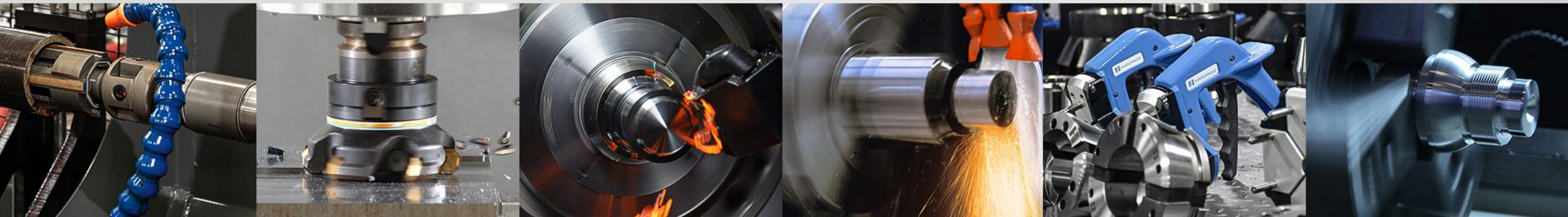
HARDINGE

STREAMLINING SiC BOULE FABRICATION

HARDINGE'S BOULEPRO 200 INVENTS LOW-COST BOULE SHAPING



AGENDA

- Who is Hardinge?
- SiC market and end use applications
- Introduction to BoulePro 200AX
  - Experience with SiC
  - Traditional approach to SiC boule shaping
  - BoulePro process
  - BoulePro advantages
  - Additional capabilities
- Related opportunities – alternate materials & markets

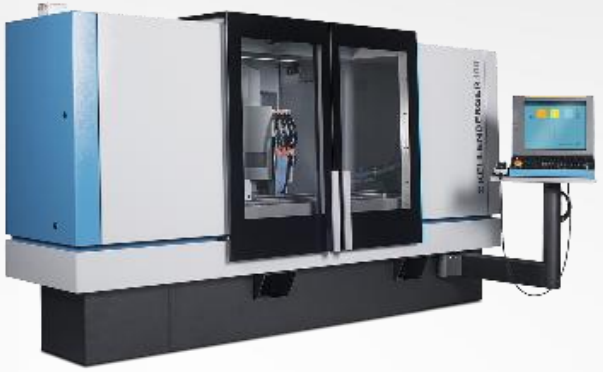
WHO IS HARDINGE?

- Global provider of high precision machine tools, automation and workholding empowering customers in manufacturing innovation for critical, hard to machine products.

- With over 130 years of experience, we offer the largest variety of machine tool solutions
- We design, manufacture, and distribute machine tools in over 65 countries across North America, Europe, and Asia.

BEST-IN-CLASS

MACHINE TOOL SOLUTIONS

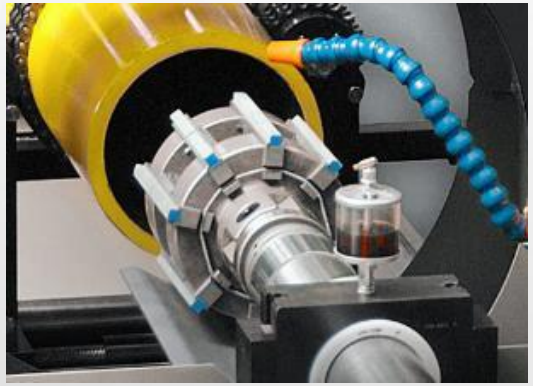


GRINDING

- Universal Cylindrical Grinders (OD/ID)
- ID Grinders
- Jig Grinders
- Specialty ID & OD Systems

WORKHOLDING

- Lathe Collets
- Swiss Collets
- Manual Chucks
- Power/Precision Chucks
- Specialty Clamping Chucks
- Quick Change Systems
- Clamping Cylinders, Jaws & Accessories



ADVANCED TECHNOLOGY

- Specialized machine design and build for hard to process material (uranium, silicon carbide)
- Automation / robotics to increase productivity
- In process controls (probes, x-ray vision systems)
- Highly specialized workholding

