



Figure 2. Small Changes in Electrical Resistances of four polymer/carbon composite films to airborne mercury vapor were observed at concentrations as low as tens of parts per billion.

closer to room temperature than to the elevated temperatures (>100°C) needed for regeneration of sensors based on noble-metal films.

The present polymer/carbon films are made from two polymers, denoted

EYN1 and EYN2 (see Figure 1), both of which are derivatives of poly-4-vinyl pyridine with amine functional groups. Composites of these polymers with 10 to 15 weight percent of carbon were prepared and solution-deposited onto

the JPL ElectronicNose sensor substrates for testing. Preliminary test results showed that the resulting sensor films gave measurable indications of airborne mercury at concentrations on the order of tens of parts per billion (ppb) or more. The operating temperature range for the sensing films was 28 to 40°C and that the sensor films regenerated spontaneously, without heating above operating temperature (see Figure 2).

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*In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:*

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## Lattice-Matched Semiconductor Layers on Single Crystalline Sapphire Substrate

**Rhombohedrally grown lattice-matched semiconductor alloys can be used in photovoltaic solar cells and photon detectors.**

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SiGe is an important semiconductor alloy for high-speed field effect transistors (FETs), high-temperature thermoelectric devices, photovoltaic solar cells, and photon detectors. The growth of SiGe layer is difficult because SiGe alloys have different lattice constants from those of the common Si wafers, which leads to a high density of defects, including dislocations, micro-twins, cracks, and delaminations.

This innovation utilizes newly developed rhombohedral epitaxy of cubic semiconductors on trigonal substrates in order to solve the lattice mismatch problem of SiGe by using trigonal single crystals like sapphire (Al<sub>2</sub>O<sub>3</sub>) as substrate to give a unique growth-orientation to the SiGe layer, which is automatically controlled at the interface upon

sapphire (0001). This technology is different from previous silicon on insulator (SOI) or SGOI (SiGe on insulator) technologies that use amorphous SiO<sub>2</sub> as the growth plane.

A cubic semiconductor crystal is a special case of a rhombohedron with the inter-planar angle,  $\alpha = 90^\circ$ . With a mathematical transformation, all rhombohedrons can be described by trigonal crystal lattice structures. Therefore, all cubic lattice constants and crystal planes (hkl)'s can be transformed into those of trigonal crystal parameters. These unique alignments enable a new opportunity of perfect lattice matching conditions, which can eliminate misfit dislocations. Previously, these atomic alignments were thought to be impossible or very difficult. With the invention of a new x-ray diffrac-

tion measurement method here, growth of cubic semiconductors on trigonal crystals became possible.

This epitaxy and lattice-matching condition can be applied not only to SiGe (111)/sapphire (0001) substrate relations, but also to other crystal structures and other materials, including similar crystal structures which have point-group rotational symmetries by 120° because the cubic (111) direction has 120° rotational symmetry. The use of slightly miscut ( $\leq 10^\circ$ ) sapphire (0001) substrate can be used to improve epitaxial relationships better by providing attractive atomic steps in the epitaxial process.

*This work was done by Sang Choi and Glen King of Langley Research Center and Yeonjoon Park. Further information is contained in a TSP (see page 1). LAR-16868-1*