Low Temperature Synthesis of Sapphire or Ruby and Their Applications

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ABSTRACT

Sapphire or ruby as a single crystal α-Al_2O_3 phase is gaining a lot of attention in recent years due to its thermal, mechanical and optical properties. The current study presents a unique method to synthesize sapphire or ruby, which optimize the traditional synthesis process, and explores some of their applications such as high refractive index thin film coating and stress transferring material. In the synthesis process, pseudoboehmite (PB) is used as a precursor and mechanical milling is employed to reduce the phase transformation temperature of pseudoboehmite to sapphire or ruby. The phase transformation of the milled PB samples was investigated by various characterization techniques. XRD data showed that PB structure is first synthesized as raw material, followed by its room temperature transformation to χ-Al_2O_3. Raman spectrum and HRTEM confirmed the presence of α-Al_2O_3 and χ-Al_2O_3 phase in the 30hr milled PB sample. Through the proposed synthesis method, there is a significant temperature reduction (approximately 200°C) for the complete transformation to sapphire or ruby during annealing, which is confirmed from thermal analysis. This is due to sapphire or ruby seeds are synthesized at room temperature in the milled sample and serve as hetero sites for nucleation in the annealing process.

In addition, XPS and EELS analysis shows unique band gap effects, both of them are consistent with theoretical value for two random choosing samples (PB milled 10hr and 30hr samples). This indicates the reliability of XPS band gap results. It is found it is possible to tune the band gap of alumina during mechanical milling through quantum confinement. FTIR result shows that PB lose water content from its structure, which can releases its surface strain during the milling process, therefore cold welding induces the increase of PB grain size. The current study also involved the application of sapphire or ruby thin films, which are deposited on substrates through ion beam sputtering from the low temperature synthesized sapphire or ruby target.