

not clear what this material was until recent comparative studies were aimed at identifying root crops. Preliminary evidence from Southern Neolithic sites indicates much larger quantities of parenchyma tissue in earlier levels on sites such as Sanganakallu than are present in samples of later periods. Although the necessary study for identification is ongoing, it should be remembered that there are numerous wild yams (*Dioscorea* spp.) native to southern India which are known ethnographically to be gathered and eaten. In addition ginger, turmeric and their relative (Zingiberaceae: *Zingiber* spp., *Curcuma* spp.) are also native, edible tubers of the peninsula, as suggested by us.

One hypothesis to consider in future work is that the domestication of pulses and tubers occurred when they were

brought from the forested, hilly ecological zones on the eastern and western sides of the Peninsula, where pulses occur at the forest margins and wild yams are numerous, into the central Deccan plateau where the climate is somewhat drier and dominated by grasslands. In these grasslands wild millets would have been readily available and these may have become the focus of cultivation. Later intensification of cereal production decreased the importance of tubers.

In addition to the staple foods outlined above, Neolithic folk would have utilized gathered fruits, nuts, vegetables and other produce. One fruit which is widely preserved and recovered archaeologically is *Ziziphus* sp. (probably *Z. jujuba*) the jujube fruit. This was certainly utilized in the Neolithic.

HYDROTHERMAL SYNTHESIS OF DIAMOND*

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EXTENDED ABSTRACT

Carbon is a versatile element that has been studied time and again for reasons of economic and technological importance. Graphite and diamond are the two pure and well known polymorphs of carbon found in nature. Besides these two forms, reports of the last few decades show that there are many other solid forms like amorphous carbon, carbines, fullerenes, carbon nanotubes, diamond like carbon and carbon nanocells. These solid forms of carbon do not yet find a place in the carbon phase diagram, which gives only the stability fields of phases like graphite, diamond and liquid phase. Graphite and diamond occur in contrasting geochemical environments. The exact processes that control their formation in nature are still debatable. But, it is very well known that the P-T- f_{O_2} and C-O-H fluid systems have played a significant role in the formation of these two pure forms. Diamond is one of the hardest minerals, crystallises in isometric system as octahedrons, dodecahedrons and cubes, wherein the carbon atoms held together by strong covalent bonding in a tetrahedral coordination. Graphite is soft, crystallises in hexagonal system and has sheet structure, wherein the carbon molecules are held together by weak van der waal's forces.

Diamond has outstanding properties, such as high thermal conductivity, high index of refraction; capable of transmitting IR and UV radiations, remarkable semiconductor properties, resistant to neutron radiation etc., and because of these it plays an indispensable role in modern industry. It is used for abrasives, cutting tools, microelectronics, optics and other applications. However, diamonds are scarce and highly priced and this motivated man to explore the synthesis of diamond. Several techniques have been employed among them the high pressure-high temperature (HPHT), Shockwave and carbon vapour deposition (CVD) methods of synthesis have been commercialised. The properties of these synthetic diamonds are nearly the same as that of the natural diamonds.

Diamonds can also be formed metastably under a variety of conditions:

- Diamonds were found in combustion products;
- they can be synthesised from fullerenes by pressurising at room temperatures;
- * by sputtering at high temperatures;
- * they can also be obtained by the decomposition of polymers of appropriate structures;

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- * by heating carbon "onions" with electron beam;
- * by chlorination of SiC and
- * by deposition from hot supercritical fluids.

These routes of preparation of diamond will probably remain a scientific curiosity.

Natural diamonds are still essentially the only source for large size single crystals required for the electronic and gem applications, which are supposed to have formed under mantle conditions (i.e. at more than 150 km of depth; 900°C and 50 kbars of pressure). The deep-seated volcanoes that erupted in various periods through deep fractures forming carrot shaped explosion pipes, commonly known as kimberlitic pipes have brought the diamonds to the surface regions. Based on the nature of host rock in the upper mantle, whether it is peridotitic or eclogitic, diamonds are recognised as p-type or e-type. The carbon derived from the primordial degassing and vapour fractionation of the CH₄ and CO₂ in the presence of sulphide immiscible liquids and nitrogen are responsible for the carbon reduction. The oxygen fugacity and strongly reducing environments mainly control the diamond stability. Generally high-pressure carbon and carbon vapour condensates (soot) are invoked for the origin of diamond in nature.

De Vries (1990) was the first to suggest the possibilities of hydrothermal synthesis of diamond based on some of the geological evidences like syngenetic C-H-O fluid and silicate mineral inclusions in natural diamonds. Szymanski (1997) pointed out that the smaller particles are more stable at low pressure and high temperature conditions compared to macroscopic diamonds and further reports that the overgrowths, embryocrystals and phantoms over natural diamonds, suggesting a mechanism of homoepitactic diamond coarsening under colloidal pneumatolytic-hydrothermal environments. The diamond paragenesis with quartz and other silicate minerals, from a kimberlite (Leung et al. 1990); in quartz veins of Brazilian itacolumite and Australian diamonds, suggest the conditions of formation of these mineral assemblages, much below the Berman - Simon P-T line.

