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Charge Particle Accelerator: A Versatile Tool for Nanotechnology

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Editorial

The extensive research carried out during last decade had shown the proof of facts that the materials at small scale show unusual physical properties. This understanding led to the development of nanotechnology, which includes synthesis of the nano-dimensional devices and utilizing them for various applications to uplift the societal standards for making the human lives easy [1]. With pros and cons, there are several approaches which can yield the desired output in terms of the synthesis of nano-materials. The uniformity and the size distribution of the nano-particles are crucial synthesis parameters in order to use them for real applications with greater efficiency. The charge particle accelerator is a versatile tool to fabricate nano-composites with excellent control on the size distribution of the particles [2,3]. In this, a carefully chosen target material is bombarded with an ion beam and, the beam parameters are controlled as per the understanding of the ion-matter interaction studies to yield desired nano-composite/structures. The ion beam synthesis of the nano-particles/composites is a bottom-up approach where large numbers of atoms agglomerate at the nucleation sites. At IUAC, we explored the potential of the ion beam approach in two different ways and synthesis of surface and buried metal nano-particles was evidenced.

In a usual practice, we make use of the implant atoms [4]. The ion beam of the metal, whose nano-particles are of interest, is developed first and then, it is allowed to incident on the target (which is the matrix of the nano-composite). Depending upon the depth of fabrication of the nano-particles, the beam energy is varied. For low ion energies (up to tens of keV), the nano-particles are fabricated on or near the surface. The high energy ion implantation yields buried nano-particles. The exact stopping/range of the ion beam in the matrix can be deduced by Stopping and Range of Ion in Matter (SRIM) software [5]. In both cases, the ion implantation is carried out at higher fluence. Subsequent thermal annealing at elevated temperature is very much required to get uniform size and a narrow size distribution of the nano-particles. A surface plasmon resonance (SPR) absorption peak at optimized ion fluence in the visible spectrum is the first confirmation of synthesis of the metal nano-particles. The peak position is highly dependent on the size, shape and distribution

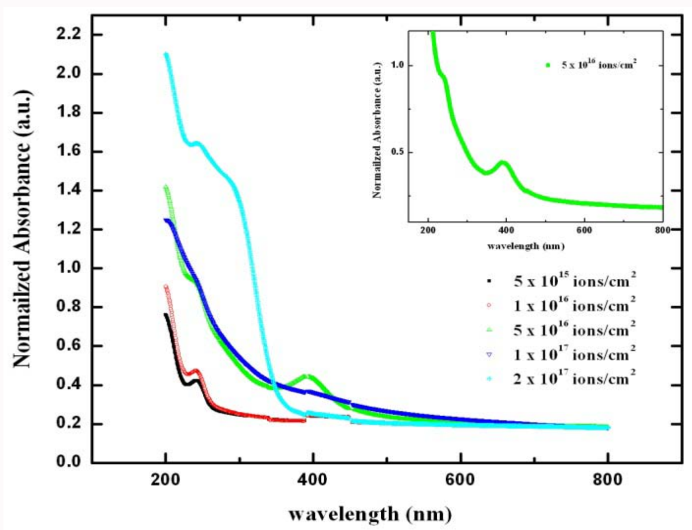

Figure 1: The UV-Visible spectra of 100keV Ni ion beam implanted (at various fluences) and subsequent annealed (at 600°C) quartz. The SPR peak at fluence of 5.0 x 10^{16} ions/cm^2 is clearly visible in the inset [4].

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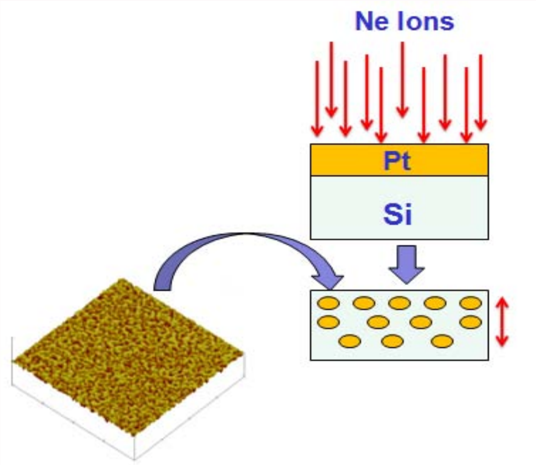

Figure 2: Synthesis of Pt nano-particles in silicon matrix using inert ion beam irradiation technique [6].

of the nano-particles, and the dielectric constant of the matrix. A typical SPR peak arising due to the synthesis of Ni nano-particles in quartz matrix via the implantation of 100keV Ni beam at fluence of 5.0×10^{16} ions/cm^2 and subsequent thermal annealing of the sample at 600^{0}C is shown in Figure 1. Other methods viz. transmission electron microscopy (TEM) and the cross-sectional secondary electron microscopy (SEM) can also be utilized to visualize the shape, size and distribution of the nano-particles.

In second case, the energy losses by the ion beams are utilized for the synthesis of nano-particles [6]. A thin metallic film (~ 3-5nm), whose nano-particles are of interest, is deposited on the substrate matrix and irradiated with high energy inert ion beam at certain fluence. The schematic of such technique to form Pt nano-particles in silicon matrix via Ne ion beam irradiation is shown in Figure 2. It is worth to note here that the surface energy of the film should be greater than that of the substrate in such a synthesis route and therefore, the metal and the substrate matrix are chosen accordingly. As beam energy is very high in this case, the ions just pass through the film. However, the beam undergoes for the energy losses (elastic and inelastic collisions) in the film and finally, leads to the synthesis of the nano-materials. As far as mechanism of nano-particle formation is concerned, the sputtering of the film takes place first and then, the energy deposition by the ion beams in the film yields molten zones which try to minimize the surface and as a result, the spherical metal nano-particles are synthesized. For longer beam irradiation as the case of high fluence, the burrowing of the nano-particles is also evidenced.

The ion beam synthesis of the nano-particles is a unique method in the sense that beam of all element in the periodic table can be developed in principle and spatially placed at desired depth by controlling its energy. Therefore, any nano-composite, which is difficult to fabricate by other means, can be synthesized by this technique with greater accuracy in the size and distribution of the nano-particles.

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