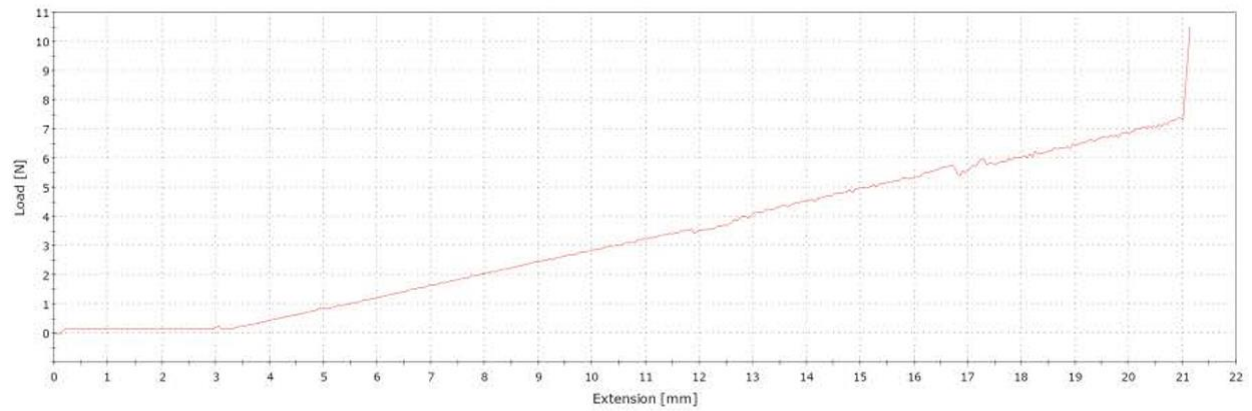


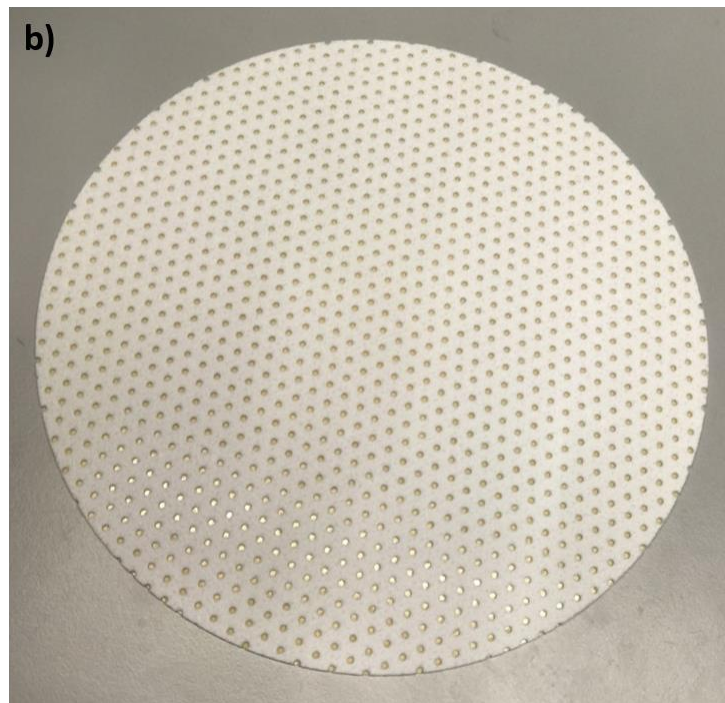
## Appendix A



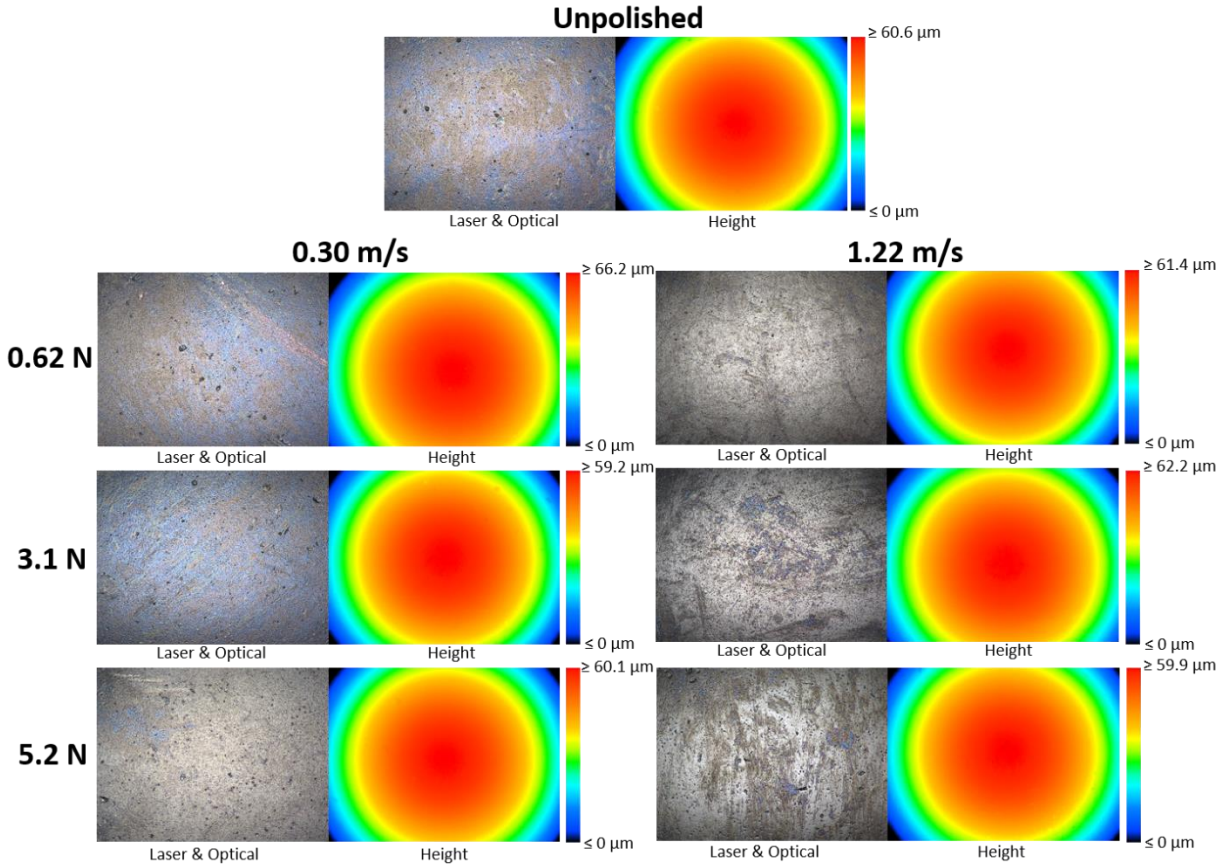
*Appendix A1: Damaged LaboPol-5 polishing machine before repairs (a), with close-up images showing the casing (b), polishing wheel and bowl (c), chemical damage to the interior and screwhead destruction (d) and loss of seal between bowl and waste pipe (e).*



*Appendix A2: Exerted normal force in relation to compressed distance of a polishing modification made by AMOLF research institute, used to determine the relevant normal force per graduation of the modification. These results were measured using an Instron Static Loading Cell 2530 Series with  $\pm 10$  N capacity.*

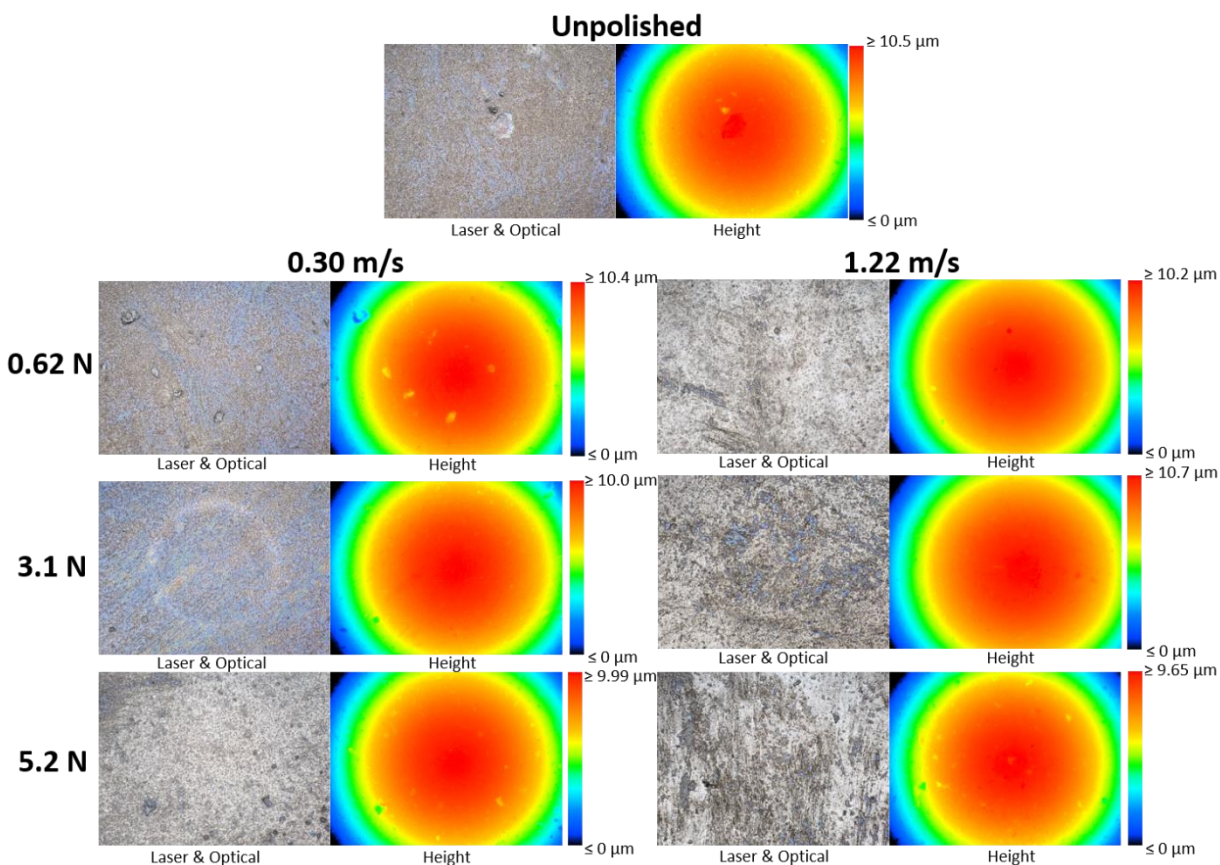


*Appendix A3: Peristaltic pump (Verderflex Peristaltic Electric Operated Positive Displacement Pump 0.24 L/min, 12 V) to produce flow of polishing slurry (a) and a SUBA X Perf II 08 polyurethane-impregnated polyester polishing pad (b) for use in combination with a LaboPol-5 polishing machine for chemical mechanical polishing.*

