band gap [74]. And high Zn concentrations (or more accurately, high DEZ flows) cause a loss of In from both GaInP [35] and AlGaInP [75]. The problem is probably associated with some parasitic gas-phase reaction involving DEZ, TMIn, and PH_3. The effect can be large enough to measurably change the growth rate and the Ga/In ratio in the material. The Ga/In ratio can be so far from lattice-matched conditions as to affect the morphology. High DEZ flows also inhibit the incorporation of Ga, but to a lesser extent.

Diffusion of zinc during epilayer growth can cause degradation of the performance of solar cells [76]. The zinc dopant in the substrate, back-surface field (BSF), or tunnel-junction layers can serve as a reservoir for zinc diffusion into the base region of an n-on-p cell. The diffusion is largely driven by point defects that are injected during the growth of the n-type layers. The diffusion can be reduced by reducing the doping levels of any of the layers (including the n-type layers), by adding diffusion barriers, and/or by using Se instead of Si doping of the n-type layers [76]. A side effect of the Zn diffusion is a disordering of any of the ordered structures [77].

The effect of changing the cap or overlying layer and cooling atmosphere on the hole concentration in Zn-doped $(Ga_{1-x}Al_x)_{0.5}In_{0.5}P$, $x = 0.7$, has been studied by Minagawa and coworkers [78]. Cooling in a H_2 atmosphere containing AsH_3 or PH_3 reduces the hole concentration. Hydrogen radicals from the decomposition of Group V hydrides easily diffuse into the epilayers and passivate the Zn acceptors. Cap layers of n- or p-GaAs help impede the indiffusion of H, and underlying layers can enhance the indiffusion of H, a special problem with p-on-n cells [76].

Magnesium

Magnesium doping (with cyclopentadienyl magnesium) in AlGaInP has been studied by a number of investigators [74, 79–82]. It is useful for achieving higher hole concentrations in AlGaInP and AlInP layers. However, the Mg incorporation efficiency decreases with decreasing temperature. Therefore, higher growth temperatures are favored, which is an advantage for AlGaInP. However, since dopant diffusion rates increase rapidly with temperature, this is a disadvantage for the fabrication of stable tunnel junctions and stable GaAs/Ge interfaces. For GaInP, it has no obvious advantages over Zn, and suffers from rather severe memory effects [80]. Also, relatively good-quality Zn-doped AlInP can be obtained by paying careful attention to source material and system purity [83].

Carbon

The use of C (from CCl_4 or CBr_4) has not been studied extensively. The halide tends to etch GaInP [84], indium more so than gallium. Also, C-doped GaInP exhibits poor minority-carrier transport properties [84, 85].

9.6.3.4 Window layers and back-surface fields

9.6.3.4.1 AlInP window layers

The function of an emitter window layer is to passivate the surface states associated with the emitter surface. These states are minority-carrier traps. Their effect is characterized by a quantity called the surface (or interface) recombination velocity, S. The value of S