MICROGRAVITY PRODUCTION OF NANOPARTICLES OF NOVEL MATERIALS USING PLASMA SYNTHESIS

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The project has just been funded. The research goal is to study the formation in reduced gravity of high quality nanoparticulate of novel materials using plasma synthesis. Particular emphasis will be placed on the production of powders of non-oxide materials like diamond, SiC, SiN, c-BN, etc. The objective of the study is to investigate the effect of gravity on plasma synthesis of these materials, and to determine how the microgravity synthesis can improve the quality and yield of the nanoparticles. It is expected that the reduced gravity will aid in the understanding of the controlling mechanisms of plasma synthesis, and will increase the yield, and quality of the synthesized powder. These materials have properties of interest in several industrial applications, such as high temperature load bearings or high speed metal machining. Furthermore, because of the nano-meter size of the particulate produced in this process, they have specific application in the fabrication of MEMS based combustion systems, and in the development and growth of nano-systems and nano-structures of these materials. These are rapidly advancing research areas, and there is a great need for high quality nanoparticles of different materials.

One of the primary systems of interest in the project will be gas-phase synthesis of nanopowder of non-oxide materials. Under laboratory conditions, the best results have been obtained when synthesis took place in plasma-enhanced flame environments. Although the powder was of high quality, the yields were quite low and limited by the short length of the reaction zone and small residence time. Since in reduced gravity the flow residence times should be larger, as it has been observed with diffusion flames, it can be inferred that nanopowders formed in microgravity will have larger yields. Also, in microgravity the distribution of nucleates and the particle growth should be more uniform, as it has been observed which several other crystal growth processes, which should increase the quality of the powder. Furthermore, recent plasma reactors operate at atmospheric pressures, which although simplifies the reactor operation, has the disadvantage of the increased buoyancy that adversely affects the flame/plasma characteristics. In microgravity, this last deterring effect will be reduced. Thus, the operation of an elevated pressure plasma synthesis reactor in microgravity has the potential of producing a high yield, high quality, powder of other non-oxide materials, such as diamond, SiC, SiN, c-BN, since they have similar synthesis.

To accomplish the stated objectives, a plasma reactor, operating in the diffusion flame mode, will be designed and built at the University of California at Berkeley. The Berkeley team combines the experience in plasma synthesis of diamond and other non-oxide materials and in premixed, diffusion and condensed phase combustion in microgravity. The reactor will be designed, keeping in mind that it will be used in ground based microgravity facilities, to operate from low to near atmospheric pressure. The expectation is that the larger residence times and better nucleate uniformity obtained in microgravity, along with higher pressures, will result in powder of high yield and quality. Normal gravity experiments will be conducted to determine the performance characteristics of the reactor, i.e., powder yield and quality, and to obtain data for comparison with the microgravity experiments. The initial experiments will be conducted with silicon carbide powder, which has similar synthesis to diamond but requires a somewhat simpler system. Upon successful accomplishment of this task, the experiments on diamond powder will be performed.

One critical parameter in the formation of significant quantities of these powders is time (of the order of hours), due to the small yield of the plasma synthesis process. For this reason, to produce significant amounts of powder, the synthesis must eventually be conducted in a facility with long microgravity operation periods, such as the Space Shuttle or Space Station. However, verification of the concepts supporting this proposal, and the reactor capabilities could be done in ground based microgravity facilities. We estimate that the total microgravity time provided by an aircraft parabolic flight, i.e., 30 to 40 parabolas with 20 to 30 seconds of microgravity each parabola, would be enough to determine the potential of the proposed system, and to obtain preliminary results. Thus the program is planned as a ground based research investigation. Given the industrial interest of these materials, and the current thrust in MEMS and nano-technology, it is envisioned that the program could lead to advances in these fields, and perhaps the eventual commercial utilization of space based facilities to produce nanoparticles using the methodology presented here.