and 2) The films are along the [111] normal to the substrate surface.

Figure 1: XRD of 7um MgO film on soda-lime glass.
Figure 2: XRD of 7μm MgO film on soda-lime glass.

Scanning Electron Microscopy was performed on the same samples (see figures 3 and 4).

Figure 3: SEM of sample done at 450°C showing grain sizes of up to 1μm.
Discussion

The characteristic peaks for MgO are known as 36.93 [111], 42.90 [200], 62.29 [220], 74.67 [311], and 78.61 [222] degrees. Such an intensely [111] oriented MgO film reported here is even more remarkable given that the diffraction data for MgO shows a ratio intensity of 999 for the [200] orientation and only 116 for the [111] orientation. Yet in these samples the [111] orientation was greater than the [200] orientation by many orders of magnitude. A [111] oriented MgO film is preferable for growth of silicon films which have a preferred [111] orientation thus greatly reducing the chances of lattice mismatch and defects and greatly increasing the chances of heteroepitaxy. It has been shown that a higher aspect ratio of lateral versus vertical growth rate can be achieved when using [111] Si orientated seed layer and may lead to continuous layers (Need reference here). An issue requiring further exploration is whether these MgO films are uniaxially textured (not biaxial textured) and if so whether or not that will affect the quality of the crystallinity of the semiconductor films deposited on the MgO films for the purposes of device fabrication. We expect that the quality of semiconductor crystallinity will not be adversely affected by a highly textured yet uniaxial MgO crystalline film, as opposed to biaxial, however this needs to be confirmed. Cross section TEM has been scheduled at the time of the writing of this paper and the results will be reported at a later date.
6.1

Conclusions

Highly textured [111] oriented MgO crystalline films have been successfully deposited by e-beam evaporation on ordinary soda-lime glass. The thickness of the MgO films was 7 \( \mu \text{m} \), but there is no reason why it cannot be less and have the same crystallinity, although further experiments verifying this are necessary. Such films will have a wide range of applications in several industries, including photovoltaics but also potentially for displays. Semiconductor films such as silicon can be deposited on these MgO films using eutectics at temperatures below the softening point of ordinary glass and having extremely high textured and strong [111] orientation leading to breakthrough efficiencies and cost effective solar cells which are easily fabricated and scalable using the common electron beam. Deposition of Al\(_2\)O\(_3\) (sapphire) on these MgO films on glass is also planned in the near future for photovoltaic applications as well as a new kind of sapphire glass for display purposes.

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Highlights

- Extremely highly textured [111] oriented MgO film on soda-lime glass.
- Grain size up to 1um.
- Immediate applications for solar, semiconductor, and display industries.
- Highly cost effective and easily scalable manufacturing technique.


The Koritala group reported the following forthcoming publication: Thickness-dependent texture development in the magnesium oxide films grown by inclined substrate deposition. To the authors’ knowledge this was never published. See reference #12 in Koritala et al above.


Kazuo Nakajima, Noritaka Usami (Eds), Crystal Growth of Si for Solar Cells (2009), p.150