Influence of heat treatment on quality of low-temperature grown ZnO films

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A wide-bandgap semiconductor of ZnO has recently attracted much interest because of their prospective applications in low-voltage and short wavelength optoelectronic devices, transparent ultraviolet protection films, and gas sensors. Its optical and electrical properties of ZnO are sensitive to preparation methods and processing conditions. For ZnO thin films fabricated by radio-frequency magnetron sputtering at low temperatures, there can be an existence of an amorphous phase that embeds ZnO crystals. Following heat treatment, the crystallization would take place in an appropriate annealing temperature range. The annealing at higher temperatures can lead to the formation of polycrystalline films. To gain more insight into this problem, we have studied influences of the annealing temperature and time on the quality of ZnO thin films grown by radio-frequency magnetron sputtering. Low-temperature grown ZnO films after prepared were annealed at temperatures between 200 and 800 ^{o}C for 15-180 minutes. This process was monitored carefully by Raman scattering (RS) spectroscopy and an x-ray diffractometer. Basing on analyzing the RS spectra, it was found that the crystallization took place strongly as increasing the annealing temperature and time. The crystallization with c-axis orientation reached above 90 % when the ZnO films were annealed at temperatures 600 - 700 ^{o}C for longer 60 minutes. With raising the annealing temperature above 700 ^{o}C, the ZnO films become polycrystalline. It means that to achieve ZnO films with high quality, the low-temperature prepared films were suggested to anneal at 700 ^{o}C for longer than 60 minutes. Photoluminescence spectroscopy was also employed to assess the quality of this film. Its spectrum revealed strong PL emissions in the ultraviolet region, and no visible emission. With higher annealing temperatures, however, the films became polycrystalline, and their PL spectra revealed a visible emission apart from the ultraviolet peaks. The ratio of the PL intensities of the UV to visible emissions was then decreased.