This Week's Citation Classic

Tietjen J J & Amick J A. The preparation and properties of vapor-deposited epitaxial $GaAs_{1-x}P_x$ using arsine and phosphine.
J. Electrochem. Soc. **113**:724-8, 1966.
[RCA Laboratories, Radio Corporation of America, Princeton, NJ]

A method is described for synthesizing epitaxial gallium-arsenide-phosphide ($GaAs_{1-x}P_x$) alloys from the vapor phase using arsine and phosphine as sources of arsenic and phosphorus. The crystals prepared by this method exhibit exceptional quality, particularly as evidenced by their electrical properties. [The *SCI*® indicates that this paper has been cited in over 235 publications since 1966.]

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August 16, 1982

"I joined RCA Laboratories in 1963 at a time when interest in light-emitting devices, including injection lasers, was at a very high level. Gallium-arsenide-phosphide ($GaAs_{1-x}P_x$) alloys were of particular interest because they could accommodate a range of visible wavelengths. The major challenge to providing material of device quality involved preparing alloys having very high crystalline perfection, chemical homogeneity, and controllable electrical properties. As a result, epitaxial crystal growth was an attractive approach and, at RCA, this was being pursued by Jim Amick. Jim was in the process of changing his program objectives to become involved in silicon materials and processing technologies, and I inherited this $GaAs_{1-x}P_x$ synthesis project. Jim had been preparing $GaAs_{1-x}P_x$ films on gallium-arsenide substrates by vapor transport of gallium via reactions with hydrogen chloride to form gallium monochloride, and evaporation of arsenic and phosphorus from solid sources. We agreed that greater uniformity might be possible by using gaseous components for the group V elements in order to avoid the exponential temperature dependence of the vapor concentration associated with solid sources. As a result, I designed the apparatus described in this paper to accommodate the use of arsine and phosphine as the sources of arsenic and phosphorus, and to provide careful mixing of these gases prior to reaction with gallium monochloride on gallium-arsenide substrates. The results, as described in the paper, were outstanding and not only led to high-quality injection lasers[1] but also to an improved understanding of electrical transport phenomena in $GaAs_{1-x}P_x$.[2]

"This vapor phase growth method was later extended to permit the preparation of a wide variety of III-V compounds, including most of the alloy systems that can be derived from aluminum and indium and some antimony and nitrogen compounds.

"As a result of this work I received an RCA Laboratories Achievement Award in 1965 and RCA's highest technical honor, the David Sarnoff Outstanding Achievement Award, in 1967. Further application of this synthesis technology to negative-electron-affinity materials,[3] presently employed in the most sensitive commercial photomultiplier tubes, led to an additional Achievement Award in 1969 and a second David Sarnoff Award in 1970.

"I believe this publication has been frequently cited because the technology described served as the precursor for the vapor phase growth of a broad range of III-V compounds which have been used in a variety of advanced devices including light-emitting diodes, varactor diodes, transferred-electron oscillators, and microwave transistors."

1. **Tietjen J J & Ochs S A.** Improved performance of $GaAs_{1-x}P_x$ laser diodes. *Proc. IEEE* **53**:180-1, 1965.
2. **Tietjen J J & Weisberg L R.** Electron mobility in $GaAs_{1-x}P_x$ alloys. *Appl. Phys. Lett.* **7**:261-3, 1965.
3. **Simon R E, Sommer A H, Tietjen J J & Williams B F.** $GaAs_{1-x}P_x$ as a new high quantum yield photoemissive material for the visible spectrum. *Appl. Phys. Lett.* **15**:43, 1969.