BEST-IN-CLASS

MACHINE TOOL SOLUTIONS

TURNING

- Multi-Functional CNC Lathes
- SUPER-PRECISION® Accuracy
- Production & Automated Cells
- Solutions for Job Shops or High-production OEMs

MILLING

- 3 to 4+1 Axis CNC Mills
- 5 Axis/5 Face CNC Mills
- Knee Mills

Table Size Range: 250 mm to 1600mm

HONING

- Horizontal and Vertical Honing Machines
- Light, Medium and Heavy-duty Honing Tools
- Vitrified & Metal bonded Super Abrasives

ADDING IN A SOLUTION BASED APPROACH

Hardinge differentiates itself by providing solutions of the highest quality, accuracy, and durability

DEFINE CUSTOMER NEEDS

- Understand customer pain points
- Identify customer's technology and product roadmap
- Define what is success

ALIGN ON APPROACH

- Identify where Hardinge's Technology overlaps customer needs
- What additional capability can Hardinge bring to the table (Service, Apps, Turnkey)
- Gather all cost and process information from end to end
- Develop TCO model for value creation

UTILIZE CROSS FUNCTIONAL EXPERTS

- Turning & Milling

- Grinding & Honing

- Aftermarket Tooling & Accessories

DELIVER CUSTOMIZED SOLUTION




FOCUSED CUSTOMER SEGMENTS

- E-Mobility
- Aerospace/Defense
- Automotive
- Medical
- Mold & Die
- Construction
- Semiconductor
- Electronics




SiC MARKET AND END USE APPLICATIONS

- Silicon Carbide is a semi-conducting or semi-insulating material used in many different types of electronic devices such as diodes, MOSFETS, JFETS, etc.
- It is replacing Silicon based devices for applications that require high power density, high frequency, and high voltage applications
- Electric Vehicles and 5G are major users of these devices
- Silicon Carbide is grown via a Physical Vapor Transport (PVT) process in high temperature furnaces, and typically takes 2-4 weeks to grow a crystal (boule) that is only a few kilograms in size (diameters of 150mm now, 200mm future)
- The crystal then needs to be shaped into a wafer ready geometry (puck) and then sliced into wafers for device makers to build on
- It is this post growth process for which Hardinge has developed an innovative solution

