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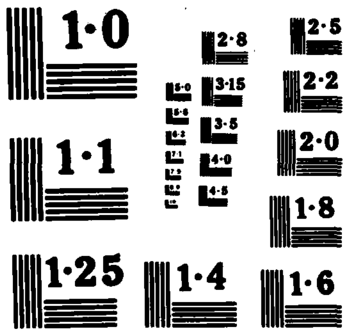
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RAMAN SCATTERING STUDIES IN SOLIDS

FINAL REPORT

R. Merlin

April 30,1985

U.S. ARMY RESEARCH OFFICE

Contract No. DAAG 29-82-K-0057

Department of Physics
University of Michigan

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Raman scattering, semiconductor heterostructures, GaAs, quantum-well structures, Ge-GaAs, shallow impurities, space-charge layers, laser-induced oxidation, magnons, surface-enhanced Raman scattering.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report deals with the following areas: (1) Raman scattering studies of semiconductor hetrostructures and superlattices- The primary interest here is an investigation of donor and acceptor spectra in GaAs-(Al,Ga)As multiple quantum wells- Other studies refer to quasi two-dimensional electron systems in Ge/GaAs and photoexcited GaAs space-charge layers; (2) laser-induced oxidation of metals- It has been found that irradiation leads to the growth of thick amorphous oxide layers. Keywords include:

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Period: 1/18/82 through 1/17/85

In the first stage of the period covered by this grant, our efforts were concentrated in setting up the Raman scattering facility. We are now fully equipped with two independent computer-controlled Raman systems, three cw-lasers and two dye-lasers, together with an optical oven and cryostats to carry out measurements in the temperature range 2-100K. The purchase of one of the Raman instruments (Spex, model 1404), and associated photon-counting detection system and optical components, was made possible with ARO and Research Corporation funding. The second spectrometer (Spex, model 1400) and also one of the lasers (Spectra Physics, model 165) belonged originally to a facility located at the Dearborn campus of the University which is no longer in use. This monochromator was totally upgraded in our laboratory. It is now fitted with a stepping-motor driver and interfaced with a microcomputer which performs the storage and on-line processing of the data. The corresponding software was developed in-house. The 9W-Ar^+ laser (Spectra Physics, model 171) and the ring dye-laser (Spectra Physics, model 380) were purchased from University funds. The third laser (Spectra Physics, model 164) and second dye-laser were part of an atomic physics project that has been discontinued. Funds for the acquisition of the liquid-helium cryostat (Janis, SuperVaritemp) were provided by ARO. The liquid-nitrogen cryostat and the optical oven were built in-house.

The Raman laboratory became fully operational by May 1982. Since then, we began with the planned research in the areas of (1) amorphous superconductors,

(2) $Cu_{2-x}S$, and (3) semiconductor heterostructures and superlattices. The latter project proved to be the most successful. Work on area (1) has been discontinued; we have been unable to obtain reproducible data from amorphous Mo-Ge alloys which, because of their high T_c, appeared as the most promising candidates for Raman experiments. Research on $Cu_{2-x}S$ still focusses on the growth aspects. We have obtained good quality single crystals, but a precise control of the stoicheometry has not yet been achieved.

The following summarizes of our accomplishments in the area of semiconductor single and multiple heterostructures. References are to papers in the list that follows this report (Ref. 10 is a review article written during the term of the current grant, but based on experimental work performed while the principle investigator was at Max Planck Institut in Suttgart):

i) We have obtained resonant Raman data revealing the presence of quasi-two-dimensional (2D) electron systems in Molecular-Beam-Epitaxy (MBE) grown Ge/GaAs heterostructures (Refs. 1 and 11). These results have contributed to settling a long-standing problem related to the behavior of interface states as a function of Ge-coverage [see: H. Brugger et al., Phys. Rev. Lett 52, 141 (1984]. Our findings were reported in an invited paper at the International Conference on Superlattices. Microstructures, and Microdevices, Urbana, Illinois, August, 1984 (Ref. 11).

ii) For the first time, we have identified transitions between donor states in GaAs-$Al_xGa_{1-x}As$ multiple quantum wells (Ref. 4). The Raman data show the expected increase in binding energy with decreasing well width, and the dependence of the binding energy on the impurity location. More recently, we have found evidence of the existence of resonant donor states, i.e., states derived from higher subbands. The latter results were presented at the International Conference on MBE-84 (Ref. 8) and are also reported in a paper submitted to Phys. Rev. Lett. (Ref. 12).

iii) We have shown that photoexcitation of semi-insulating GaAs leads to the formation of a quasi-2D electron system confined at the surface (Refs. 5 and 9). This observation allows a determination of the Fermi-level position at the surface using Raman scattering.

Other than the projects mentioned above, the following refers to research areas not contemplated in the original proposal:

i) We have found that laser irradiation of Ti-alloys leads to the growth of $>10^3$Å thick amorphous oxide layers, analogous to anodic-oxidation (Ref. 6).

ii) Large dielectric anomalies were found at the ferroelastic phase transition in K_2CrO_4. These results, reported at the APS meeting in Detroit (March, 1984), point to a large coupling between orientational and vibrational degrees of freedom. The dielectric measurements have further revealed a new phase transformation at ~330K. Preliminary Raman and X-ray data suggest the possible occurrence of a low-temperature commensurate phase.

iii) Two small projects on magnons in antiferromagnets (Ref. 3) and surface-enhanced Raman scattering (Refs. 2 and 7) were completed. In the latter we reported the first results of enhanced scattering from adsorbates on semiconductor surfaces.

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T.A. Perry (graduate student)
S.D. Russell (graduate student)
D. Gammon (graduate student)

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