Damage in III/V semiconductors caused by hard- and soft-etching plasmas

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Damage in III/V semiconductors caused by processing in high- and low-density plasmas is investigated employing material-specific analytical methods. To distinguish the various regimes of damage, four different ambients out of the palette of plasma constituents were chosen: as borderline cases, argon which is associated with hard etching causing crystal lattice disordering until complete amorphization, and hydrogen which is the prototype of soft etching causing bond breaking between the lattice constituents without changing the crystal site, and the two model ambients Ar/Cl_2 and $Ar/CH_4/Cl_2/H_2$ which are widely used to etch Ga-containing compound semiconductors. Several probes and methods are employed which are selectively sensitive to the different kinds of damage: damage of the crystal lattice with photoluminescence, scanning electron microscopy and scanning transmission electron microscopy, and the concentration gradient of a chemically reactive species (hydrogen) with secondary ion mass spectrometry. Its reaction with lattice atoms (acceptor passivation), is recorded by capacitance/voltage and Hall measurements. For irreversible damage (knock out of atomic lattice sites), there can be detected only one damage zone reaching not deeper than 30 nm. The depth is inversely proportional to the lattice energy and proportional to the kinetic energy of the projectiles. In contrast to this rather shallow damage, the penetration depth of hydrogen amounts up to several microns. Since the subsequent passivation of acceptor atoms is a chemical reaction, it can be reverted at elevated temperatures. It has turned out, with all methods applied, that the gentlest ambient to etch Ga-containing III/V semiconductors is Ar/Cl_2. This is not restricted to the smoothness of the surfaces but refers to all quantitative measurements which are applied in this study. [DOI: 10.1116/1.1355760]