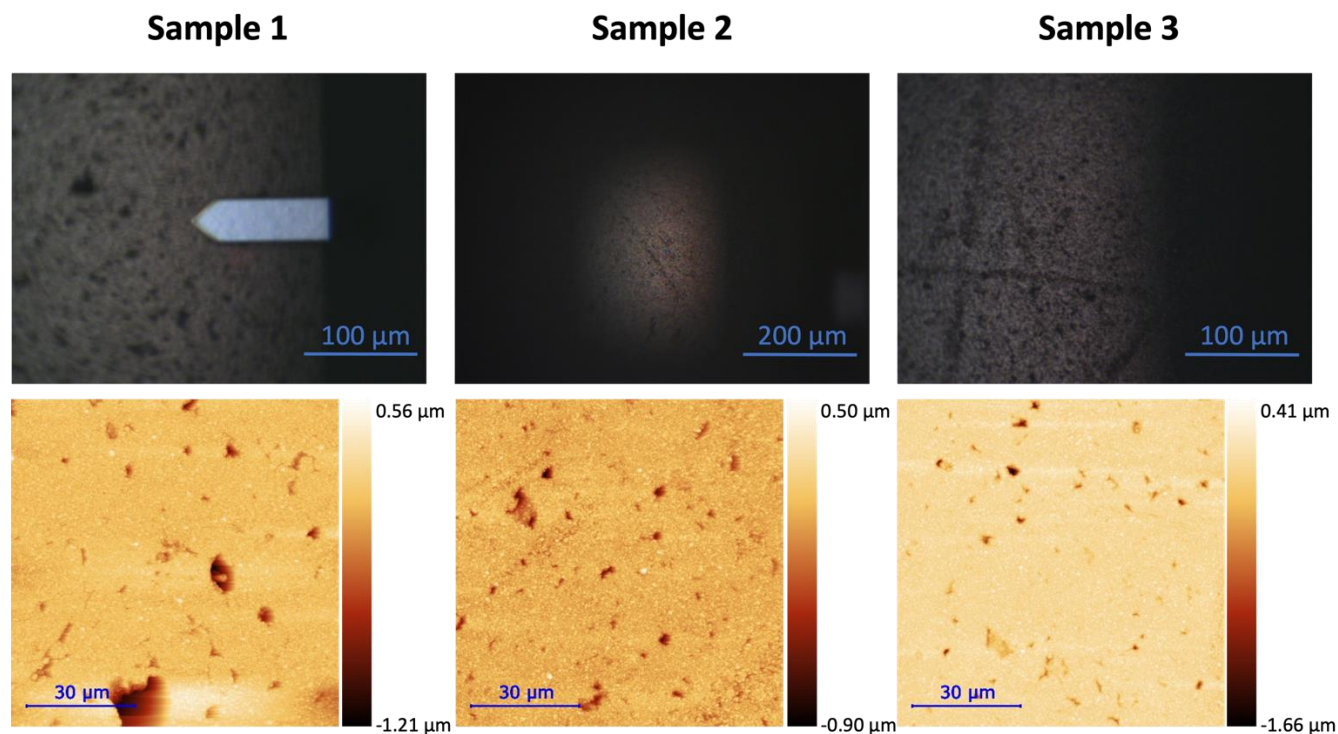


*Appendix A4: Optical focus variation profilometry paired images (702  $\mu\text{m}$  x 506  $\mu\text{m}$ , 686 nm / pixel and 659 nm / pixel respectively) (laser & optical on left, height on right of each pair) of the apex area of B-doped (2000 – 4000 ppm) microcrystalline diamond coated SiC hemispheres (3 mm diameter) when chemical mechanical polishing has been performed using normal forces of  $0.62 \pm 0.21 \text{ N}$  (2nd row),  $3.1 \pm 0.2 \text{ N}$  (3rd row) and  $5.2 \pm 0.2 \text{ N}$  (bottom row) and sliding speed averages of  $0.30 \pm 0.09 \text{ m/s}$  (left column of bottom 3 rows) and  $1.22 \pm 0.38 \text{ m/s}$  (right column of bottom 3 rows), as well as the apex of an unpolished sample (top). Chemical mechanical polishing was performed for 10 minutes using colloidal silica (70 nm diameter) in deionized water (17 % weight/volume, pH 9, 0.18 L/min) with a SUBA X (polyurethane impregnated polyester pad) and a Struers LaboPol-5 polishing machine. Images were obtained using laser-scanning confocal microscope (Keyence VK-X1000) in standard ambient temperature and pressure conditions.*

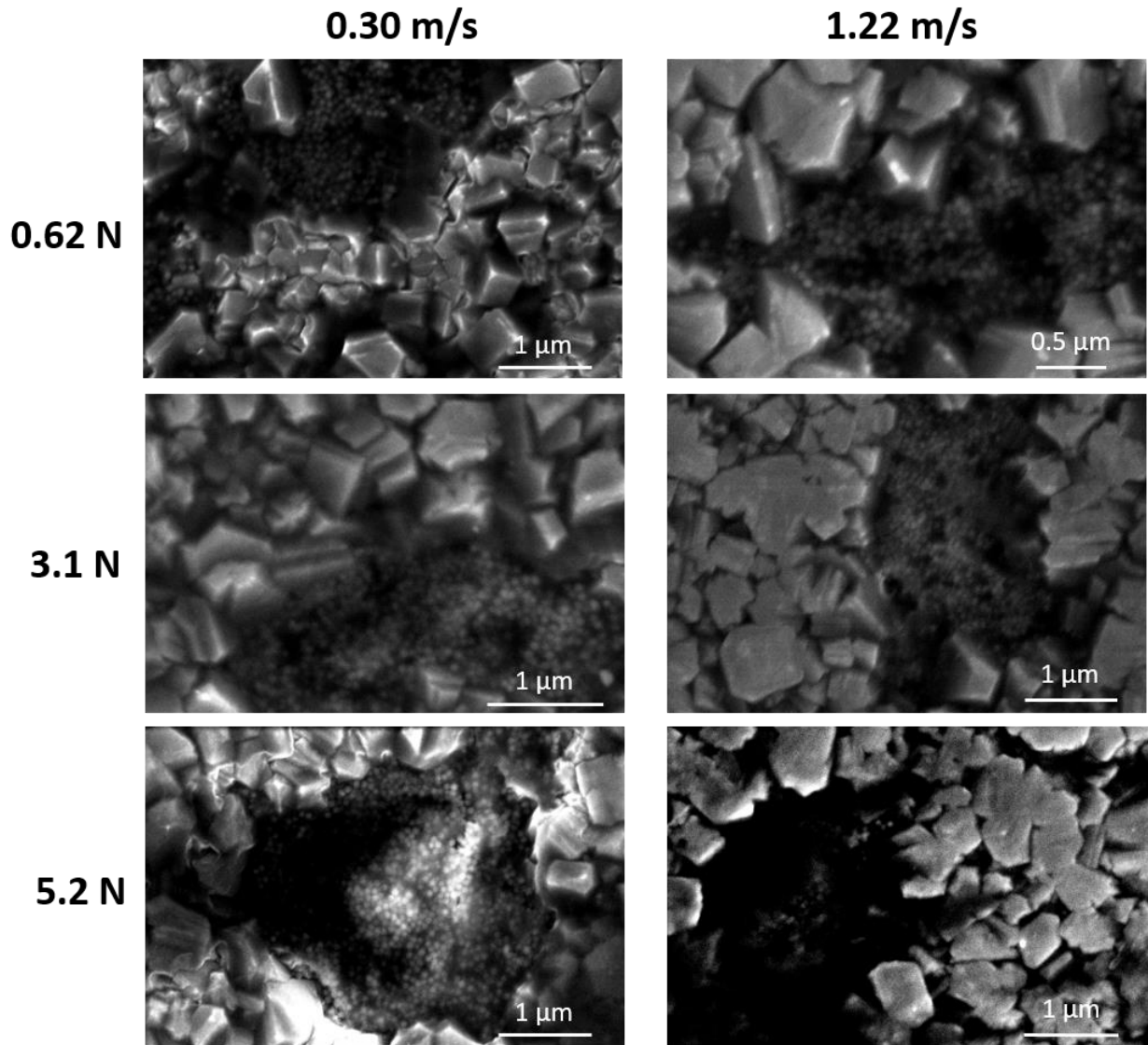




Appendix A5: Optical focus variation profilometry paired images ( $283\ \mu\text{m} \times 212\ \mu\text{m}$ ,  $138\ \text{nm} / \text{pixel}$  along both axes) (laser & optical on left, height on right of each pair) of the apex area of B-doped (2000 – 4000 ppm) microcrystalline-diamond-coated SiC hemispheres (3 mm diameter) when chemical mechanical polishing has been performed using normal forces of  $0.62 \pm 0.21\ \text{N}$  (2nd row),  $3.1 \pm 0.2\ \text{N}$  (3rd row) and  $5.2 \pm 0.2\ \text{N}$  (bottom row) and sliding speed averages of  $0.30 \pm 0.09\ \text{m/s}$  (left column of bottom 3 rows) and  $1.22 \pm 0.38\ \text{m/s}$  (right column of bottom 3 rows), as well as the apex of an unpolished sample (top). Chemical mechanical polishing was performed for 10 minutes using colloidal silica (70 nm diameter) in deionized water (17 % weight/volume, pH 9, 0.18 L/min) with a SUBA X (polyurethane impregnated polyester pad) and a Struers LaboPol-5 polishing machine. Images were obtained using laser-scanning confocal microscope (Keyence VK-X1000) in standard ambient temperature and pressure conditions.

