Molecular Beam Epitaxy Growth of High-Quality Arsenic-Doped HgCdTe

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We have initiated a joint effort to better elucidate the fundamental mechanisms underlying As-doping in molecular beam epitaxy (MBE)-grown HgCdTe. We have greatly increased the As incorporation rate by using an As cracker cell. With a cracker temperature of 700°C, As incorporation as high as 4×10^{20} cm^{-3} has been achieved by using an As-reservoir temperature of only 175°C. This allows the growth of highly doped layers with high quality as measured by low dislocation density. Annealing experiments show higher As-activation efficiency with higher anneal temperatures for longer time and higher Hg overpressures. Data are presented for layers with a wide range of doping levels and for layer composition from 0.2 to 0.6.

Key words: Molecular beam epitaxy (MBE), HgCdTe, As doping, activation anneal

INTRODUCTION

In principle, the flexible epitaxial-growth method of molecular beam epitaxy (MBE) should allow the growth of in-situ p- and n-type doped layers for the fabrication of both single- and multi-color, infrared focal plane arrays. While n-type doping using indium is straightforward, extrinsic p-type doping in HgCdTe is difficult. Column 1A and 1B elements are fast diffusers whose electrical activities as acceptors are strongly influenced by Hg vacancies. For these reasons, they are not preferred. The Column V elements have the advantage of not being fast diffusers, but incorporation mechanisms during MBE growth cause them to occupy the Hg sublattice or interstitial sites, acting as donors or neutral complexes. High-temperature anneals under Hg overpressure are then necessary to cause a site transfer to the Te sublattice. This is achievable using As, the usual acceptor used in the technology today. However, the process is not well understood from either technological or theoretical views. In addition, As suffers from having a low sticking coefficient at the typical MBE-growth temperatures where quality is highest (lowest dislocation density).[1] This typically means that either the growth temperature must be lowered (possibly compromising dislocation density) or very high As fluxes must be used (potential contamination issue of the MBE chamber).

We have initiated a joint effort to better elucidate the fundamental mechanisms underlying As doping with parallel studies on undoped and In-doped layers for comparison. HgCdTe layers are grown at Rockwell Scientific Company (RSC, Camarillo, CA) and undergo various types of activation anneals. Suitable samples are then sent to West Virginia University (WVU, Morgantown, WV) for detailed characterization that involve quantitative mobility-spectrum Hall analysis (QMSA), temperature-dependent lifetime measurements, photoluminescence (PL) measurements, and electron-paramagnetic resonance measurements. These advanced characterization methods have seldom been applied systematically over the wide range of composition and doping level necessary to understand fundamental microscopic processes. SRI International (SRI, Menlo Park, CA) provides detailed microscopic-material modeling studies. This work covers growth and annealing work at RSC; a separate paper covers the characterization work at WVU.[2]

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