COMMERCIALIZATION ASSISTANCE PROGRAM

Diamond Sensor Development for Sensing Radiation and Temperature

AET, Inc.

Business Opportunity:

Most current radiation and temperature sensing solutions are based on sensors fabricated from silicon. These silicon-based sensors are typically used in the aerospace industry for monitoring the environmental parameters for missiles and other air vehicles. The silicon-based sensors have been attractive due to their low manufacturing cost and their ease of integration with existing electronics. However, sensing in increasingly harsher radiation and temperature environments is becoming an industry requirement. In these high radiation and high temperature environments, silicon-based sensors perform poorly as they become insensitive to changes in temperature and radiation, and in extreme cases, they fail completely. There is an industry requirement, and thus a business opportunity for sensors that offer high performance sensing characteristics in these high radiation and temperature environments.

Advanced Engineering Technology (AET Inc.) and Vanderbilt University have developed sensors made from diamond that provides high performance sensing and unsurpassed reliability in high radiation and high temperature environments, yet are par with silicon in terms of cost.

For military applications, AET is looking for a government contractor to collaborate or license this technology into an existing contract program or anticipated proposal. For non-military applications, AET is looking for industry-specific licensees, product investors, or clients for end-use applications. AET is also looking to find Integrated Circuit (IC) manufacturers for final industrial design and volume production.

Company Background:

AET was founded in 1995 as an IC design and development company specializing in radiation hardened IC's and technologies for harsh environments. AET currently has a professional staff of 5 and has added IC simulation, prototyping, and testing to its design and development capabilities.

Industry Problem:

As technologies continue to evolve, the requirement of operating in harsh environments such as military, space, oil drilling, and heavy machinery advance the boundaries in design criteria. As one technical area in a system advances, it pulls on greater performance from other areas. The ability to sense small fluctuations in environmental parameters such as radiation and temperature have become critical requirements. For these parameters, the next-generation sensors must posses:

1. The ability to sense very small changes in very high levels of radiation and temperature. Silicon-based sensors become insensitive to changes in these high levels while diamond-based sensors are extremely sensitive to these changes.
2. The sensors must be inexpensive which allows them to be distributed throughout the target system. AET and Vanderbilt have developed a fabrication process for diamond sensors that is identical to that used in traditional silicon sensor fabrication. Thus, diamond sensors can be fabricated at very low costs.
3. The sensors must be able to integrate with the current system electronics. Current and future system electronics is a silicon environment. Advances in Silicon-On-Insulator (SOI) technology and geometries in the nanoscale provide ultra high performance and extremely reliable electronics for high temperature and high radiation environments. Unfortunately, they make for very poor sensors. AET and Vanderbilt have developed a technique whereby diamond sensors may be fabricated directly on fully fabricated silicon wafers. The diamond-based sensor solution developed by AET and Vanderbilt meets all three of these industry requirements for the next generation high performance sensing solutions.

Technology:

AET and Vanderbilt have developed diamond sensors that can be integrated into a silicon chip. This technology provides both the high performance sensing and environmental strength of diamond with the high performance signal processing circuitry of silicon.

AET has developed a process flow for combining high performance silicon integrated circuit structures and diamond sensors on the same chip. This allows the high performance silicon-based system electronics to reside in silicon where it belongs and the high performance sensing to reside in diamond. The two are interfaced through standard IC processing techniques.

The silicon process proceeds through standard wafer processing steps including multiple metal layers and a passivation layer. At this point, the high performance silicon electronics have been fabricated. The diamond sensors are then fabricated on the finished fully functional silicon wafer. The diamond sensors are then interfaced with the silicon electronics through a conventional wire bonding process.

The resulting IC contains both the high performance silicon system electronics as well as the high performance diamond sensors in a single chip solution.

Advantages:

- <u>Higher performance sensing technology in harsh environments</u>. Traditional silicon sensors, at best, under-perform and in most applications become insensitive or fail. Diamond sensors excel in these environments.
- <u>Integrating diamond sensors with silicon integrated circuit electronics</u>. Low cost and high reliability are inherent in the one IC solution. A traditional solution for integrating diamond sensors with silicon electronics would require two IC's, packaged in a Multi-Chip Module (MCM). MCM's are costly and prone to reliability problems.
- <u>Cost effective fabrication lends to distribution throughout target system applications</u>. One sensor per system is typically the norm. Diamond sensors fabricated on silicon electronics are extremely cost effective, reliable, and lend themselves to such a desired distributed sensing solution.

Differentiating Feature:

AET's diamond sensor is readily integrate able with existing system electronics. The electrical signals from a sensor must also be compatible with the target application's existing

control and logic circuitry. By integrating a silicon-based layer of circuitry, the signals from the diamond sensors can be modulated such that the sensor output can be tuned for the target application's electrical requirements.

Stage of Development:

Proof of concept and feasibility of diamond sensors was completed in a Phase I SBIR program. Researchers are currently continuing the development and optimization of the diamond sensors. Data is being taken for radiation and temperature sensitivity. The integration of the diamond sensors with silicon IC's is underway. First proof of concept sensor prototype expected in summer 2009.

Competing Technologies:

There are no competing technologies that offer the superior performance, unsurpassed reliability, and ease of integration provided by AET's diamond-based sensor system. There are individual technologies that provide high performance sensing in high radiation or high temperature environments. These are expensive solutions and are typically deployed only on the most mission critical systems.

Applications:

- Missiles and air-vehicles. Sensors on the outside of these vehicles are needed for early warning of harsh environments that may harm sensitive electronics and other components.
- Oil and natural gas exploration. Integrating ultra high performance temperature sensors into a drilling system would provide high temperature monitoring along the drill pipe avoiding catastrophic failure.
- Automotive systems. Automotive sensors and their control electronics are currently contained in very expensive modules. Employing diamond sensors with silicon electronics would not only reduce automotive system cost, but also reduce end user replacement cost as well.

Benefits:

- Military Systems (air vehicles, missiles) – Improved sensing in radiation and high temperature environments. Distributed sensing capability replaces single high-cost sensor
- Commercial Systems (oil exploration, automotive) – Inexpensive sensing in extreme temperature environments. Workers benefit from added safety.

Intellectual Property:

AET Inc. owns the intellectual property relating to fabricating diamond sensors on silicon. Vanderbilt owns the intellectual property of the diamond sensor fabrication process. A licensing agreement will be negotiated between AET and Vanderbilt for the use of the diamond sensor fabrication process.