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Reactive sputter deposition of transparent and low refractive-index MgF2 thin films using a double-grid negative-ion retarding electrode

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MgF_2 thin films deposited by magnetron sputtering show optical absorption in the visible range because of the formation of F defects or Mg clusters by the incidence of energetic F- ions to substrate [1,2]. In addition, deposition rate of sputter deposited MgF_2 thin film is less than a few nm/s [1, 2], which is regarded as rather low compared to that of other compound thin films. In this study, effectiveness of negative bias voltage applied to a double-grid electrode set between the cathode and the substrate on increase in film deposition rate and suppression of optical adsorption has been examined in MgF_2 reactive sputter deposition using Ar-CF_4 mixture as discharge gas.

The sputtering apparatus used in the experiments was a batch-type system with the cathode of a Mg plate (76.2 mm dia., 99.99 % in purity). The distance between the target and the substrate was 51 mm. A double-grid electrode with 120 mm by 120 mm squared was set between the target and the substrate. The distance from the grounded grid to the target and between the two grids were 15 and 6 mm, respectively. The grid adjacent to the target was grounded and the other was biased. The pressure of discharge gas of Ar+CF_4 was kept at 0.8 Pa. The flow rates of Ar and CF_4 were 2.5 sccm, respectively. The cathode was driven by dc power supply (AE MDX 1.5K). The cathode power ranged 100-108 W for a constant discharge current of 0.3 A. The retarding voltage was changed from 0 to -500 V. Borosilicate glass plates (80 × 80 × 0.9 mm^3) were used as substrate. Thickness of thin films was measured by using a stylus profiler. Optical transmittance and reflectance were measured by a double-beam spectrophotometer.

The change in the retarding voltage affected both the film deposition rate and optical absorption. The MgF_2 thin film deposited without applying a retarding voltage to the driven grid showed the multiple-ring-shaped area with ptical absorption. By applying a retarding voltage of -50 V, the ring-shape was disappeared and transparent MgF_2 thin films were deposited. The optical absorption coefficient of thin films was reduced to $<2\times10^{-4}$ nm^{-1} in the visible range and the refractive index was <1.40. The film deposition rate was increased to >10 nm/min from < 1nm/min by applying a retarding voltage of -30 to -500 V. In addition, the film thickness uniformity distribution in the substrate was drastically improved due to the increase of the deposition rate in the area facing to the target erosion.

[1] L. Martinů, et al., Thin films prepared by sputtering MgF_2 in an rf planar magnetron, Vacuum 35 (1985) 531.

[2] K.Iwahori, et al., Optical properties of fluoride thin films deposited by RF magnetron sputtering, Appl. Opt. 45 (2006) 4598 -4602.

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