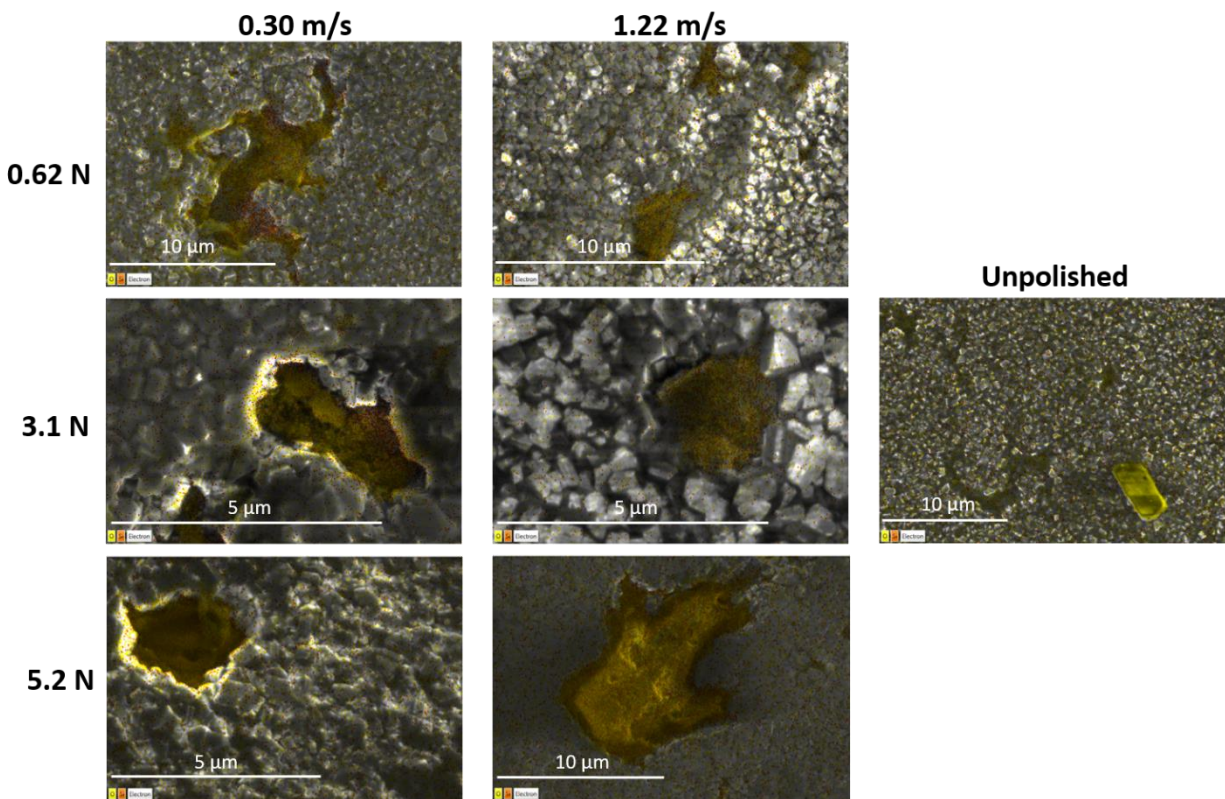


*Appendix A6: Atomic force microscopy micrographs (90 µm x 90 µm, 2048 pixels x 2048 pixels) and optical images taken of the apex of three (left row, middle row and right row) B-doped (2000 - 4000 ppm) microcrystalline diamond coated SiC hemispheres (3 mm diameter). Atomic force microscopy micrographs were obtained using a Bruker Dimension ICON with ScanAsyst in 'Tapping Mode in Air' with a Bruker RTESPA-300-30 AFM probe, (30 ± 4.5 nm tip radius made of antimony-(n)-doped silicon) in standard ambient temperature and pressure conditions. The resulting images were processed using Gwyddion 2.58 (64 bit) to remove the spherical background, correct horizontal scarring and produce the false colour range representing height.*

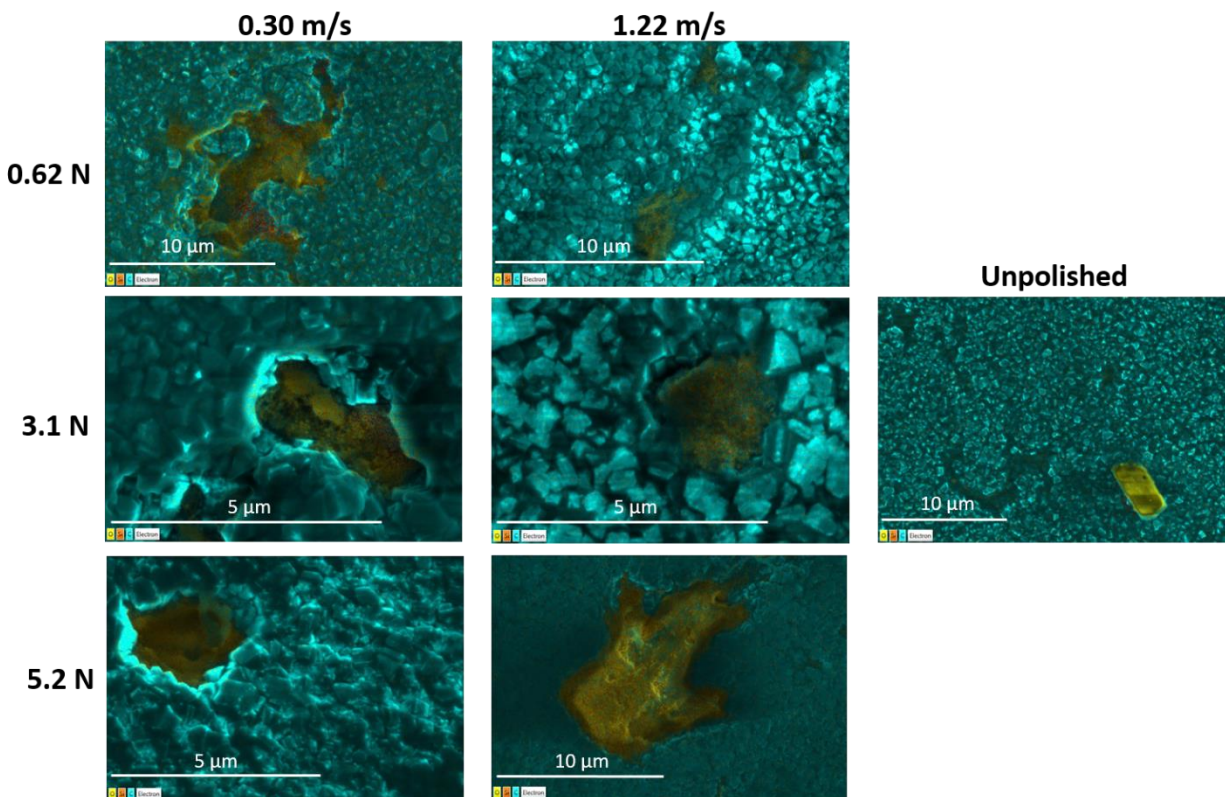


*Appendix A7: Scanning electron microscopy images of B-doped (2000 – 4000 ppm) microcrystalline diamond coated SiC hemispheres (3 mm diameter), showing holes (produced from errors in coating growth) within the surface, after being subject to chemical mechanical polishing under normal forces of  $0.62 \pm 0.21$  N (top row),  $3.1 \pm 0.2$  N (middle row) and  $5.2 \pm 0.2$  N (bottom row) and sliding speed averages of  $0.30 \pm 0.09$  m/s (left column) and  $1.22 \pm 0.38$  m/s (middle column). Chemical mechanical polishing was performed for 10 minutes using colloidal silica (70 nm diameter) in deionized water (17 % weight/volume, pH 9, 0.18 L/min) with a SUBA X (polyurethane impregnated polyester pad) and a Struers LaboPol-5 polishing machine. SEM images were obtained by FEI Verios 460 SEM.*



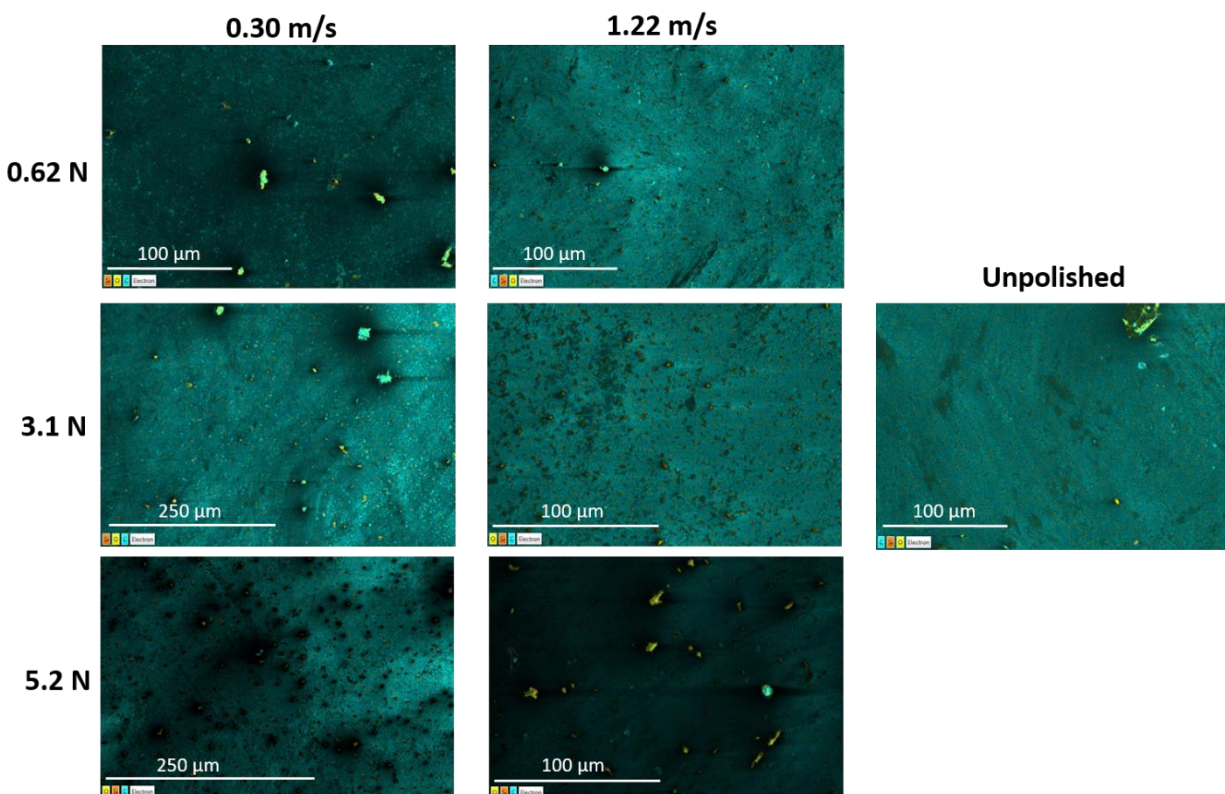


Appendix A8: Energy dispersive x-ray overlaid oxygen (yellow) and silicon (orange) maps of B-doped (2000 – 4000 ppm) microcrystalline diamond coated SiC hemispheres (3 mm diameter), showing holes (produced from errors in coating growth) within the surface, after being subject to chemical mechanical polishing under normal forces of  $0.62 \pm 0.21$  N (top row),  $3.1 \pm 0.2$  N (middle row of left and middle columns) and  $5.2 \pm 0.2$  N (bottom row) and sliding speed averages of  $0.30 \pm 0.09$  m/s (left column) and  $1.22 \pm 0.38$  m/s (middle column), as well as the apex of an unpolished sample (right). Chemical mechanical polishing was performed for 10 minutes using colloidal silica (70 nm diameter) in deionized water (17 % weight/volume, pH 9, 0.18 L/min) with a SUBA X (polyurethane impregnated polyester pad) and a Struers LaboPol-5 polishing machine. Energy dispersive x-ray map images were obtained by FEI Verios 460 SEM with an Oxford X-Max 80 mm<sup>2</sup> Energy Dispersive Spectrometer detector.

