A COMPARISON OF ALLENDE DIAMOND WITH DIAMOND FROM DETONATION SOOT. David Blake, Friedemann Freund, Ted Bunch and Sherwood Chang, Planetary Biology Branch, NASA Ames Research Center, Moffett Field, CA 94035, Alexander Tielens, Space Sciences Division, NASA Ames Research Center, Moffett Field, CA 94035 and N. Roy Greiner, Los Alamos National Laboratory, Los Alamos, NM 87545

Since the discovery of submicroscopic diamond in oxidized acid residues of carbonaceous chondrites\(^1\) (i.e., the C\(6\) component), a variety of papers have been written presenting experimental, observational, and theoretical evidence for the mode of formation of the diamond. Lewis et al.\(^1\) postulated a low-pressure Chemical Vapor Deposition (CVD) mechanism of formation similar to that of recent laboratory syntheses\(^2\), based on the fact that there was no known mechanism for the production of the necessary high pressures in interstellar space, except in large bodies and in impacts involving large bodies. Hecht\(^3\) hypothesizes that diamond may be formed by "shock heating" or particle bombardment of amorphous carbon grains which already had some sp\(^3\) bonding character. Nuth\(^4\) argues that 5 nm diamond crystals may be favored energetically over similar sized graphite nuclei due to surface free energy contributions. All of these authors either postulate or assume low pressure formational conditions for the meteoritic diamond, but none show definitive or even persuasive evidence of a low pressure origin. Tielens et al.\(^5\) calculate that high velocity grain-grain collisions such as are expected to occur in supernova shocks will produce sufficiently high pressures and temperatures to convert graphite or amorphous carbon grains into polycrystalline diamond. Blake et al.\(^6\) present a variety of data to characterize the C\(6\) diamond phase and show that the diamond may form in its stability field following (5). Greiner et al.\(^7,8\) describe diamond in the detonation soot from high explosives ignited in argon-filled chambers and note that diamonds so formed are of similar size (\(-4\) nm) and yield a similar IR spectrum to the meteoritic diamond of the C\(6\) component. In this report we compare diamonds from Allende C\(6\) residue with diamonds from a residue similarly prepared from detonation soot.

Figure 1 shows high magnification bright field and dark field TEM images of diamond isolated from the Allende meteorite. Compact masses, fractions of a micron in size, contain cryptocrystalline diamond whose crystals range in size from less than 0.5 nm to 7.5 nm. Selected area electron diffraction patterns of the diamond masses show Debye-Scherrer ring patterns from even the smallest aperture size (fig. 1c). Figure 2, a-c show equivalent micrographs from diamond clumps in detonation soot residue. The size and shape of the masses, the size and shape of individual crystallites, and the degree of crystallinity of the material are nearly identical to the meteoritic diamond. Thus, this comparison shows that the properties of the meteoritic diamond are consistent with shock synthesis. In contrast, studies of low pressure CVD diamond\(^2,6\) show these materials to be microstructurally distinct from either the Allende diamond or the diamond from detonation soot. Some low pressure diamond-like amorphous carbon (DLC) films, however, have been reported which contain microcrystalline diamond.\(^9,10\) Taking these data into account, it appears that analogs exist for both low pressure and high pressure diamond nucleation and growth, and that no prima facie evidence exists for choosing one model over the other.

If interstellar diamond is formed under high pressure conditions, we envision the following scenario for its production: Charged interstellar grains, consisting primarily of amorphous carbon, gyrate at high velocity around the magnetic field behind strong supernova shock waves. If such C grains, about 100 nm in size, collide with each other in the velocity range of 10-100 km/sec., the resulting shock wave within the particles will melt the aromatic carbon structure in the stability field of diamond. Polycrystalline diamond would crystallize directly from the melt during shock unloading, on a time scale of the order of 10\(^{-10}\) seconds. Assuming a low viscosity of the C melt and maximum crystallization rate, the size of the diamond crystallites cannot be larger than about 10 nm. Gasses implanted within the original carbonaceous grains may be segregated and trapped at grain boundaries.

COMPARISON OF ALLENDE AND DETONATION SOOT DIAMOND
Blake, D.F., et al.


Fig. 1. TEM of diamond from Allende residue. a). Bright field (BF) image of a mass of diamond, scale bar = 20 nm. b). Dark field (DF) image of same region as 1(a), using a portion of the (111) powder ring. c). Selected area electron diffraction (SAED) pattern of a small mass of diamond.

Fig. 2. TEM of diamond from detonation soot residue. a). BF image, same magnification as 1(a). b). DF image of same region as 2(a), using a portion of the (111) powder ring. c). SAED pattern.