Announcing the Final Examination of Zhilin Xie for the degree of Doctor of Philosophy

Time & Location: October 27, 2014 at 10:30 AM in ENG 288
Title: Rhenium, Osmium and Iridium Diborides by Mechanochemistry: Synthesis, Structure, Thermal Stability and Mechanical Properties

Borides are implemented in a range of industrial applications due to their unique mechanical, electrical, thermal and catalytic properties. In particular, transition metal diborides are of special interest. In the recent years, borides of rhenium (Re), osmium (Os) and iridium (Ir) have been studied as for their ultra-hardness and superior stiffness. In this dissertation, a mechanochemical method is introduced to produce rhenium diboride (ReB2) powder, a novel hexagonal osmium diboride (hâ€“OsB2), and iridium boridesâ€™ powders. Densification by Spark Plasma Sintering, thermal stability and mechanical properties of hâ€“OsB2 were also studied.

ReB2 was recently reported to exhibit high hardness and low compressibility, which both are strong functions of its stoichiometry, namely Re to B ratio. Most of the techniques used for ReB2 synthesis reported 1:2.5 Re to B ratio because of the loss of the B during high temperature synthesis. However, as a result of B excess, the amorphous boron, located along the grain boundaries of polycrystalline ReB2, would degrade the ReB2 properties. Therefore, techniques which could allow synthesizing the stoichiometric ReB2 preferably at room temperature are in high demand. ReB2 powder was synthesized at low temperature using mechanochemical route by milling elemental crystalline Re and amorphous B powders in the SPEX 8000 high energy ball mill for 80 hours. The formation of boron and perrhenic acids are also reported after ReB2 powder was exposed to the moist air environment for a twelve month period of time.

Hexagonal osmium diboride (hâ€“OsB2), a theoretically predicted high-pressure phase, has been synthesized for the first time by a mechanochemical method, i.e., high energy ball milling. Xâ€“ray diffraction (XRD) indicated the formation of hâ€“OsB2 after 2.5 hours of milling, and the reaction reaches equilibrium after 18 hours of milling. The lattice parameters of the hâ€“OsB2 are a=2.916 Å... and c=7.376 Å..., with a P63/mmc space group. Transmission electron microscopy confirmed the appearance of the hâ€“OsB2 phase. The thermal stability of hâ€“OsB2 powder was studied by heating under argon up to 876°C and cooling in vacuo down to â€“225°C. The oxidation mechanism of hâ€“OsB2 has also been proposed. The hexagonal phase partially converted to the orthorhombic phase (20 wt.%) after spark plasma sintering of hâ€“OsB2 at 1500°C and 50MPa for 5 minutes. Hardness and Youngâ€™s modulus of the hâ€“OsB2 were measured to be 31 Å± 9 GPa and 574 Å± 112 GPa, respectively by nanoindentation method.

Prior to this research a number of compounds have been prepared in Irâ€“B system with lower than 2 boron stoichiometry, and no IrB2 phases have been synthesized experimentally. In this dissertation, three new iridium boride phases, ReB2â€“type IrB2, AlB2â€“type IrB2 and IrB have been synthesized with a similar mechanochemical method. The formation of these three phases has been confirmed by both Xâ€“ray diffraction (XRD) and transmission electron microscope (TEM) after 30 hours of ball milling and 48 hours of annealing. The IrB2 phases have hexagonal crystal structures and the new IrB phase has an orthorhombic crystal structure. The segregation of iridium from iridium boridesâ€™ lattices has also been studied by high resolution TEM.

Major: Mechanical Engineering

Educational Career:
Bachelor's of Process and Control Engineering, BS, 2010, China University of Petroleum
Master's of Mechanical Engineering, MS, 2012, University of Central Florida

Committee in Charge:
Nina Orlovskaya, Chair, Department of Mechanical and Aerospace Engineering
Richard Blair, Co-Chair, Department of Mechanical and Aerospace Engineering; Department of Physics
Jan Gou, Department of Mechanical and Aerospace Engineering
Seetha Raghavan, Department of Mechanical and Aerospace Engineering
Linan An, Department of Materials Science and Engineering

Approved for distribution by Nina Orlovskaya, Committee Chair, on October 12, 2014.

The public is welcome to attend.