The varied scenario of diamond formation in nature as well as the reports of diamond synthesis at extreme conditions necessitates for the search for still more new techniques of diamond synthesis. The following are some of the important research groups, which are actively working towards the synthesis of diamond at low pressure-temperature (hydrothermal) conditions:

- Szymanski et al. (1995) reported the synthesis of thin colourless film of polycrystalline diamond over natural diamond seed using a specially prepared water solution at 400°C and 170 MPa.

- Roy and co-workers (1996) came up with an experimental hypothesis that the carbon exposed to atomic hydrogen while it is still crystallising will deposit as diamond. Thus, they employed low-pressure solid-state sources (LPSSS), using a composite paste consisting of graphite or carbon black with micron sized diamond seed and a substrate material reacting at 900°C in H₂ microwave plasma.
- Gogotsi et al. (1995) have attempted the hydrothermal epitaxial coarsening of diamond through decomposition of diamond seeded β -SiC powder in the presence of water at 700-750°C and 100-500 MPa.

The above-mentioned reports indicate that they have invariably used micron-sized diamond as seed and/or a metal catalyst along with the charge material. Coarsening of diamond seed was their significant claim but the characterisation of these materials does not demonstrate convincingly the growth. Though the argument that the C-O-H fluids could be the source for the formation of diamond in nature may be valid, however, none of the above experimental approaches have been able to generate an appropriate C-O-H fluid environment in the system.

The above facts encouraged us to explore further the hydrothermal technique employing Tuttle-Roy autoclave. The charge material was taken in sealed gold tubes, the charge was β -SiC powder and organic compounds without excess water in the system. The experiments were carried out at 800°C and 150-200 MPa for 80-120 hours duration. The dissociation of organic compounds in a closed system leads to an increased atomic hydrogen concentration as well as an increase in C_nH_x radicals and these are known to produce highly reducing atmosphere with low oxygen fugacity, inside the capsule. The decomposition of silicon carbide into carbon particles and quartz crystals was found in almost all the runs. XRD studies do not give diffraction lines of any carbon phase, may be because of lack of ordering and due to the fact that carbon has strong absorption for X-rays. The optical microscopic and SEM studies reveal that the majority of the carbon particles were glassy or disordered graphitic carbon and some of them are nano or micron sized spherical particles. These spherical shaped carbon particles are porous and spongy and we can also see the development of scales over their surface. In some broken spheres, we are amazed to see the development of nano-sized crystallites, similar to the crystallisation seen in the cavities of basaltic lava flows. In order to understand fully the development of such nano crystallites it is necessary to understand the exact nature of possible fluid species, their reaction mechanism and supported by thermo-chemical modelling. The micro Raman spectra of these spherical

shaped carbon particles has strong and sharp bands at $\sim 1335\text{ cm}^{-1}$ and $\sim 1560\text{ cm}^{-1}$ which were referred to the D and G band of C-C stretching vibrations. The spectra from the run product of ma-66 compares well with that of the spectra obtained for the commercially available diamond powder, supplied by the HYPREZ, Co., USA. The scales, which are found over the spheres, were formed at the contact of carbon spherules with that of the inner walls of the gold capsules. This indicates that their formation was due to the localised melting and recrystallisation into nano scale particles and crystallites. All these features indicate that the super critical fluid environment has proved to be

congenial for the synthesis of sp^3 bonded carbon under hydrothermal conditions. Thus, the above results prove that the nucleation of the sp^3 -bonded carbon was possible under hydrothermal conditions; which was not the case in the previous attempts where only the overgrowths or epitaxial coarsening of the seeds were reported.

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EARTH SCIENCES AND INFORMATION TECHNOLOGY: ROLE OF OPEN SOURCE SOFTWARE

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EXTENDED ABSTRACT

The use of computers in various spheres of earth science activities has become common place and inevitable today but a multitude of challenges have also cropped up. The rapid changes of technology both on hardware and software fronts make many of the already implemented technologies obsolete within a short span of yield time. Valuable resources are often wasted when new technologies do not give returns which they promise and require further costly upgradations.

Prices of hardware are nose-diving while more and more computing power is made available cheaply due to

improvements and innovations in production technology. On the downside of this phenomena is the fact that many of already installed and usually normally working hardware tends to be termed obsolete. But software prices continue to rise at a fast pace. The 'half-life' of software is usually very short and demands for changing over to newer versions come within months of the initial implementation.

Increased dependence on computerization with integration of internet technologies makes IT security a major area of concern. Virus attacks, data theft, snooping

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