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Photoluminescence of ZnO layers grown on opals by chemical deposition from zinc nitrate solution

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Abstract
The emission from ZnO layers grown on the surface of bulk opals using chemical deposition is studied under excitation by the 351.1 nm line of an Ar^+ laser at different excitation power densities and temperatures. The emission spectrum exhibits narrow photoluminescence (PL) bands associated with the recombination of bound and free excitons as well a relatively broad band around 3.31 eV. The width of the excitonic lines (2–3 meV) along with their energy position are indicative of the high quality and strain-free state of the layer. The origin of the 3.31 eV PL band is discussed in connection with its dependence upon the excitation power density and temperature.

Zinc oxide (ZnO) is a promising material for manufacturing photodetectors, laser diodes for the blue to ultraviolet spectral regions, transparent field effect transistors, and so on [1–3]. ZnO is considered as a material most suitable for the realization of room-temperature polariton lasers [4]. Nowadays expensive microwave plasma-enhanced molecular-beam epitaxy (PEMBE) [3, 5–7] or eximer laser-assisted molecular beam epitaxy (L-MBE) techniques [8, 9] are used for the growth of high-quality ZnO layers. However, more simple chemical routes would be more attractive provided that they also assure a high quality of the material. One common problem for all approaches of heteroepitaxial growth is the strain that the layer experiences as a result of heterostructure lattice mismatch. This strain relaxes via cracks and formation of defects over a critical layer thickness. Nanoheteroepitaxy has recently been proposed as a tool that significantly extends the thickness of pseudomorphic growth in mismatched heterostructures [10–12]. It was shown that the three-dimensional (3D) stress relief mechanisms that are active when an epilayer is nucleated as an array of nanoscale islands on a compliant patterned substrate will significantly reduce the strain energy in the epilayer and extend the critical thickness dramatically [10]. Synthetic opal structures are suitable substrates in this sense, since they represent a pattern with the nanostructure sizes controlled by the diameter of the colloidal spheres. 3D opal structures are also ideal matrices for filling with semiconductors, metals, magnetic materials, etc in order to fabricate arrays of quantum dots, photonic crystals and other low-dimensional systems [13–15]. Opal structures allow one to grow thick strain-free epitaxial layers as well as thin nanotextured films. Yu *et al* have shown that textured ZnO films might have higher quantum efficiency than GaN and could become a material for next-generation UV semiconductor lasers [16]. In this paper we report a simple and efficient method to prepare high-quality free of strain ZnO films on opal substrates from a zinc nitrate solution.

Silica opal spheres were synthesized through the hydrolysis of tetraethyl orthosilicate (TEOS) in water–ethanol solution in the presence of ammonium hydroxide following Stober's method [17] with some modification of the component ratio [18]. Bulk opals were prepared by natural sedimentation of the silica particles in a water suspension. After drying procedure at 150 °C, the samples were annealed at 1020 °C for 5 h. These technological steps resulted in opal structures