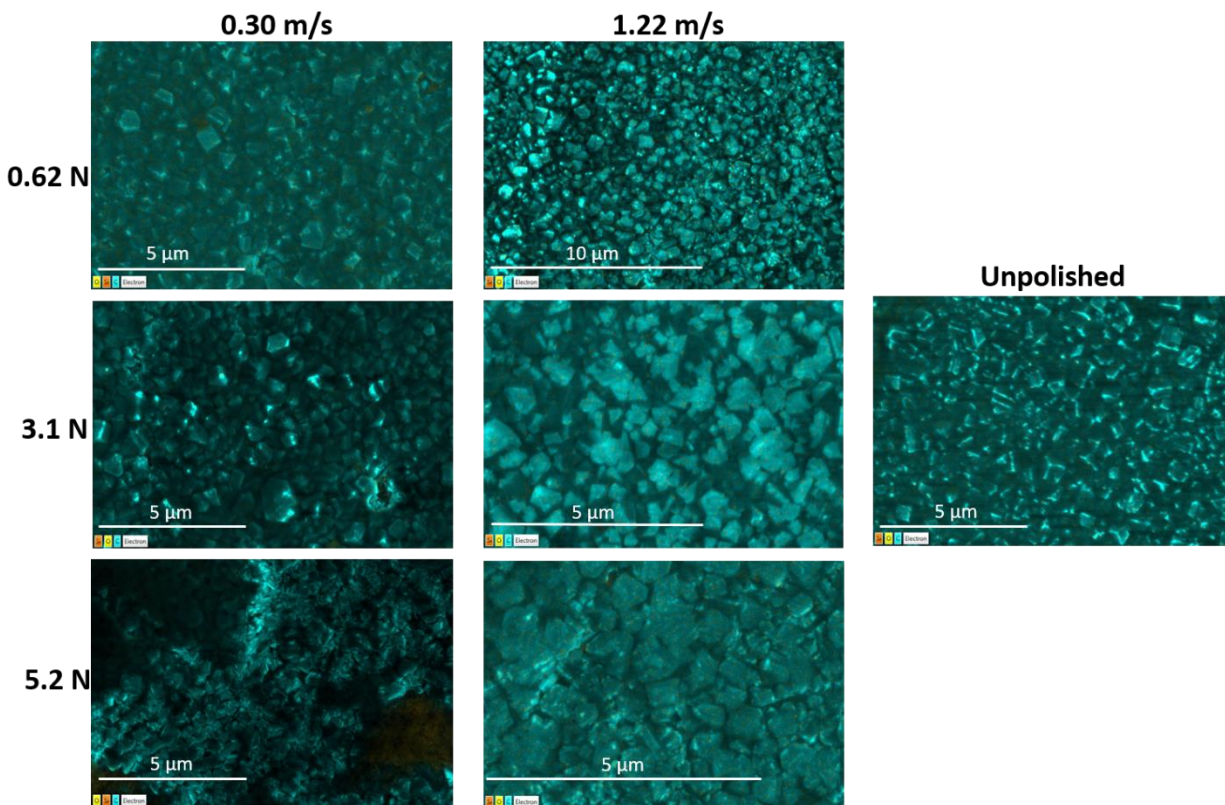


Appendix A9: Energy dispersive x-ray overlaid oxygen (yellow), silicon (orange) and carbon (blue) maps of B-doped (2000 – 4000 ppm) microcrystalline diamond coated SiC hemispheres (3 mm diameter), showing holes (produced from errors in coating growth) within the surface, after being subject to chemical mechanical polishing under normal forces of  $0.62 \pm 0.21$  N (top row),  $3.1 \pm 0.2$  N (middle row of left and middle column) and  $5.2 \pm 0.2$  N (bottom row) and sliding speed averages of  $0.30 \pm 0.09$  m/s (left column) and  $1.22 \pm 0.38$  m/s (middle column), as well as the apex of an unpolished sample (right). Chemical mechanical polishing was performed for 10 minutes using colloidal silica (70 nm diameter) in deionized water (17 % weight/volume, pH 9, 0.18 L/min) with a SUBA X (polyurethane impregnated polyester pad) and a Struers LaboPol-5 polishing machine. Energy dispersive x-ray map images were obtained by FEI Verios 460 SEM with an Oxford X-Max 80 mm<sup>2</sup> Energy Dispersive Spectrometer detector.

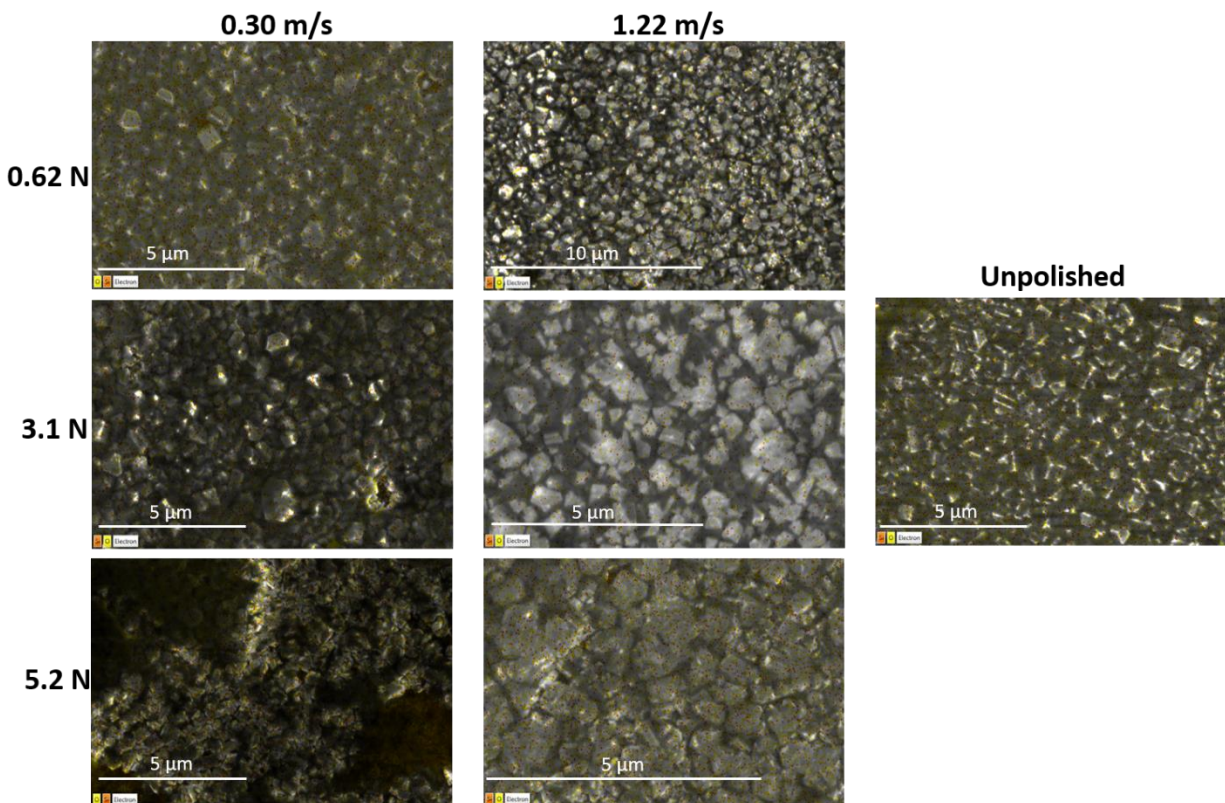




Appendix A10: Energy dispersive x-ray overlaid oxygen (yellow), silicon (orange) and carbon (blue) maps of the identified and surrounding area of significant chemical mechanical polishing of B-doped (2000 – 4000 ppm) microcrystalline diamond coated SiC hemispheres (3 mm diameter) when performed under normal forces of  $0.62 \pm 0.21$  N (top row),  $3.1 \pm 0.2$  N (middle row of left and middle column) and  $5.2 \pm 0.2$  N (bottom row) and sliding speed averages of  $0.30 \pm 0.09$  m/s (left column) and  $1.22 \pm 0.38$  m/s (middle column), as well as the apex of an unpolished sample (right). Chemical mechanical polishing was performed for 10 minutes using colloidal silica (70 nm diameter) in deionized water (17 % weight/volume, pH 9, 0.18 L/min) with a SUBA X (polyurethane impregnated polyester pad) and a Struers LaboPol-5 polishing machine. Energy dispersive x-ray map images were obtained by FEI Verios 460 SEM with an Oxford X-Max 80 mm<sup>2</sup> Energy Dispersive Spectrometer detector.

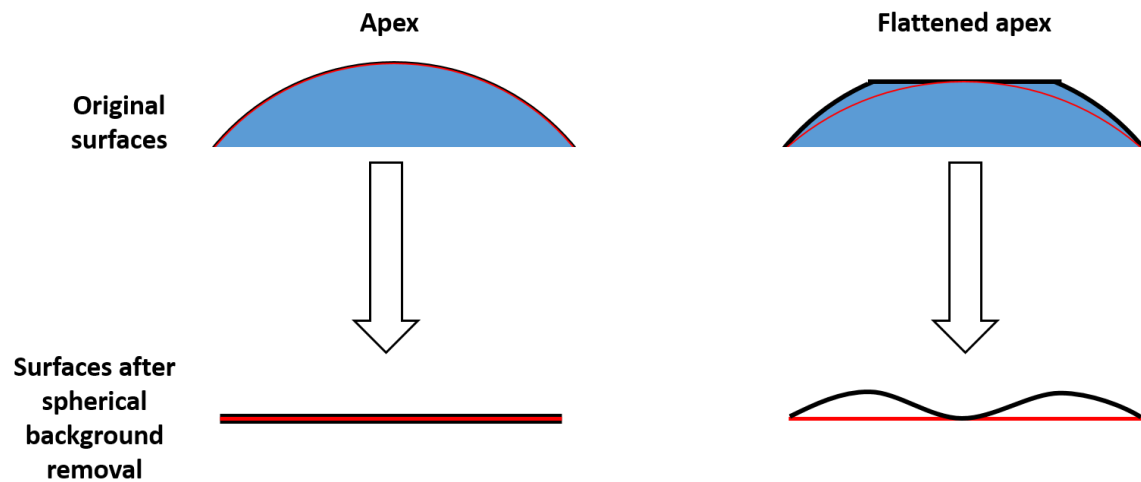


Appendix A11: Energy dispersive x-ray overlaid oxygen (yellow), silicon (orange) and carbon (blue) maps within the identified area of significant chemical mechanical polishing of B-doped (2000 – 4000 ppm) microcrystalline diamond coated SiC hemispheres (3 mm diameter) when performed under normal forces of  $0.62 \pm 0.21$  N (top row),  $3.1 \pm 0.2$  N (middle row of left and middle columns) and  $5.2 \pm 0.2$  N (bottom row) and sliding speed averages of  $0.30 \pm 0.09$  m/s (left column) and  $1.22 \pm 0.38$  m/s (middle column), as well as the apex of an unpolished sample (right). Chemical mechanical polishing was performed for 10 minutes using colloidal silica (70 nm diameter) in deionized water (17 % weight/volume, pH 9, 0.18 L/min) with a SUBA X (polyurethane impregnated polyester pad) and a Struers LaboPol-5 polishing machine. Energy dispersive x-ray map images were obtained by FEI Verios 460 SEM with an Oxford X-Max 80 mm<sup>2</sup> Energy Dispersive Spectrometer detector. These maps were taken in a manner to avoid larger particles not part of the microcrystalline diamond surface and holes produced because of issues during the microcrystalline diamond coating growth onto the SiC hemispheres.

