Nanodiamond Foil Product for H^- Stripping to Support Spallation Neutron Source (SNS) and Related Applications

RD Vispute[a], Henry Ermer[a], Phillip Sinsky[a], Andrew Seiser[a], R. W. Shaw[b]

[a]*Blue Wave Semiconductors, Inc., 1450 South Rolling Road, UMBC Technology Center, Baltimore Maryland, USA,*

[b]*Chemical Sciences Division, Oak Ridge National Laboratory,USA*

Contact Author email address: rd@bluewavesemi.com

Thin diamond foils are needed in many particle accelerator experiments on nuclear and atomic physics as well as in some interdisciplinary research. Particularly, nanodiamond form is attractive for this purpose as it possesses a unique combination of diamond properties such as high thermal conductivity, mechanical strength and high radiation hardness, therefore, it is considered as a potential material for ion beam stripper foils. The foil must be able to survive the typically 6 month operation period of the SNS, without the need for costly shutdowns and repairs. Thus, a single nanodiamond foil about the size of a postage stamp is critical to the entire operation of SNS and similar sources in US laboratories and around the World.

Nanocrystalline, polycrystalline and their admixture films are fabricated using a hot filament chemical vapor deposition system. Process variables such as substrate temperature, process gas ratio of $H_2/Ar/CH_4$, plasma biasing, substrate to filament distance, filament temperature, carburization conditions, and filament geometry are optimized to achieve high purity diamond films without significant heavy metal contamination. In-situ laser reflectance interferometry tool (LRI) is used for monitoring growth characteristics of diamond thin film materials. The integrated LRI with HFCVD process provides real time information on the growth of films and can quickly illustrate growth features and control over film thickness. By knowing the wavelength of the laser and by knowing the refractive index of the film, growth rate and film thickness can be determined. This helps to monitor accurately the targeted 250 micro-g/cm^3 thickness of nanodiamond foil to be manufactured for spallation neutron source. Using LRI integrated HCVD, we correlated several important growth parameters of poly and nanodiamond films including seeding process. Our LRI results clearly indicated that seeding procedure strongly affects initial growth stages of diamond film through early start of oscillations. As the film starts to grow the laser reflectance decreases, until nucleation layer is continuous on the substrate. After that laser reflectance starts to increase and oscillations can be measured. SEM measurements were conducted to confirm the in-situ film thickness measurements using LRI. Using this approach, nanodimaond foil product is under development. The process parameters are also optimized for thermal and intrinsic stress management to fabricate free standing thin foils with minimal curling during irradiation. Optimization process removes pinholes to lowest possible density in the foils. The sp^3/sp^2 bounds are controlled to optimize electrical resistivity to reduce the possibility of surface charging damaging the foils. The results will be presented in the light of development of nanodimond foil product that will be able to withstand a few MW beam and be able to still be used when the SNS upgrades to greater than 3MW beam in the future.

Figures:

Below we highlight important results related to this research work. The additional supporting results will be presented in the conference.

Fig. 1 Blue Wave HFCVD System with filament arrangement capable of reaching more than 2200°C for growth of diamond films.

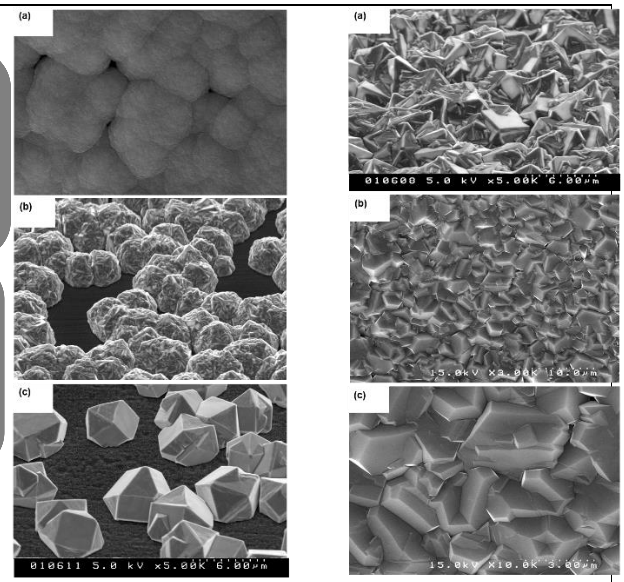

Fig. 2 SEM micrographs of the HFCVD diamond films grown at (a) 7sccm of (b) 5sccm and (c) 2 sccm of CH4 in H2 of about 93-98 sccm of H2., Right side images show micrographs of the HFCVD diamond films grown at substrate rotation of 10 rpm for (a) 6 hrs and 25 hrs respectively. Fig 2(c) is the magnified image of 2 (b).

Fig. 3 Free standing nanodiamond film

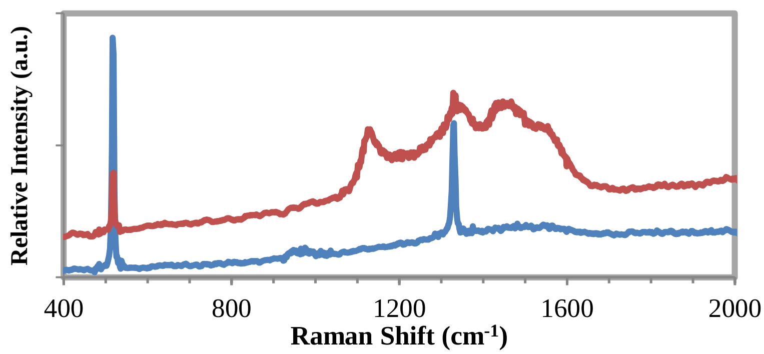

Fig. 4 Raman spectrum of nanodiamond, red, and polycrystalline diamond, blue.

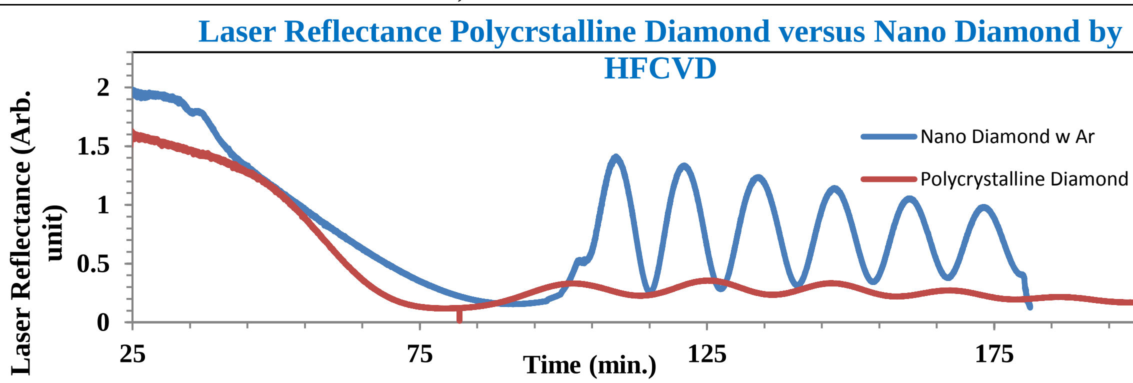

Fig. 5 Laser Reflectance graph showing comparison of nano and polycrystalline diamond after nucleation