

Focused Electron Beam Micro- and Nanopatterning of Thin Films Derived from Sol-Gels Based on TiO₂ Precursors for Planar Photonics

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Streszczenie

Titanium dioxide (TiO_2) is an attractive material for planar photonics; thus, the fabrication of TiO_2 micro- and nanostructures has been a topic of many reports in recent years. In this work, we have presented systematic studies on focused electron beam (e-beam) micro- and nanopatterning of sol-gel-derived layers based on different alkoxide precursors of TiO_2 stabilized with benzoylacetone (BzAc). The e-beam method is a flexible high-resolution technique, whereas the use of the sol-gel process, which utilizes precursors of titania in the condensed phase, enables lower electron doses in comparison to gas-phase precursors from injection systems. As the sol-gel process is relatively complex, we analyzed the effect of different process parameters on the patterning. It has given us insight into the phenomena related to the e-beam irradiation of sol-gel-derived layers based on titanium alkoxide precursors. We have examined patterned films using scanning and transmission electron microscopy, energy-dispersive X-ray spectroscopy, ellipsometry, and profilometry. We have shown that the role of the alkoxy chain length in the processing of sol-gel-derived layers is more significant in the case of alcohol solvents than titania precursors. Moreover, high-resolution periodic nanostructures with steep sidewalls and high aspect ratio can be patterned, especially when the molar ratio of BzAc to titanium alkoxide in sol is increased from 1:1 to 2:1. Although the patterned films have a high concentration of carbon, it can be completely removed by annealing at 500 °C. This heat treatment leads to an increase in the refractive index from 1.59 to 2.11 (at the wavelength of 632.8 nm), but the patterned film turns polycrystalline in the nanoscale, showing the anatase phase of TiO_2 . The obtained results indicate that the investigated patterning method can be potentially applied for direct writing of planar photonic components with nanoscale features such as grating couplers for sensors. Nevertheless, the fabrication of high-quality TiO_2 structures still needs optimization.

Słowa kluczowe

sol-gel, titanium alkoxides, focused electron beam, direct writing, refractive index, photonics, Annealing (metallurgy), Layers, Materials, Oxides, Precursors

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