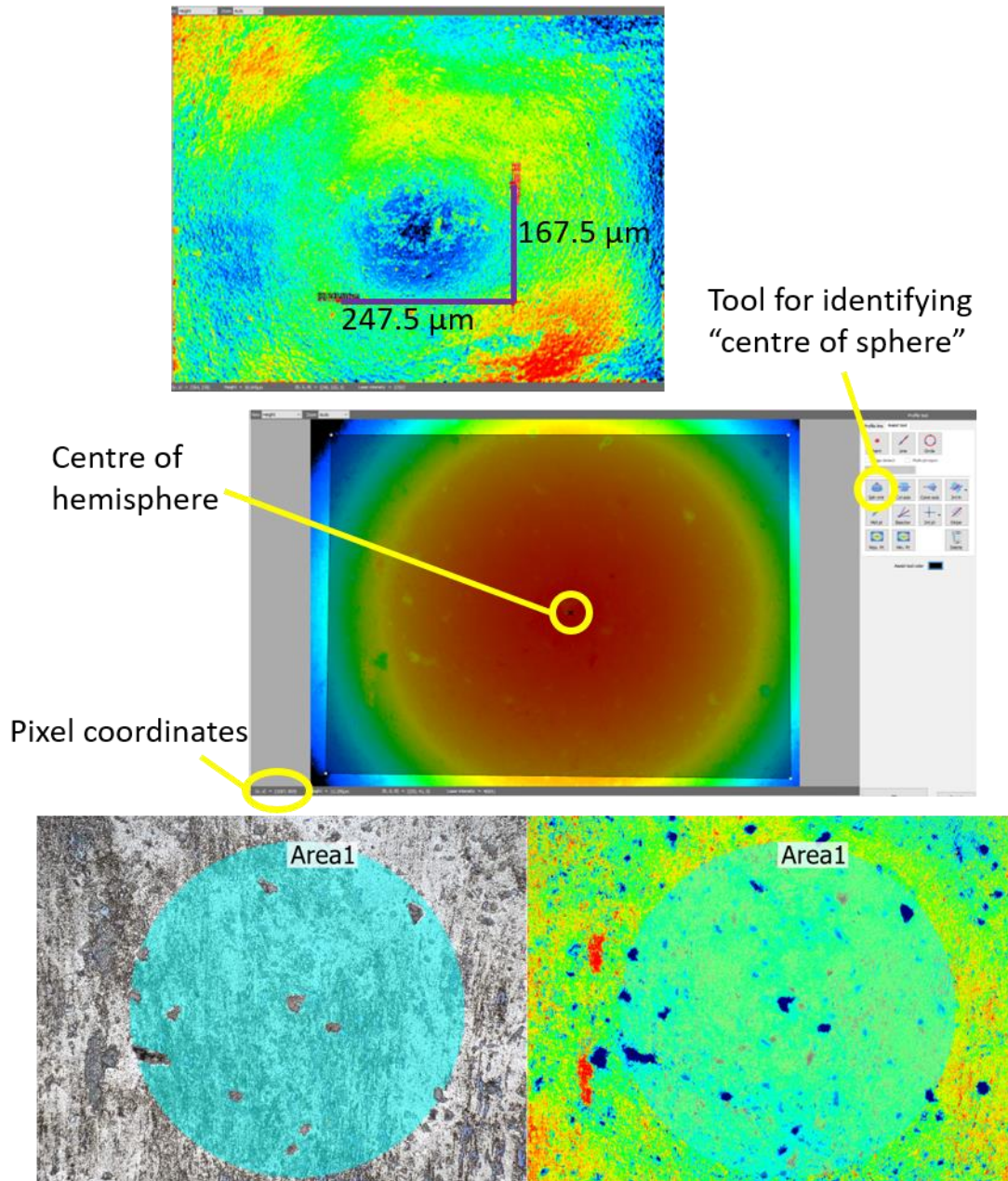


Appendix A12: Energy dispersive x-ray overlaid oxygen (yellow) and silicon (orange) maps within the identified area of significant chemical mechanical polishing of B-doped (2000 – 4000 ppm) microcrystalline diamond coated SiC hemispheres (3 mm diameter) when performed under normal forces of  $0.62 \pm 0.21$  N (top row),  $3.1 \pm 0.2$  N (middle row of left and middle columns) and  $5.2 \pm 0.2$  N (bottom row) and sliding speed averages of  $0.30 \pm 0.09$  m/s (left column) and  $1.22 \pm 0.38$  m/s (middle column), as well as the apex of an unpolished sample (right). Chemical mechanical polishing was performed for 10 minutes using colloidal silica (70 nm diameter) in deionized water (17 % weight/volume, pH 9, 0.18 L/min) with a SUBA X (polyurethane impregnated polyester pad) and a Struers LaboPol-5 polishing machine. Energy dispersive x-ray map images were obtained by FEI Verios 460 SEM with an Oxford X-Max 80 mm<sup>2</sup> Energy Dispersive Spectrometer detector. These maps were taken in a manner to avoid larger particles not part of the microcrystalline diamond surface and holes produced because of issues during the microcrystalline diamond coating growth onto the SiC hemispheres.

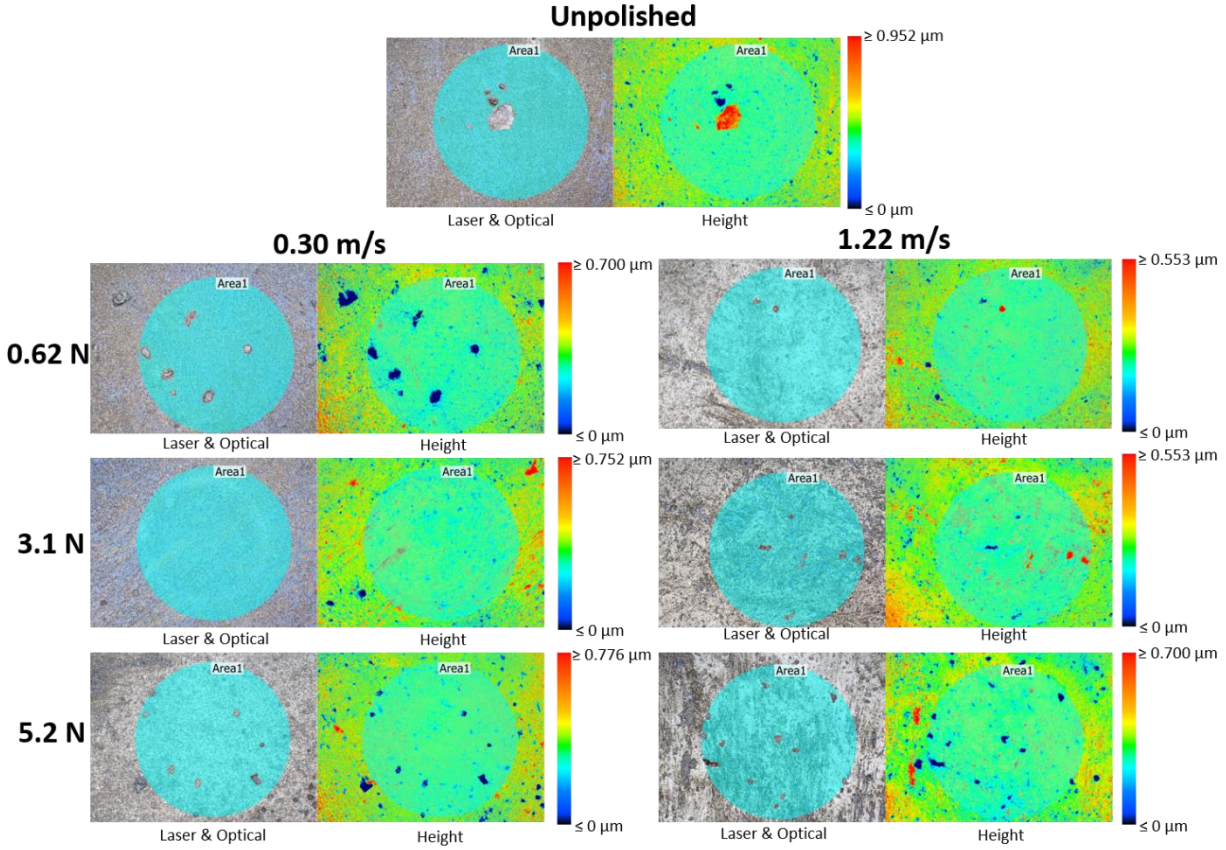




*Appendix A13: Illustration on how spherical-based surfaces (top) can exhibit substantial lower height variations in the surfaces represented with spherical background removal (bottom) in “regular” apex surfaces (left) compared to flattened apex surfaces (right), where the background removal is carried out automatically by software.*

