Formation of SiC Thin Films by Ion Beam Synthesis

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1 Introduction

Ion beam synthesis (IBS) is a promising technique for forming homogeneous, stoichiometric, large-area thin films of epitaxial 3C-SiC within or on a silicon wafer. Although well-known in silicon device technology as a technique to form buried SiO$_2$ or metal silicide layers, the IBS technique has only recently attracted larger interest as a means of creating buried or near-surface SiC films. In this chapter the major recent achievements will be reviewed, our present understanding of the temperature and dose dependence of the mechanisms involved in the IBS of SiC will be summarized, the characteristics of IBS formed layers will be described and first applications of such SiC layers will be compiled. As the IBS technique has not been described in the preceding Silicon Carbide volumes [1], the review will start with a brief description of the basics of the IBS technique and a short chronological summary of early observations. The presentation will be limited to the use of directed ion beams with energies of some keV to few MeV and will not include beam assisted deposition techniques.

2 Fundamentals of Ion Beam Synthesis

Ion beam synthesis has been successfully applied to create homogeneous films consisting of one to four atomic species forming an elemental layer, an alloy or a compound. The either amorphous, polycrystalline or single-crystalline thin films are usually formed in a two-step process: a high-dose implantation to roughly adjust the chemical composition of a near-surface region and a subsequent annealing step to redistribute the implanted atoms from a more or less Gaussian depth distribution into a box-like depth profile corresponding to a homogeneous layer. The annealing step also serves to reduce the density of lattice defects in the synthesized layer and its vicinity. In most materials systems investigated so far, the piling-up of the depth distribution of implanted atoms during annealing has been attributed to the Ostwald ripening of precipitates, i.e. the growth of larger precipitates near the ion profile peak at the expense of dissolving smaller ones in the wings of the depth distribution, driven by the minimization of the systems total interfacial energy. Therefore
Fig. 1. Phenomena occurring during the ion beam synthesis of layers

it is clear today that the depth and size distribution of all crystalline and amorphous phases in the as-implanted state has a large impact on the desired redistribution of implanted atoms during annealing: together with the defect distribution, it sets the starting conditions for the diffusive redistribution of atoms during the anneal. The major processes playing a role in usual IBS are sketched in Fig. 1, even though this picture has to be slightly modified (for the precipitate size distribution) in the case of SiC layer synthesis in silicon, as we will see later.

High-dose implantation usually leads to a supersaturation of the implanted atomic species followed by the nucleation, growth and coalescence of precipitates, in particular at the peak of the ion profile. Either during implantation or during the post-implantation anneal Ostwald ripening causes a coarsening of the impurity size distribution. Under ideal conditions, this results in the growth of just one precipitate, the buried layer. The transport of implanted impurity atoms from the profile wings towards the centre may be supported by snow plough effects, which may occur if the peak of the ion distribution is located within a buried amorphous layer and the annealing step causes crystallization of this zone.

The depth position of the ion beam synthesized layer can be adjusted by means of the ion energy. For a reliable prediction of ion ranges, typical high-dose effects such as sputter erosion of the surface, changes of the ion ranges due to composition dependent stopping power changes and swelling effects have to be taken into account. In addition, diffusive redistribution of implanted atoms during implantation – in some cases mediated by the implantation induced lattice defects – may influence the ion profile and thus the resulting layer position. Owing to these effects, a reliable prediction of high-dose ion profiles is presently not available and properties such as the stoichiometry dose $D_s$, i.e. the dose $D$ at which the desired stoichiometric com-