INTRODUCTION TO BOULEPRO 200AX

CRYSTAL GROWTH

WAFERING

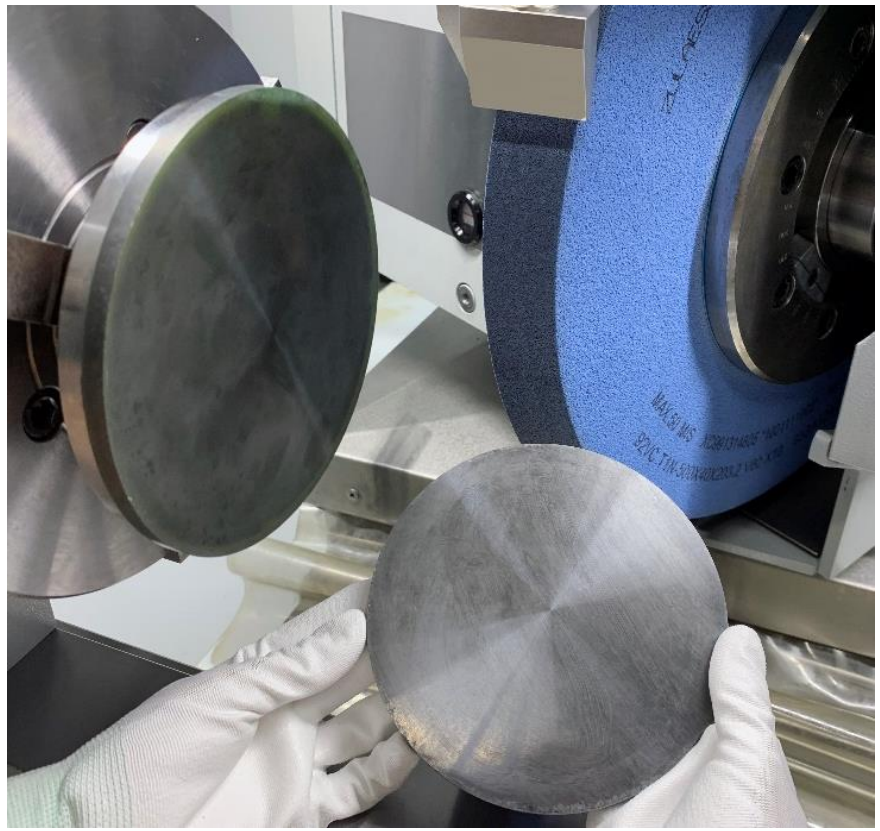
INTRODUCTION TO BOULEPRO 200AX

CRYSTAL GROWTH

WAFERING

INTRODUCTION TO BOULEPRO 200AX – EXPERIENCE WITH SiC

- Extensive experience machining SiC material meant for semiconductor applications as well as non-semi applications
- Worked with a variety of SiC boules from Tier 1 suppliers to new entrants.
- Successfully optimized all steps to convert a SiC boule to wafer ready puck – OD, Flat and Notch, Dome / Seed side removal, material handling
- Integrated all of the steps into a fully automated machine design, including XRD to identify and compensate for crystal orientation (patent pending Single Step Dual plane Compensation, SSDC), to provide SiC crystal producers with the most efficient and lowest cost solution
- Internally processing material for SiC substrate manufacturers and performing customer demonstrations on the BoulePro 200AX



INTRODUCTION TO BOULEPRO 200AX – TRADITIONAL APPROACH TO BOULE SHAPING

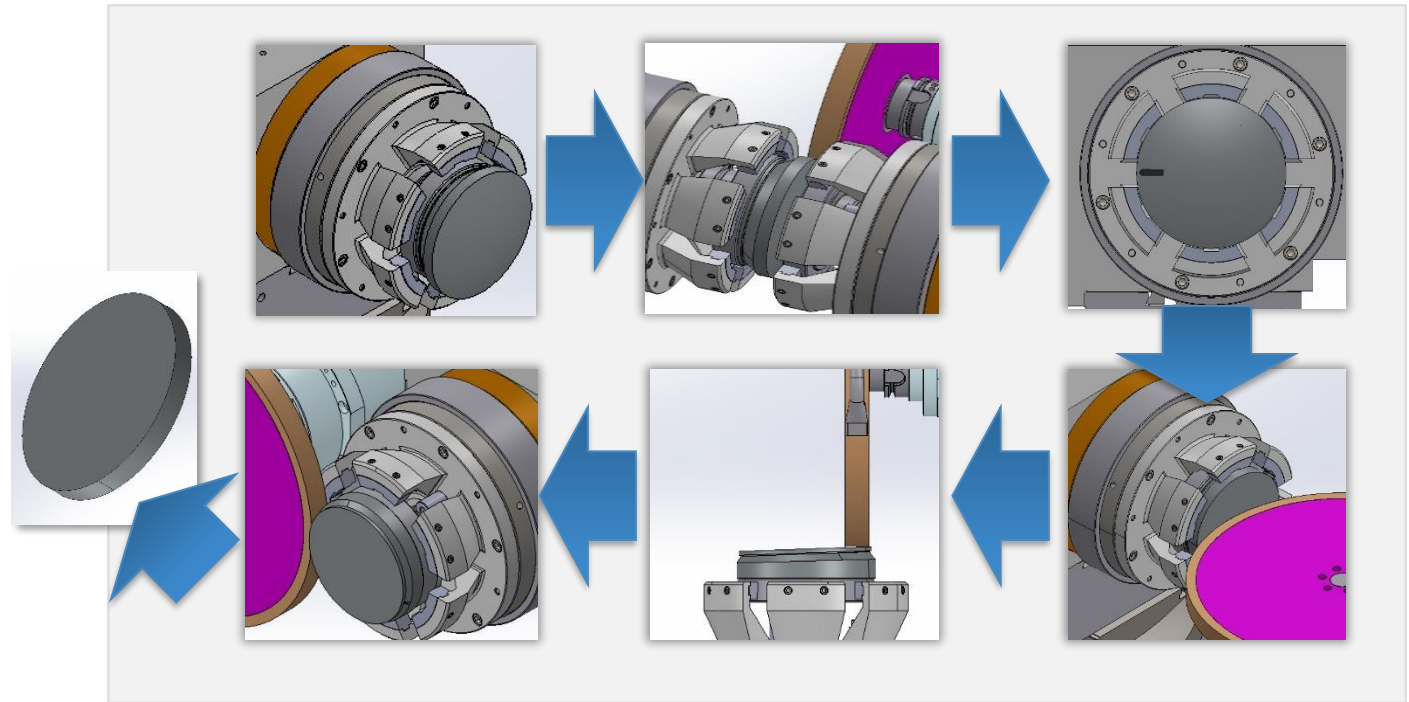
THE TRADITIONAL APPROACH TO BOULE SHAPING IS HIGHLY INEFFICIENT AND COSTLY DUE TO THE FOLLOWING:

