Electrical Properties of LuAs:InGaAs Superlattices for Terahertz Applications

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Currently there is a need for compact solid-state devices that generate high-power, tunable, continuous-wave terahertz radiation for spectroscopy and sensing applications. Optical heterodyning, or photomixing, is a promising method for generating frequencies in the terahertz range (0.1 to 10 THz). In the photomixing technique, the photoconductance of a material is optically modulated at the beat frequency of two lasers incident on the surface. The photoconductive material must simultaneously possess (1) high dark resistivity, (2) excellent carrier transport properties, and (3) short carrier lifetime. State-of-the-art photomixers use superlattices of semimetallic ErAs nanoparticles epitaxially-embedded in GaAs [1] as the photoconducting material. However, in order to leverage ubiquitous fiber-optic communications lasers available at 1550 nm, a narrower bandgap matrix material than GaAs is required. To this end, ErAs:$In_{0.53}Ga_{0.47}As$ superlattices have been explored [2], but photomixer performance remains poor due to the unacceptably low resistivity because the Fermi level in the nanocomposite aligns near the conduction band edge of InGaAs.

We present, for the first time, the use of LuAs nanoparticles embedded in an InGaAs matrix and investigate their suitability for photomixer applications. Like ErAs, LuAs is considered to be a semimetal; however, it possesses a smaller lattice parameter, which results in a higher resistivity for LuAs:InGaAs than for ErAs:InGaAs. Samples were grown in a Varian Gen II molecular beam epitaxy (MBE) system on Fe doped InP(100) substrates. 30 period ErAs:InGaAs and LuAs:InGaAs superlattices were grown with rare-earth arsenide depositions, ranging from 0.4-1.2 monolayers (ML), separated by 40 nm InGaAs. X-ray diffraction studies (Fig. 1) indicate good material quality for both sets of samples. Preliminary room temperature Hall Effect measurements (Fig. 2 and 3) show a 3x improvement in resistivity and a 10% improvement in mobility for LuAs:InGaAs, which are both promising for photomixer applications. Temperature-dependent Hall Effect studies are now underway to compare the Fermi level alignment in these material systems and to correlate the Fermi level position with the MBE growth conditions. With further refinement, LuAs:InGaAs photoconductive materials may enable photoconductive THz sources pumped by 1550 nm diode lasers.

References:

[1] J.E. Bjarnason and E.R. Brown, *Appl. Phys. Lett.,* **87**, 134105 (2005).

[2] D.C. Driscoll, M. Hanson, C. Kadow, and A.C. Gossard, *Appl. Phys. Lett.,* **78**, 1703 (2001).

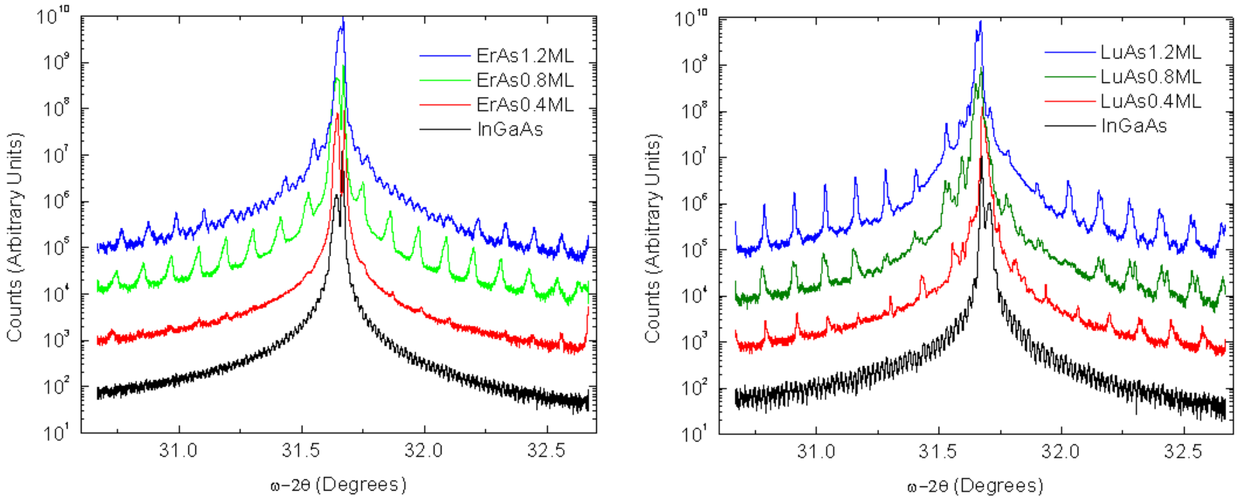

Figure 1. ω-2θ scans of (a) ErAs:InGaAs superlattices with varying Er deposition (0.4, 0.8, and 1.2 ML) and (b) LuAs:InGaAs superlattices with varying LuAs deposition (0.4, 0.8, and 1.2 ML). All materials were grown on Fe doped InP (100). The large number of fringes demonstrate high quality material.

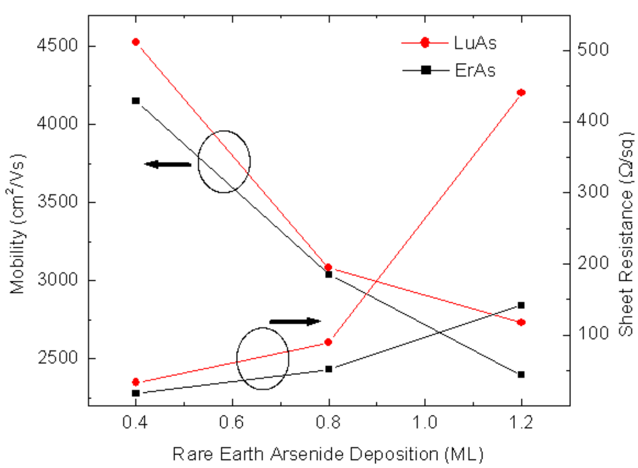

Figure 2. Mobility and sheet resistance measurements of ErAs:InGaAs and LuAs:InGaAs superlattices. The LuAs-containing material had higher overall mobility and higher sheet resistance at 1.2 ML.

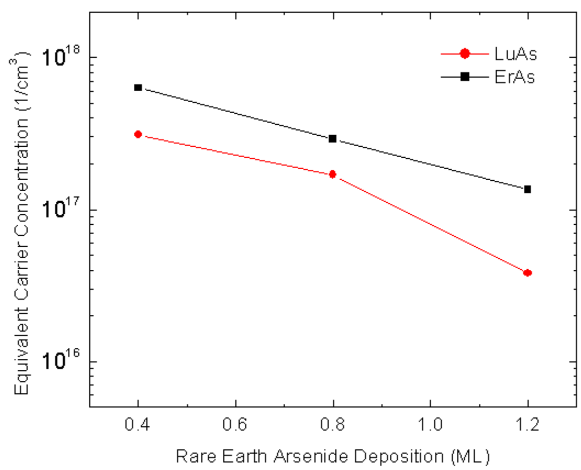

Figure 3. Carrier concentrations of LuAs:InGaAs and ErAs:InGaAs superlattices, extracted from room temperature Hall effect measurements.