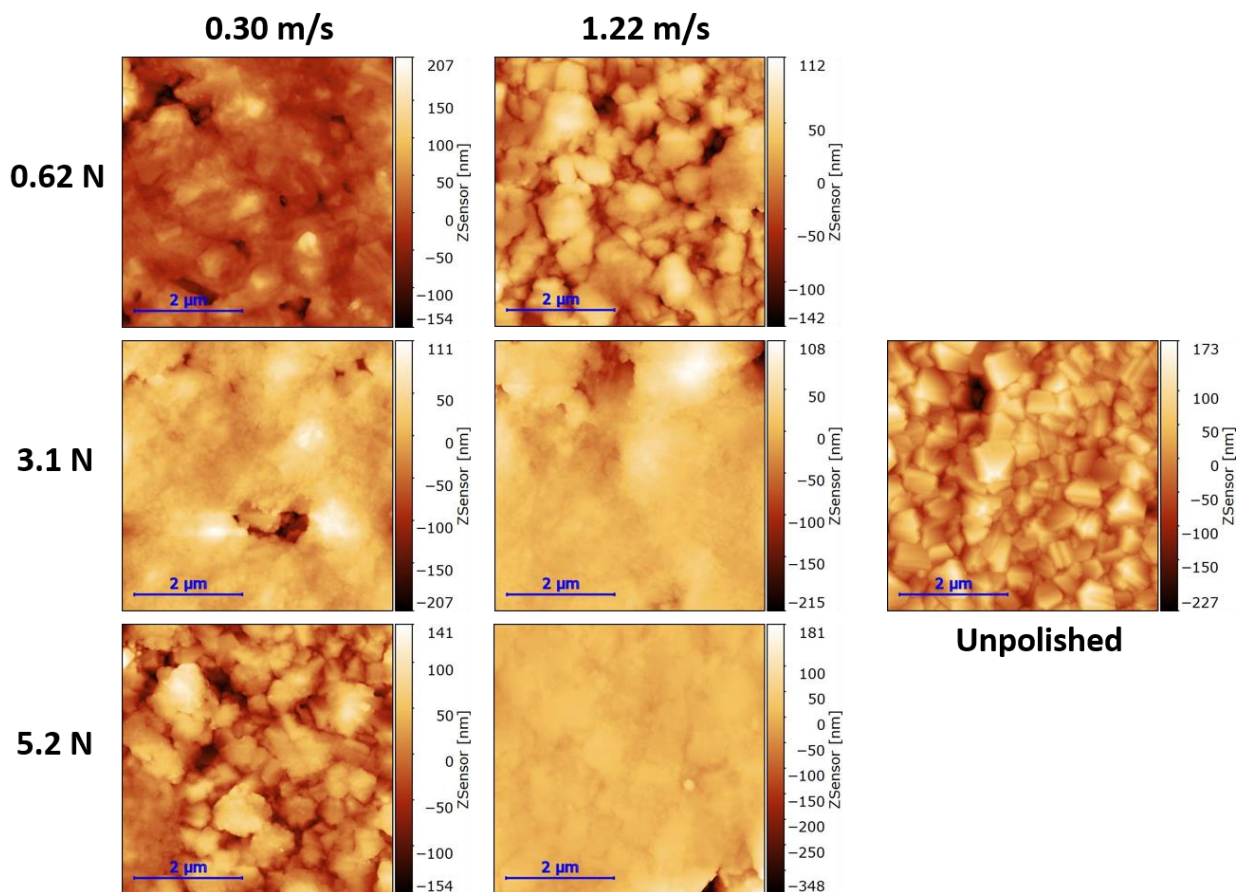


Appendix A14: Illustrations outlining the process used to produce comparable area of analysis across samples of B-doped (2000 – 4000 ppm) microcrystalline-diamond-coated SiC hemispheres (3 mm diameter) subject to chemical mechanical polishing with varying polishing parameters. The images outline determination of the smallest area including the most polished region (top image (702  $\mu\text{m}$  x 526  $\mu\text{m}$ , 686 nm / pixel and 659 nm / pixel respectively, flattened to remove spherical background)), determination of the pixel associated with the apex of the hemisphere (centre) and a representation of the circle area for comparable analysis with outlying low and high heights removed by-eye (bottom (283  $\mu\text{m}$  x 212  $\mu\text{m}$ , 138 nm / pixel along both axes, flattened to remove spherical background)). Images were obtained using laser-scanning confocal microscope (Keyence VK-X1000) and were processed by Keyence MultiFile Analyzer to remove the spherical background, fit ~95 % of the bell curve of heights into the false colour for height range with the median in the centre of the height range and produce the circle for analysis with the centre based around the apex of the sphere and holes of outlying depths and peaks of outlying heights removed by-eye.

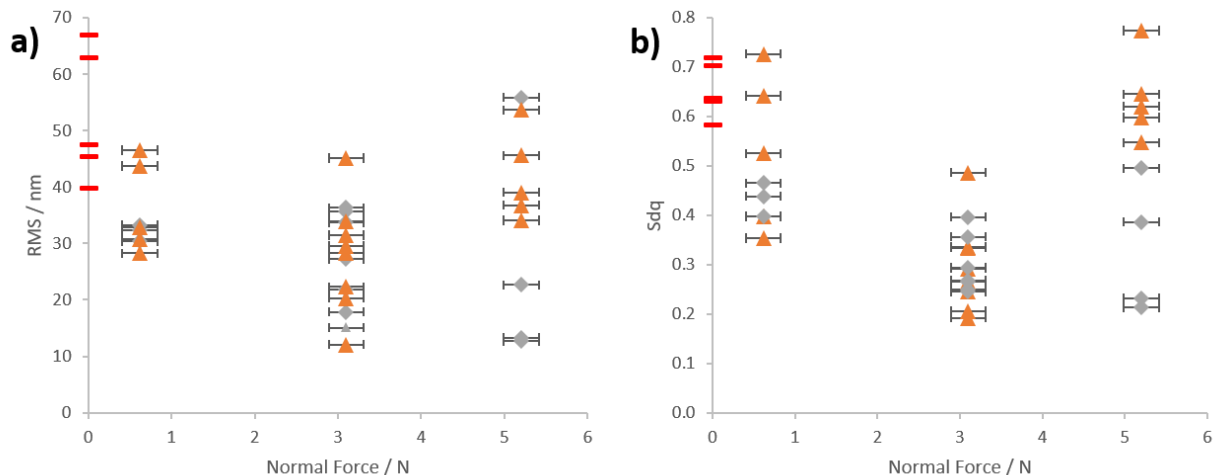


Appendix A15: Optical focus variation profilometry paired images ( $283 \mu\text{m} \times 212 \mu\text{m}$ ,  $138 \text{ nm} / \text{pixel}$  along both axes) (laser & optical on left, height on right of each pair) displaying the analyzed circle area ( $195 \mu\text{m}$  diameter) of the apex of B-doped (2000 – 4000 ppm) microcrystalline-diamond-coated SiC hemispheres (3 mm diameter) subject to chemical mechanical polishing using normal forces of  $0.62 \pm 0.21 \text{ N}$  (2nd row),  $3.1 \pm 0.2 \text{ N}$  (3rd row) and  $5.2 \pm 0.2 \text{ N}$  (bottom row) and sliding speed averages of  $0.30 \pm 0.09 \text{ m/s}$  (left column of bottom 3 rows) and  $1.22 \pm 0.38 \text{ m/s}$  (right column of bottom 3 rows), as well as the apex of an unpolished sample (top). Chemical mechanical polishing was performed for 10 minutes using colloidal silica (70 nm diameter) in deionized water (17 % weight/volume, pH 9, 0.18 L/min) with a SUBA X (polyurethane impregnated polyester pad) and a Struers LaboPol-5 polishing machine. Images were obtained using a laser-scanning confocal microscope (Keyence VK-X1000) in standard ambient temperature and pressure conditions. The images have been processed by Keyence MultiFile Analyzer to remove the spherical background, fit ~95 % of the bell curve of heights into the false colour for height range with the median in the centre of the height range and produce the circle for analysis with the centre based around the apex of the sphere and remove holes of outlying depths and peaks of outlying heights by-eye.

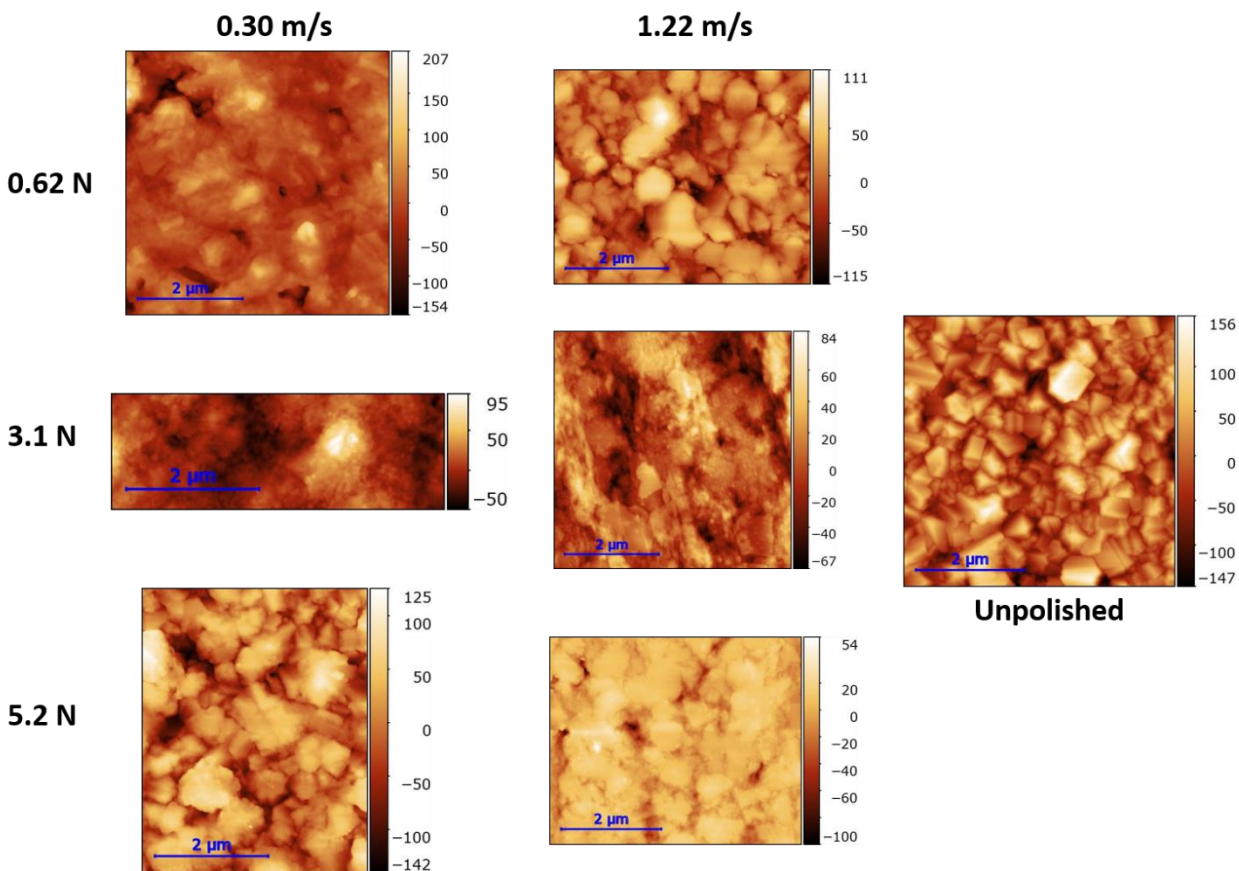




Appendix A16: Representative AFM micrograph images (5  $\mu\text{m}$  x 5  $\mu\text{m}$ , 512 pixels x 512 pixels) taken of the apex area ( $\sim 100 \mu\text{m}$  x  $100 \mu\text{m}$ ) of B-doped (2000 - 4000 ppm) microcrystalline diamond coated SiC hemisphere samples (3 mm diameter) subject to chemical mechanical polishing using normal forces of  $0.62 \pm 0.21 \text{ N}$  (top row),  $3.1 \pm 0.2 \text{ N}$  (middle row of left and middle columns) and  $5.2 \pm 0.2 \text{ N}$  (bottom row) and sliding speed averages of  $0.30 \pm 0.09 \text{ m/s}$  (left column) and  $1.22 \pm 0.38 \text{ m/s}$  (middle column), as well as the apex of an unpolished sample (right). Chemical mechanical polishing was performed for 10 minutes using colloidal silica (70 nm diameter) in deionized water (17 % weight/volume, pH 9, 0.18 L/min) with a SUBA X (polyurethane impregnated polyester pad) and a Struers LaboPol-5 polishing machine. Images were obtained using AFM using a Bruker Dimension ICON with ScanAsyst in 'Tapping Mode in Air' with a Bruker RTESPA-300-30 AFM probe, ( $30 \pm 4.5 \text{ nm}$  tip radius made of antimony-(n)-doped silicon) in standard ambient temperature and pressure conditions. The resulting images were processed using Gwyddion 2.58 (64 bit) to remove the spherical background, correct horizontal scarring and produce the false colour range representing height.



