Materials Science & Engineering Doctoral Defense

Growth and characterization of novel thin films for microelectronic applications

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abstract

I studied the properties of novel $Co_2FeAl_{0.5}Si_{0.5}$ (CFAS), $ZnGeAs_2$, and FeS_2 (pyrite) thin films for microelectronic applications ranging from spintronic to photovoltaic.

CFAS is a half metal with theoretical spin polarization of 100%. I investigated its potential as a spin injector, for spintronic applications, by studying the critical steps involved in the injection of spin polarized electron populations from tunnel junctions containing CFAS electrodes. Epitaxial CFAS thin films with $L2_1$ structure and saturation magnetizations of over 1200 emu/cm^3 were produced by optimization of the sputtering growth conditions. Point contact Andreev reflection measurements show that the spin polarization at the CFAS electrode surface exceeds 70%. Analyses of the electrical properties of tunnel junctions with a superconducting Pb counter-electrode indicate that transport through native Al oxide barriers is mostly from direct tunneling, while that through the native CFAS oxide barriers is not.

$ZnGeAs_2$ is a semiconductor comprised of only inexpensive and earth-abundant elements. The electronic structure and defect properties are similar in many ways to GaAs. Thus, in theory, efficient solar cells could be made with $ZnGeAs_2$ if similar quality material to that of GaAs could be produced. To understand the thermochemistry and determine the rate limiting steps of $ZnGeAs_2$ thin-film synthesis, the (a) thermal decomposition rate and (b) elemental composition and deposition rate of films were measured. It is concluded that the $ZnGeAs_2$ thin film synthesis is a metastable process with an activation energy of 1.08 ± 0.05 eV for the kinetically-limited decomposition rate and an evaporation coefficient of $\sim10^{-3}$. The thermochemical analysis presented here can be used to predict optimal conditions of $ZnGeAs_2$ physical vapor deposition and thermal processing.

Pyrite (FeS_2) is another semiconductor that has tremendous potential for use in photovoltaic applications if high quality materials could be made. Here, I present the layer-by-layer growth of single-phase pyrite thin-films on heated substrates using sequential evaporation of Fe under high-vacuum followed by sulfidation at S pressures between 1 mTorr and 1 Torr. High-resolution transmission electron microscopy reveals high-quality, defect-free pyrite grains were produces by this method. It is demonstrated that epitaxial pyrite layer was produced on natural pyrite substrates with this method.

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