PHILOSOPHICAL MAGAZINE A, 2000, VOL. 80, NO. 9, 2099–2108

A model of dislocation blocking and its application to the development of misfit dislocation arrays

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[*Received 2 June 1999 and accepted 15 October 1999*]

ABSTRACT

During the relaxation of strained semiconductor layers, gliding threading dislocations can be blocked by pre-existing misfit dislocations lying perpendicular to the glide direction. It has been suggested that this process is less significant when the layer is grown on an off-cut (i.e. vicinal plane) substrate. We present a statistical analysis of the simpler cases and a computer simulation of the more complex cases which shows that there should be no difference between the blocking behaviour on exact or off-cut substrates.

§ 1. INTRODUCTION

The development of arrays of misfit dislocations frequently controls the relaxation of heteroepitaxial semiconductor layers. For this reason there has been a great deal of interest in methods of estimating and measuring the critical layer thickness beyond which it is energetically favourable for a strained layer to relax. More recently interest has focused on the dynamics of the relaxation process, since it is evident from many experimental results that relaxation by movement and/or multiplication of dislocations usually starts long after the critical layer thickness has been exceeded (see for example Dodson and Tsao (1987) and Beanland *et al.* (1996)).

For semiconductor layers grown on III–V substrates, in which the threading dislocation density is significant (typically at least 10^4 lines cm^{-2}) the first relaxation mechanism to operate is the movement by glide of threading dislocations (TDs) across the epilayer, laying down lengths of 60° misfit dislocation (MD) in their wake. The extent of this early 'primary' relaxation is proportional to the total length of MD and if the strain is substantial this will be limited by exhaustion of TDs. Exhaustion will occur when all the TDs initially present have either slipped out of the epilayer at the edge of the wafer or have had their glide blocked by some means. Thereafter, further 'secondary' relaxation can only occur if new dislocation sources are created or if one or more dislocation multiplication mechanisms start to operate (see for example Beanland (1992)). These secondary mechanisms are not considered further in this paper.

For III–V epilayers grown on (001) substrates TDs can glide on one of two glide planes in each of two orthogonal ⟨110⟩ directions. Each gliding TD therefore encounters previously-laid-down MDs orthogonal to its path, which may have Burgers vectors parallel or non-parallel to it. Freund (1990) has analysed many of

Philosophical Magazine A ISSN 0141–8610 print/ISSN 1460-6992 online
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