AN INVESTIGATION OF QUANTUM DOT MOLECULE STRUCTURE DERIVATIVES

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ABSTRACT

For this thesis, the author investigated variants of quantum dot molecule (QDM) structures in the $Ge_{0.3}Si_{0.7}$/Si(001) system on patterned arrays under systematically varied focused ion beam (FIB) patterning conditions. QDM structures (regularly four-fold self-assembled quantum dots bound by a central pit) due to their size and shape make interesting candidates for nanoelectronic applications such as quantum cellular automata; however, deviation from this structure can be undesirable for such applications. The author was seeking to identify, classify, and determine what is making these irregular structures appear.

A set of nine arrays were examined using atomic force microscopy (AFM), six QDM structure types were identified and classified. A computer program was then written to determine whether there were correlations between positions of the six different QDM structures. Energy dispersive spectrometry (EDS) was used to evaluate possible variations in film composition at various points in the array pattern and AFM was also used to evaluate the geometry of patterned pits after Si buffer layer growth.

It was found that for a fixed ion energy of 20 keV, the maximum increase any one particular variant QDM was ~3% of the total population and for a fixed ion energy of 30 keV, the maximum increase in a variant QDM population was ~15% (both percentage increases started with an initial population of 0). Also, for a fixed array fabrication time of 5 seconds, ion energy did not affect the growth of QDM variants but longer mill times (10 - 20 seconds) did promote up to five fold more irregular type QDM structures (an increase from ~3-15% of the total population). A correlation between pits with aspect ratios greater than about 2 and the formation of variant QDMs was identified. EDS measurements yielded a nominal composition of 20.5% Ge with a relative error of 1.5% in all areas of the sample (unpatterned, patterned areas with regular type QDMs, and patterned areas with irregular type QDMs). A minimum likeliness of regular structures to be within 2-2.5 μm of each other in a patterned array was also discovered.

Knowledge about the chemical and physical environments of these variant QDMs as well as the conditions under which they grow, may provide insight not only to the variant structures, but regular type QDMs as well.