Appendix A17: Resulting RMS roughness (a) and Sdq (b) within the apex area ( $\sim 100 \mu\text{m} \times 100 \mu\text{m}$ ) of B-doped (2000 - 4000 ppm) microcrystalline diamond coated (MCD) SiC hemisphere samples (3 mm diameter) subject to chemical mechanical polishing using different normal forces and  $0.30 \pm 0.09 \text{ m/s}$  (orange triangles) and  $1.22 \pm 0.38 \text{ m/s}$  (grey diamonds) average sliding speeds, as well as comparisons against unpolished samples (red lines). Chemical mechanical polishing was performed for 10 minutes using colloidal silica (70 nm diameter) in deionized water (17 % weight/volume, pH 9, 0.18 L/min) with a SUBA X (polyurethane impregnated polyester pad) and a Struers LaboPol-5 polishing machine. Results were measured over  $5 \mu\text{m} \times 5 \mu\text{m}$  areas on the apex area by Bruker ICON atomic force microscope, using a RTESPA 300-30 ( $30 \pm 4.5 \text{ nm}$  tip radius made of antimony-(n)-doped silicon) probe in tapping mode in air in standard ambient temperature and pressure conditions. The resulting images were processed using Gwyddion 2.58 (64 bit) to remove the spherical background, correct horizontal scarring and produce the false colour range representing height, followed by cropping to remove holes in the MCD coating from issues with the coating growth process.



Appendix A18: Representative AFM micrographs ( $5\ \mu\text{m} \times 5\ \mu\text{m}$ , 512 pixels  $\times$  512 pixels) taken within the apex area ( $\sim 100\ \mu\text{m} \times 100\ \mu\text{m}$ ) of B-doped (2000 - 4000 ppm) microcrystalline diamond coated (MCD) SiC hemisphere samples (3 mm diameter) subject to chemical mechanical polishing using normal forces of  $0.62 \pm 0.21\ \text{N}$  (top row),  $3.1 \pm 0.2\ \text{N}$  (middle row of left and middle columns) and  $5.2 \pm 0.2\ \text{N}$  (bottom row) and sliding speed averages of  $0.30 \pm 0.09\ \text{m/s}$  (left column) and  $1.22 \pm 0.38\ \text{m/s}$  (middle column), as well as the apex of an unpolished sample (right). Chemical mechanical polishing was performed for 10 minutes using colloidal silica (70 nm diameter) in deionized water (17 % weight/volume, pH 9, 0.18 L/min) with a SUBA X (polyurethane impregnated polyester pad) and a Struers LaboPol-5 polishing machine. AFM micrographs were obtained using a Bruker Dimension ICON with ScanAsyst in 'Tapping Mode in Air' with a Bruker RTESPA-300-30 AFM probe, ( $30 \pm 4.5\ \text{nm}$  tip radius made of antimony-(n)-doped silicon) in standard ambient temperature and pressure conditions. The resulting images were processed using Gwyddion 2.58 (64 bit) to remove the spherical background, correct horizontal scarring and produce the false colour range representing height, followed by cropping to remove holes in the MCD coating from issues with the coating growth process.



## **Appendix B**

### **Standard Operating Procedure (SOP) for chemical mechanical polishing of chemical vapour deposition polycrystalline diamond coated silicon carbide hemispheres**

#### **Equipment Used**

Struers LaboPol-5 polishing machine with Struers LaboForce-1 and polishing modification (made in AMOLF workshop, designed by Henk-Jan Boluijt), SUBA X polishing pad, Kinik hand dresser with Kinik Diagrid™ S-PD32P-xFN CMP Pad Conditioner, fume hood, polycrystalline diamond coated hemispheres, peristaltic pump, stainless steel spill tray, Versilon F-5500-A tubing, 1 L PP measuring cylinder, 2 x 250 mL glass beakers, 1 L PP measuring beaker with handle, 2 L PP measuring beaker with handle, HDPE short stem funnel (210 mm funnel diameter), plastic 10 mL transfer pipettes, magnetic stirrer and PTFE coated stirrer bar, HBM digital heated ultrasonic bath, 2 x 10 L PP container.

#### **Nature of hazards + frequency of encounter**

*Ultra-Sol™ S27 (aqueous dispersion containing amorphous silica gel (45-55 %, CAS 112926-00-8), deionized water, ethanol (CAS 64-17-5).*

##### **Ultra-Sol™ S27:**

No hazard statements or risk phrases.

No dangerous components.

##### **Deionized water:**

No hazard statements or risk phrases.

No dangerous components.

##### **Ethanol:**

Hazard statement H225: Highly flammable liquid and vapour.

## Emergency action

- *Leave the room and call immediately for assistance at 4000.*

## Precautions

- Ultra-Sol™ S27: Ensure good ventilation/exhaustion. Wear protective work clothing, safety glasses and nitrile gloves ( $\geq 0.4$  mm). Wash hands during breaks and at the end of work. Avoid prolonged or repeated contact with skin. Avoid contact with eyes. Do not inhale fumes. Do not allow to enter drainage system, surface or ground water. Do not allow to enter the ground/soil. Remove contaminated clothing. IF SWALLOWED: Rinse out mouth and then drink plenty of water. In case of persistent symptoms, consult doctor. IF IN EYES: Rinse opened eye for several minutes in running water. If symptoms persist, consult doctor. IF INHALED: Supply fresh air. Consult doctor in case of symptoms. IF ON SKIN: Wash with soap and water. If skin irritation continues, consult doctor.
- Storage of Ultra-Sol™ S27: Observe all local and national regulations for storage of water polluting products. Use polyolefine containers. Unsuitable material for container: steel. Store in well-ventilated, cool, dry conditions in well-sealed containers. Protect from frost.
- In case of accidental release of Ultra-Sol™ S27: Ensure adequate ventilation. Avoid contact with skin, eyes and clothes. Do not allow to enter drainage system, surface or ground water. Do not allow to enter the ground/soil. Absorb with liquid-binding material (sand, diatomite, acid binders, universal binders, sawdust). Send for recovery or disposal in suitable containers. Dispose of material collected according to regulations.
- Ethanol: Keep away from heat, hot surfaces, sparks, open flames and other ignition sources. No smoking. Keep container tightly closed. Ground and bond container and receiving equipment. Use explosion-proof equipment. IF SWALLOWED: Do NOT induce vomiting. Rinse out mouth and provide liquid slowly and as much as casualty can comfortably drink. Observe patient carefully and seek medical advice. IF IN EYES: Rinse opened eye with water. Seek medical attention immediately. Removal of contact lens after an eye injury should be done by skilled personnel only. IF INHALED: Remove from contaminated area. Lay patient down. Keep warm and rested. Follow first aid guidelines. IF ON SKIN OR HAIR: Take off immediately all contaminated clothing and rinse skin or hair with water.
- In case of fire involving Ultra-Sol™ S27: Use CO<sub>2</sub>, extinguishing powder or water spray/fog. Fight larger fires with water spray/fog or alcohol-resistant foam. Product does not burn. Silica fumes may arise from Ultra-Sol S27 slurry/mixture. Carbon monoxide, carbon dioxide, nitrogen oxides, ammonia, nitrosamines may arise from Challenge 700-HT. Under certain fire conditions, traces of other toxic gases cannot be excluded from arising from Challenge 700-HT.
- In case of fire involving ethanol: Use ethanol resistant foam, normal protein foam, dry chemical powder, or CO<sub>2</sub> to extinguish.
- In case of power failure: Stop the experiment, ensure all taps and bottle lids are closed. Close the fume hood. Block the hood from being opened using tape/ribbon found within room 0.12.

## Fume-hood

Ensure that the fume-hood is working throughout the experiment – contact Thomas Meijvogel (8161) or Mark Mol (8115) if it is not working properly. If neither Thomas or Mark are available, contact another technician. If the fume hood is confirmed to be broken by a technician, contact the maintenance number on the fume hood (+31 (0) 76 204 3015 / [info@dupa.nl](mailto:info@dupa.nl))

## Setup

Dilution of slurry: All equipment in fume-hood. Mixing to be performed within spill tray. Use a 10 L PP container for the diluted slurry. Use a 2 L PP measuring beaker, 1 L PP measuring beaker, 1 L PP measuring cylinder, 210 mm HDPE short stem funnel, magnetic stirrer, PTFE coated stirrer bar and plastic pipettes for accurate and safe dilution.

Conditioning: All equipment in fume-hood. Conditioning to be performed within spill tray. Use the Kinik pad conditioner fixed to the Kinik hand dresser. Use the Suba-X polishing pad fixed onto the LaboPol-5.

Chemical mechanical polishing: All equipment in fume-hood. Polishing machine to be within spill tray. LaboForce-1 with modification fixed onto LaboPol-5. Suba-X polishing pad fixed onto LaboPol-5. 10 L PP container with diluted slurry connected by Versilon F-5500-A tubing to LaboPol-5 via peristaltic pump. Peristaltic pump applying pressure to ensure tap on LaboPol-5 can determine flow rate of slurry. Separate 10 L PP container connected to waste output of LaboPol-5.

Post-polish cleaning: All equipment in fume-hood. Cleaning to be performed within spill tray. Cleaning to be performed using 2 x 250 mL glass beakers, HBM digital heated ultrasonic bath.



### **Dilution of slurry**

1. Measure out 500 mL of Ultra-Sol S27 and distribute into a 2 L PP measuring beaker using a 1 L measuring cylinder and 210 mm funnel. Via the same measuring cylinder and funnel measure out 1 L of DI water and add this to the PP beaker with the 500 mL amount of Ultra-Sol S27.
2. Using magnetic stirrer with PTFE coated magnetic bar mix effectively. Be careful of sputtering.
3. Pour the contents into the 10 L PP “slurry” container, being careful to collect the stirrer bar during pouring.
4. Repeat steps 1 to 4 (inclusive) until enough slurry is prepared for CMP of all samples.
5. Label, store and clean appropriately, in the case of the 10 L PP slurry container.

