# MODEL AX6560 CVD DIAMOND DEPOSITION SYSTEM for Tooling Applications

- Deposits CVD diamond at growth rates and uniformity necessary for practical, cost-effective tooling applications
- Enables pilot production of CVD diamond-coated tools
- Provides a path to full-scale production
- Includes proprietary process knowledge, which significantly shortens the user's learning curve
- Easy to use
- Available with extensive after-sales service and support for high reliability and uptime

**Seki Technotron**

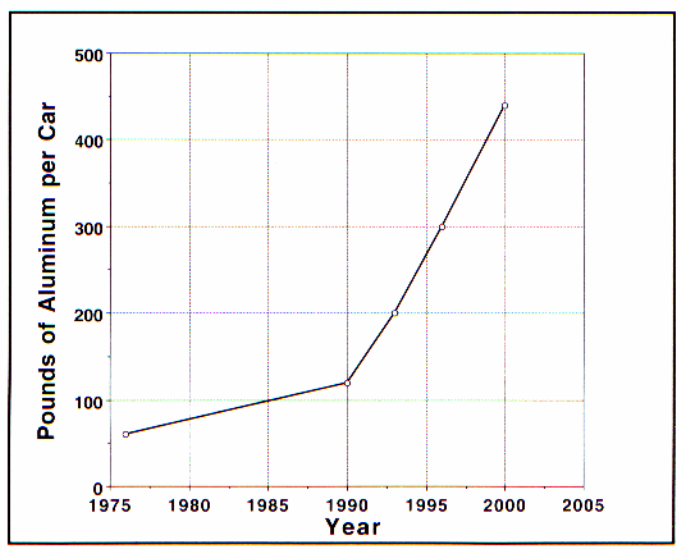
## INTRODUCTION

The AX6560 CVD Diamond Deposition System provides users with key benefits associated with chemical vapor deposition (CVD) diamond. Diamond's remarkable properties — it is the hardest known material, has the highest tensile and compressive strength, and has low thermal expansion — make it the ultimate choice for tool coating applications. CVD diamond-coated tools last longer, produce finer cuts, and operate at sharper rake angles than any other tools. Diamond is the unsurpassed choice for cutting and machining of non-ferrous metals — a diamond-coated cutting tool can cut a 1,200 mile groove in bronze before requiring sharpening, which is almost 60 times longer than a tungsten carbide tool and 240 times longer than a steel tool.*

CVD diamond-coated tool inserts offer several advantages over polycrystalline diamond (PCD) inserts. Among these advantages are:

- lower cost
- multiple cutting edges on a single tool
- tools with advanced chip breaker designs can be coated
- elimination of the need to polish the diamond edge since, with proper morphology, tools can be used as grown

All these factors increasingly make CVD diamond the coating of choice for tungsten carbide, silicon nitride, and silicon carbide tools used to cut and machine such materials as: aluminum, copper, zinc and magnesium alloys, superalloys, many forms of composites and plastics, advanced ceramics, and wood. The move to CVD diamond tools is expected to accelerate with the increasing use of advanced non-ferrous materials and the decreasing use of steel. For example, driven by the need for improved gas mileage, the amount of aluminum used in automobiles is expected to increase rapidly in the next few years, as shown in the figure below. This increase is a consequence of the replacement of heavy steel parts with strong, lightweight, high silicon content aluminum alloys and other composites.




The AX6560 combines ASTeX's most advanced microwave reactor design and high growth rate diamond deposition processes into a turnkey system for pilot production of CVD diamond-coated tool inserts. The AX6560 is designed with the needs of the manufacturing environment in mind, including: easy loading, push-button operation, low maintenance, and high uptime. In addition, the AX6560 is ideally suited for robotic tool handling in a production environment.

**CVD Diamond and Related Superhard Materials*, C. James Russell, (Decision Resources, Inc., 1993).

## ADVANTAGES

The AX6560 can be your enabling instrument in the CVD diamond market. Following is a list of the AX6560's key user benefits and a detailed discussion of the system features which facilitate these benefits. The AX6560:

### • Deposits CVD diamond at growth rates and uniformity necessary for practical, cost-effective tooling applications

The AX6560 takes advantage of ASTeX's recently developed, high-power density deposition processes to provide CVD diamond coatings at high rates over a batch area approximately 4.0 inches in diameter. Specially designed tool holders allow excellent coating uniformity. Tool spacing is optimized to provide adequate flank coverage.