- Use of multiple tool sets to perform different functions (OD grind, flat / notch, X-ray, seed / dome removal)
- Use of multiple operators for various tool sets – significant footprint and utilities required
- Gluing and de-gluing the boule to different carriers for different steps
- Increased process variability from manual material handling and setups
- No common best practices driving optimization

INTRODUCTION TO BOULEPRO 200AX – BOULEPRO PROCESS

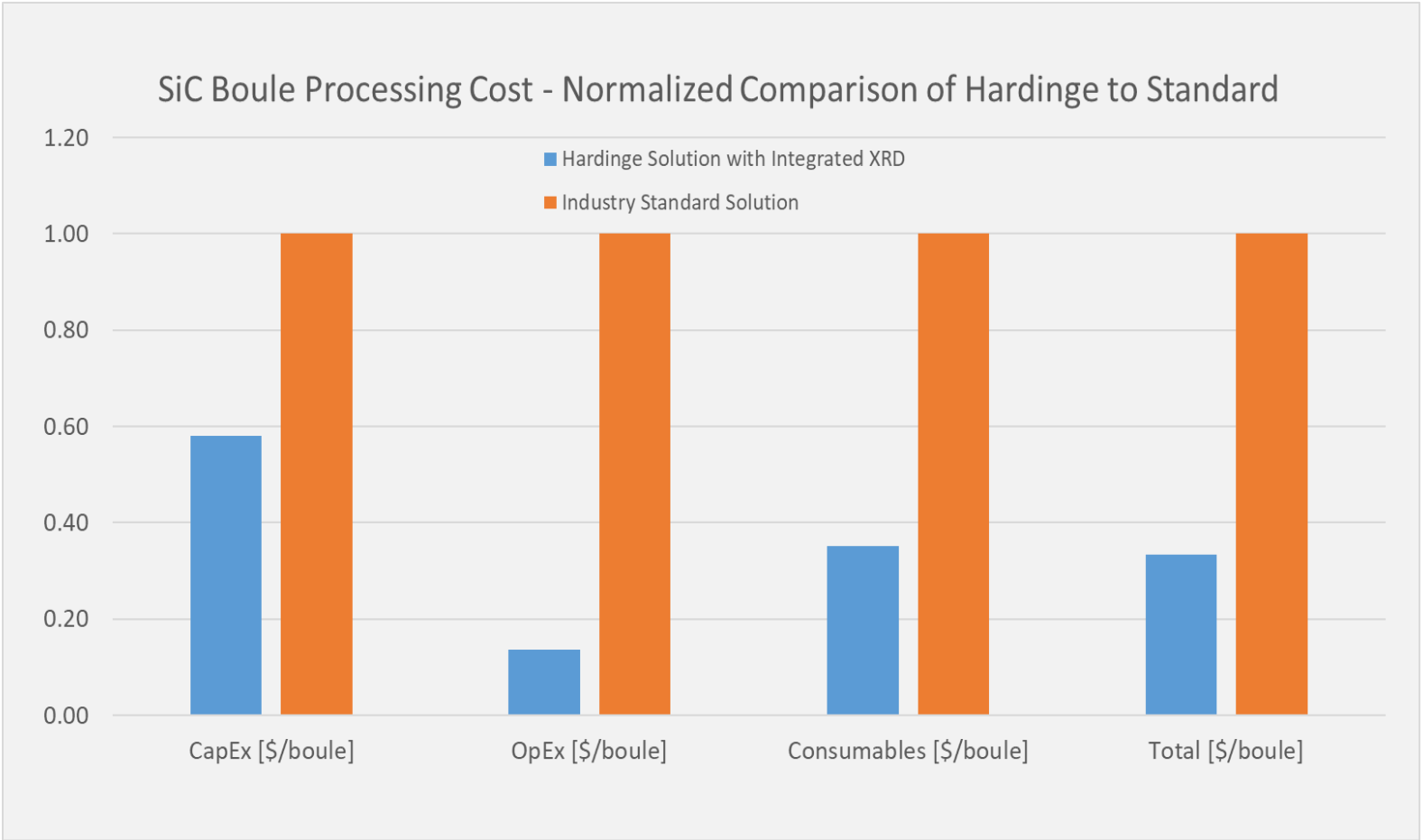
- The BoulePro 200AX is a fully automated, self-contained machine tool that processes as grown SiC boules to wafer ready pucks with no gluing / fixturing, external material setup or manual intervention needed. With its patent pending single step, dual plane compensation (SSDC) capability enabled by the integrated X-ray diffraction (XRD) tool, the BoulePro carries out all steps of the boule to puck conversion process in a dramatically shortened period.