### **Conditioning**

Conditioning is carried out to increase the polishing pad surface roughness to improve the material removal and change in surface roughness rates, as well as extend the lifetime of the polishing pad. If conditioning is deemed necessary, carry out as follows:

1. Ensure the pad is clean and dry.
2. Fix the Kinik Diagrid™ CMP pad conditioner to the Kinik hand dresser and fix the polishing pad to the polishing machine.
3. Rub the conditioner against the pad for 10 minutes, whilst trying to maintain even pressure and area coverage of the applied surface of the polishing pad to produce an even conditioning. Maintain consistency in conditioning of the polishing pad across multiple experiments.

### **Chemical mechanical polishing**

Ensure before and during the experiment that there are enough 10 L PP waste containers available and the pressure of the containers is risk-free (no large pressure gradient against the room). Ensure the hemispheres to be polished is secure to prevent rolling. Chemical mechanical polishing is carried out as follows:

1. Before polishing and if necessary, condition the pad as outlined under ‘**Conditioning**’.
2. Ensure slurry container is securely connected to inflow pipeline and peristaltic pump produces desired effective pressure. Ensure waste pipeline is securely connected to appropriate waste container(s).
3. Adjust rotation speed to 50 rpm, direct the tap over the pad, turn on the polishing machine and then open the tap until there is distribution of slurry over the pad, especially the section of the pad which comes into contact with the sphere.
4. Add the hemisphere sample in a sample holder to the modification then lower the modification to the polishing pad, at the area between pad centre and pad edge, until contact between the

hemisphere and polishing pad pushes the sample holder away from the modification plate (such that any normal force applied is directed onto the pad and not the modification plate). Adjust the force applied by the modification to match the targeted downforce between the hemisphere and the pad.

5. Adjust the rotation speed of the polishing machine to match the targeted sliding speed. Open the tap to allow flow of slurry onto the pad and turn the polishing machine on to allow flow of slurry onto the pad and polishing to take place. Start recording the time passed.
6. At the desired time has passed, turn off the polishing machine and tap, and lift the modification to remove the sphere.
7. The polishing pad and sphere may be cleaned as outlined under '**Post-polish cleaning**'.
8. Repeat steps 1 to 9 (inclusive) until all samples have been polished. If waste container appears more than  $\frac{3}{4}$  full, do not carry out another polish, replace the waste container and take the full container to the appropriate chemical waste disposal, or inform a technician. Polishing can resume once waste container has been replaced. If there is not enough slurry for another polish, empty and rinse out remaining slurry using DI water into slurry waste and repeat '**Dilution of slurry**'.
9. Thoroughly rinse all the equipment used with DI water and leave to air-dry.

### **Post-polish cleaning**

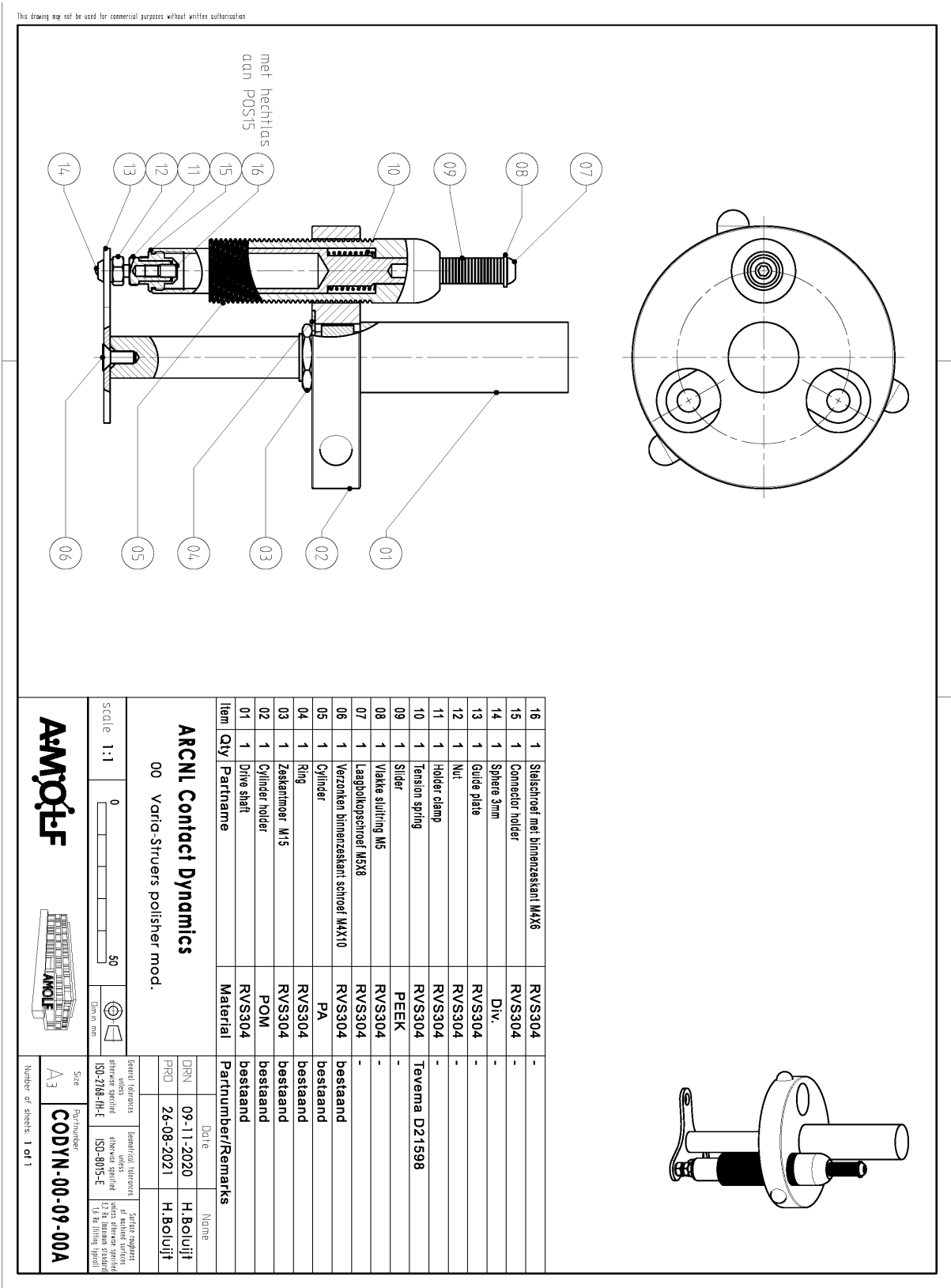
Post-polish cleaning is carried out to remove slurry & debris and prevent staining. Post-polish cleaning is carried out as follows:

1. Into a 250 mL glass beaker tall enough to fit into the ultrasonic cleaner without spilling, pour enough ethanol to ensure a sample would be submerged and the beaker does not float.
2. Place the sample into the beaker of ethanol.
3. Place the beaker into the ultrasonic bath, ensuring no spillage occurs and that the beaker is stable.
4. Turn the ultrasonic bath on at a low frequency, 005 power and 25 °C for 5 minutes.
5. Remove the beaker and rub the sample with a cotton bud in the same direction for a couple minutes without removing the sample from the ethanol.
6. Repeat steps 3 and 4.
7. In a separate 250 mL glass beaker, repeat step 1 using deionized water instead of ethanol.
8. Transfer the sample from the beaker of ethanol to the beaker of deionized water.
9. Repeat steps 3 and 4.
10. Remove the sample from the beaker and transfer to a piece of paper towel on a clean surface, with the apex directed away from the paper towel. Leave to air-dry.
11. Label, store and clean appropriately.

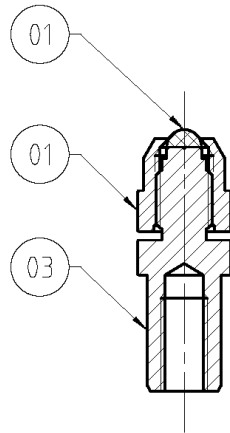
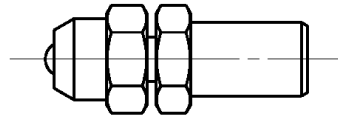
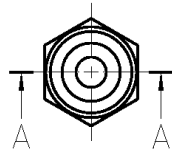
**Waste disposal and clean-up**

- Slurry and Ultra-Sol S27 must be disposed in waste container specific for slurry waste.
- Ethanol must be disposed in halogen-poor organic waste container.
- Rinse all equipment used with water and dispose accordingly.
- Gloves must be disposed as solid waste.
- Paper towel with slurry or cleaning product to be disposed of as solid lab waste.
- Clean fume hood, spill tray and polishing machine.

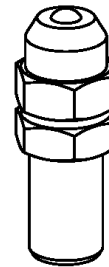
Appendix C: Polishing Modification and Hemisphere Holder Diagrams







SECTION A-A



| 03                                                                                                                                                                      | 1   | Half Sphere Holder | RVS304                                                                                           | -                                                 |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|--------------------|--------------------------------------------------------------------------------------------------|---------------------------------------------------|
| 01                                                                                                                                                                      | 2   | Nut                | RVS304                                                                                           | -                                                 |
| 01                                                                                                                                                                      | 1   | Half Sphere        | Div.                                                                                             | -                                                 |
| Item                                                                                                                                                                    | Qty | Partname           | Material                                                                                         | Partnumber/Remarks                                |
| <b>ARCNL Contact Dynamics</b><br>00 Varia-UMT Half Sphere Holder                                                                                                        |     |                    |                                                                                                  | Date                                              |
|                                                                                                                                                                         |     |                    | DRN                                                                                              | 01-07-2020                                        |
|                                                                                                                                                                         |     |                    | PRD                                                                                              | 26-08-2021                                        |
|                                                                                                                                                                         |     |                    |                                                                                                  | Name                                              |
|                                                                                                                                                                         |     |                    |                                                                                                  | H.Boluijt                                         |
|                                                                                                                                                                         |     |                    |                                                                                                  | H.Boluijt                                         |
|                                                                                                                                                                         |     |                    | General tolerances unless otherwise specified                                                    | Geometrical tolerances unless otherwise specified |
|                                                                                                                                                                         |     |                    | ISO-2768-FH-E                                                                                    | ISO-8015-E                                        |
|                                                                                                                                                                         |     |                    | Surface roughness of machined surfaces unless otherwise specified                                |                                                   |
|                                                                                                                                                                         |     |                    | 3,2 Ra (maximum standard)                                                                        |                                                   |
|                                                                                                                                                                         |     |                    | 1,6 Ra (fitting typical)                                                                         |                                                   |
| scale: 2:1                                                                                                                                                              |     | 0 25               | <br>Dim.in mm |                                                   |
|   |     |                    | Size<br>A4                                                                                       | Partnumber:<br><b>CODYN-00-07-00</b>              |
| Number of sheets: 1 of 1                                                                                                                                                |     |                    |                                                                                                  |                                                   |

This drawing may not be used for commercial purposes without written authorisation