### • Enables pilot production of CVD diamond-coated tools

The following example for a batch of 20 SPG422-type inserts illustrates the economics of AX6560 operation in a pilot production application. Run time is assumed to be seven hours, including loading, pump-down, and venting. A three-shift, five-day week and 85% uptime are assumed (remaining time is used for routine maintenance and repairs). Annually computed results are shown below.

***Example of AX6560 Economics* in Pilot Tool Insert Production***

| **SPG422 Production** | ***Annual Insert Yield*** |
|---|---|
| 930 batches at 20 tools each, with insert yield assumed at 75% | 14,000 |
| **Depreciation**** | ***Annual Cost*** |
| $480,000 over five-year period | $96,000 |
| Support facilities over five-year period | 12,000 |
| **Consumables** | |
| Electricity at $0.10/kWh | 5,000 |
| Gas consumption (mainly hydrogen) | 1,500 |
| Magnetrons (one per year) | 5,000 |
| **Space** | |
| 100 sq ft at $80/sq ft (complete with facilities) | 8,000 |
| **Labor** | |
| Operator 0.2 FTE ($30,000/yr + 150% OH rate) — three shifts | 47,000 |
| Supervisor 0.1 FTE ($50,000/yr + 150% OH rate) — three shifts | 37,500 |
| **Cost of Capital** | 30,000 |
| **Service and Maintenance** | |
| Service contract with ASTeX | 35,000 |
| **Total Annual Operating Costs** | **$277,000** |
| **Cost per insert** | **$20** |

**For illustrative purposes only; actual numbers may vary.*
***Greater economies may be achieved with multiple system purchases.*

### • Provides a path to full-scale production

The AX6560 is the second reactor in a series that incorporates ASTeX's newly developed microwave diamond deposition reactor technology (patents pending). This new technology will continue to be developed by ASTeX for further scale up to still greater throughput systems. The AX6560, which is available immediately, enables the user sufficient tool production capacity for rapid development of the adhesion technology required to capture a significant market share in the highly competitive tool insert market. Economic calculations, based on the projected performance of the next generation systems, indicate a further factor of 4 reduction in the per-tool coating cost over those shown in the table above. Such low production costs would allow an aggressive pricing structure for diamond-coated inserts to ensure their success as a PCD replacement.

- **Includes proprietary process knowledge, which significantly shortens the user's learning curve**

  A number of process recipes, developed specifically for use with the high-power density system, are included. In addition, unique tool fixturing (for SPG422 inserts) is provided for optimization of deposition uniformity on each tool and for different tools within a batch. Customer support for the development of other fixturing is available at a nominal consulting fee rate.

- **Easy to use**

  The AX6560 is completely computer controlled — it can run immediately at the touch of a button. Process recipes are stored and can be loaded within the system to ensure reproducibility and eliminate operator error.

- **Available with extensive after-sales service and support for high reliability and uptime**

  Free installation and three-day training for the operator are included in the price. A service contract (to cover periodic visits for routine maintenance) is available.


*Above: SEM photograph of one corner of a diamond-coated $SiN_x$ insert.*
*Below: Closer view of tool insert shown above.**


Tungsten carbide with a 6% cobalt binder is the most common tool insert material used for machining hard metals, composites, and ceramics. Due to its broad use, this material has been selected by the tool insert industry as the prime candidate for diamond coating development. The cobalt binder leads to formation of a graphitic interlayer with poor adhesion properties, thus making the development of adherent films a challenge. However, over the past year, several companies have announced the development of adhesion techniques which have resolved this issue. The race is on to capture a significant fraction of the diamond-coated tool insert market.