- The process flow can be adjusted from customer to customer and boule to boule, however, the general process flow is as follows:
  - Boule load
  - Initial OD applied
  - Rough dome grind
  - XRD taken
  - Finish dome grind
  - Handoff to secondary workhead
  - Seed side removal
  - XRD to confirm
  - Final OD and flat / notch
  - Remove wafer ready puck



INTRODUCTION TO BOULEPRO 200AX – BOULEPRO ADVANTAGES

- 85% reduction in labor cost
- 80% reduction in manufacturing footprint
- One machine tool accomplishes all the required steps in a fully automated process that takes two – three hours
- Advanced degree of automation provides for improved process repeatability
- Total cost (CapEx, OpEx, consumables) reduction of nearly 70% compared to today's industry standard



INTRODUCTION TO BOULEPRO 200AX – ADDITIONAL CAPABILITIES

UV LIGHT INSPECTION FOR FOREIGN POLYTYPE:

- When SiC boules are placed under a UV light, certain foreign polytypes, such as 6H, will show as a different color. The UV light shows the location of the 6H inclusion(s) and the machine removes it, so the final SiC puck contains only the desired 4H polytype.

LASER SCRIBING

- The ability to make a laser scribe on the finished SiC puck surface can be added so the customer can appropriately track the lot #, boule #, etc. for material tracking purposes.

VISION SYSTEM:

- The vision system can take high end photos of the boule or puck as the customer desires at any stage of the process.

All the additional capability can be added into the BoulePro at anytime – completely retrofittable into existing machines

RELATED OPPORTUNITIES - ALTERNATE MATERIALS & MARKETS

- Many other rapidly growing material markets with opportunity for fully automated processes for hard to machine and/or unique material

- SiC Ceramics market is one such growing area
  - Advantages in material properties
    - Lightweight, low thermal expansion, high strength, chemical inertness – automotive, aerospace defense, machinery manufacturing, etc.
  - PVT SiC for semiconductor substrate material
  - CVD SiC
  - Recrystallized
  - Hot pressed
  - Reaction bonded
  - Direct sintered

- Kenneth Research estimated this market at ~950M revenue for 2021 with a CAGR of ~20% for the next decade

- Hardinge is exploring this market and others looking for similar opportunities!

HARDINGE®

THANK YOU