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Please fill in your manuscript title.	New Superhard Boron Nitrides Material Technology for Breakthrough Milling Operations

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Abstract

Milling is a part of most important operations in many drilling problem complications but it is very time-consuming (~40 days) and costly (several million dollars). All mill tool materials are composed of the major tungsten carbide (WC) material (hardness ~20 GPa) with different morphologies for different applications but do not provide sufficient wear resistance and thermal stability for fast milling. Two new superhard wurtzite boron nitride (w-BN) and cubic boron nitride (c-BN) from pure w-BN starting powder are for the first time synthesized via innovative ultra-high pressure and ultra-high temperature (UHPHT) technology for upgrading workover milling applications.

The high purity w-BN powder was used as starting material. The powder was treated with 400 °C for one hour under vacuum to remove the impurities. The starting materials that were contained in an Re capsule were subjected to UHPHT treatments under pressures of ~ 20 GPa and temperatures of ~ 1900 °C in an innovative two-stage (6-8 systems) large volume multi-anvil apparatus. Both superhard w-BN and c-BN materials from pure w-BN powders have been produced under controlled pressure conditions with a 100 °C/minute heating rate. The samples were quenched to ambient temperature with a cooling rate of about 50 °C/min, and then decompressed to the surrounding pressure for characterization.

We have successfully synthesized pure polycrystalline w-BN and c-BN bulk materials directly from w-BN starting powder by ultra HPHT technology for the first time. It is found that the usage of pure w-BN initial material, the critical synthesis temperature control along with slower heating rates favor the synthesis of those pure BN compacts. Modern characterizations such as XRD, SEM, TEM, and SAD confirm the syntheses of superhard pure w-BN and c-BN bulk materials. The Vickers hardness of those compacts are first determined to be ~ 70 GPa. Thermal Gravimetric Analysis (TGA) results show that both w-BN and c-BN exhibit the highest thermal stability with an onset oxidation temperature at 920 °C in air for w-BN and 1,140 °C for c-BN, which are significantly higher than WC and diamond (~600°C).
Our innovative ultra-high pressure and high temperature technology provides an excellent opportunity to break through our drilling tool materials for game-changing drilling and workover operations. In terms of both super hardness and excellent thermal stability, the superior performance of both w-BN and c-BN

materials is ideal for milling ferrous and non-ferrous drilling tool materials that will change our current workover operations in a cost-effective and high efficiency manner.