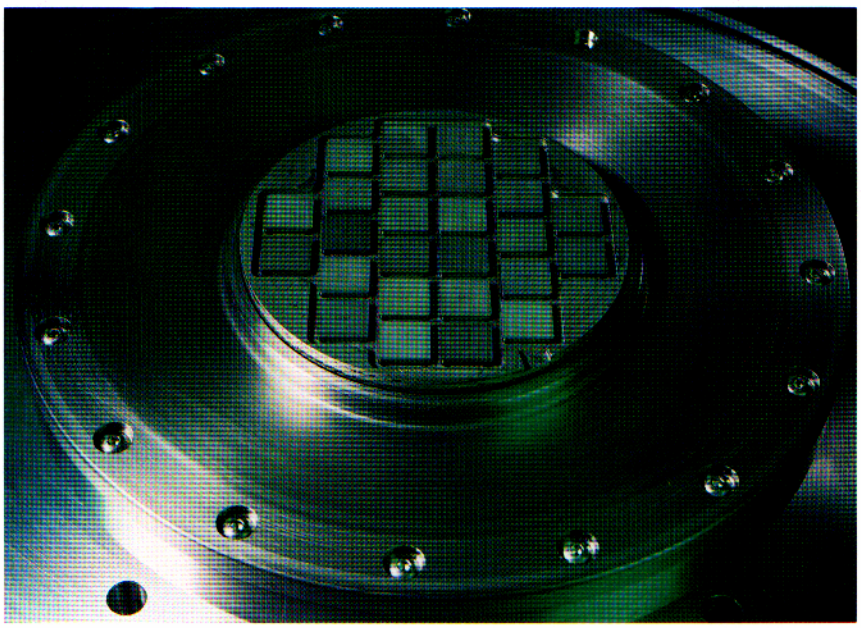
Optimization of the morphology and size of diamond crystals in a film is relevant to the surface finish of the workpiece. ASTeX works closely with its customers to develop deposition processes which give the desired finish without the need for polishing the inserts after deposition.

**A wide range of crystal morphologies and sizes are possible.*

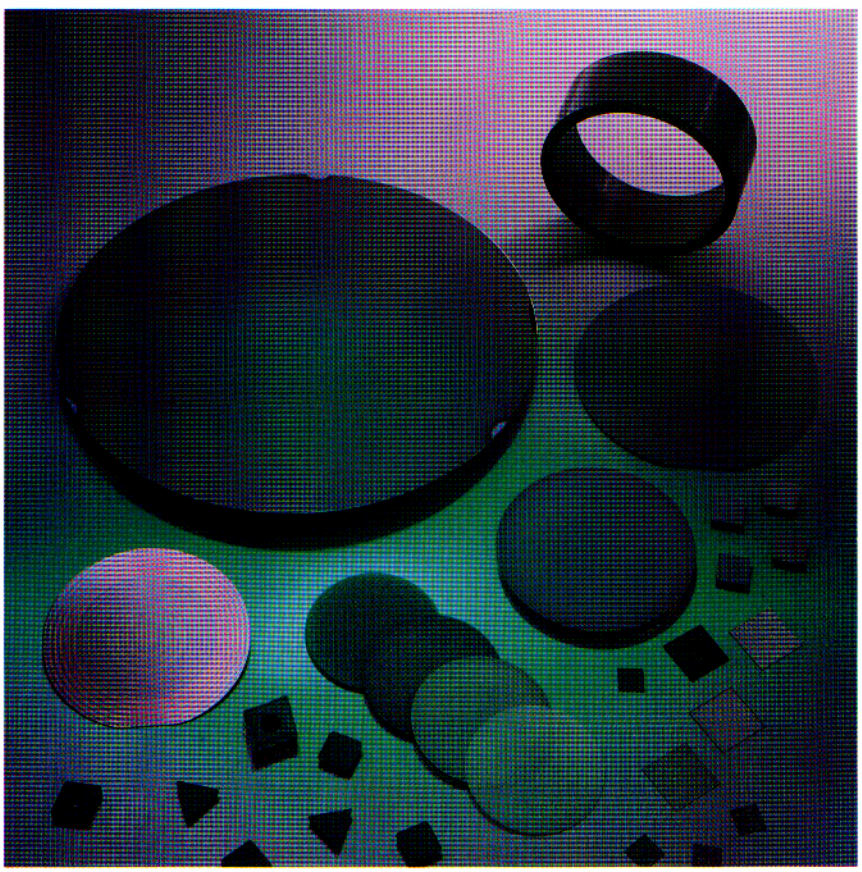
## CVD Diamond Products

The figure below shows an example of a loading configuration for SPG422 inserts over a 4 inch diameter loading area. The AX6560 is designed to provide clear and easy access to substrates, making loading and unloading a simple operation. This design also allows the straightforward implementation of robotics for loading operations, if desired.

The AX6500 Series of reactors is designed to satisfy customer needs in all applications areas for thin and thick diamond films. Specialized reactors are available or under development for each application area, including tool inserts, thermal management, optics, and electronics.



*Above: SPG422 inserts in standard tool fixture on AX6560 substrate stage.*
*Below: Examples of CVD diamond-coated wafers and tool inserts, as well as thick diamond films suitable for thermal management applications.*



Revision 2

## BRIEF TECHNICAL DESCRIPTION

### *AX6560 Reactor Chamber and Vacuum System:*

An extruded and cast aluminum frame encloses all the valves, vacuum components, and instrumentation for system operation and monitoring. This enclosure holds all the components of the microwave system and reactor assembly. The enclosure has removable side panels for complete interior access. An externally-mounted pump is standard; a turbomolecular pump is optional.

### *Control System:*

The control system is designed for unattended system operation. The computerized distributed control system provides fully automatic, semi-automatic, or fully manual modes of operation via an interactive color graphic display. The control system also performs data logging of system parameters for future analysis. Real time trending, alarm annunciation, and report generation and print-out are supported. An unlimited number of process recipes can be stored in files.

### *Gas Handling System:*

The modular intelligent gas handling system is controlled via an RS-422 communication port and is capable of accurate distribution of up to six process gases. Four gas channels are standard. Independent purging of individual gas lines is provided via computer control. The gas handling system may be installed in a location remote from the reactor chamber. Vacuum interlocks and a provision for an enclosure purge are included to insure safe operation.

### *Control Rack:*

The control rack enclosure contains the microwave power supply, computer, and control system components. Single phase 115 VAC is generated locally for all controls and system instrumentation. A spare circuit for scientific instrumentation is included. A low voltage EMO circuit is provided for remote emergency system shut-down.

## SPECIFICATIONS

### *Processing Chamber:*

| | |
|---|---|
| *Chamber Material* | Aluminum Alloy |
| *Maximum Substrate Size* | 4 in. diameter |
| *Access* | Top-loading |

### *Gas Pod:*

| | |
|---|---|
| *Number of gases* | 4 standard, expandable to 6 |

### *Microwave Generator:*

| | |
|---|---|
| *Output Power* | 1000 – 8000 W, continuously variable |
| *Operating Frequency* | 2450 MHz nominal |
| *Regulation* | 1.0 % of output power |
| *Tuning* | Automatic |

### *Overall:*

| | | |
|---|---|---|
| *Electrical Service* | Line Power Input | 480 VAC, 60 Hz, 25A/Phase<br>*or*<br>380 VAC, 50 Hz, 30 A/Phase<br>3-phase, wye, 4-wire, ground |
| *Cooling Water* | Deionized at 60 - 80 PSIG, with flow of 8 GPM | |
| *Dimensions* | Processing Module with Gas Pod | |
| | *chamber closed* | 36 in. w, 24 in. d, 58 in. h |
| | *chamber open* | 36 in. w, 24 in. d, 75 in. h |
| | Gas Pod | 21 in. w, 10 in. d, 47 in. h |
| | Control Rack | 24 in. w, 36 in. d, 79 in. h |
| | Vacuum Rack | 30 in. w, 24 in. d, 54 in. h |

## OPTIONS

| | |
|---|---|
| *Additional Gas Channels* | *Up to 2 (for a total of 6 gas channels)* |
| *Turbomolecular Pump Package* | |
| *Infrared Pyrometer* | |

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