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Formation and Characterization of Cobalt Nanoparticles in Silica by Ion Implantation

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Metallic nanoparticles are of both fundamental and technological interest, with applications ranging from nonlinear optics to plasmonics, and light trapping in solar cells [1-4]. Cobalt nanoparticles were synthesized via ion implantation in a 100 nm silica layer, thermally grown on a silicon substrate with 50 keV Co ions and the fluence was 6×10^{16} ions/cm^2. According to Monte-Carlo ion-range simulation code SRIM 2007 [5], at this energy the average range of Co ions in SiO_2 is ~ 43 nm. After implantation the samples were annealed separately at various temperatures in nitrogen atmosphere at 500^{o}C, 700^{o}C, 900^{o}C for one hour and 900^{o}C for two hours. Transmission Electron Microscopy (TEM) cross sectional images show the formation of different sized Co nanoparticles at each annealing temperature (Fig. 1 a-d). The average size of nanoparticles increases with the increasing annealing temperature (Fig. 2.e) and the distribution of nanoparticles at different annealing temperatures are shown in Fig. 2.a-d.

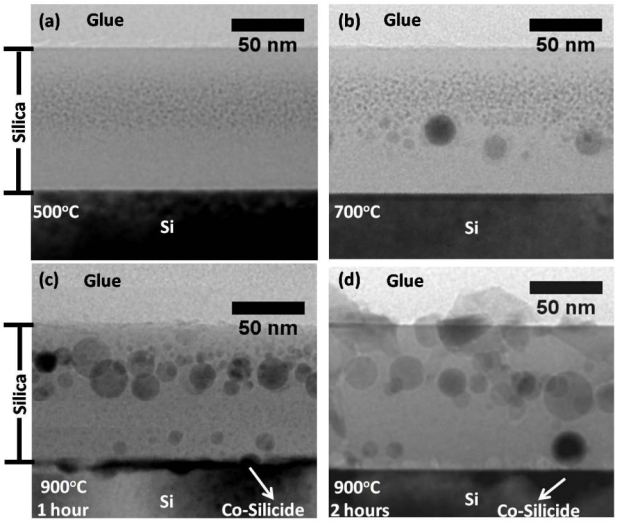

Fig. 1 TEM cross section images of Co implanted silica samples (Fluence: 6×10^{16} ions/cm^2). Samples were annealed at (a) 500^{o}C, (b) 700^{o}C, (c) 900^{o}C (1hour) and (d) 900^{o}C (2 hours).

It is also interesting to see the enhanced diffusion of Co with the increasing annealing temperature. Smallest nanoparticles with average diameter ~ 1.8 nm are formed at 500°C as shown in Fig. 1 (a). The 700°C annealed sample shows more growth and diffusion of nanoparticles closer to the Si/SiO_2 interface. The average sizes of nanoparticles are ~1.8 nm closer to the surface and ~18.5nm closer to the Si/SiO_2 interface. As the temperature is increased to 900°C, Co diffuses towards the surface and Si/SiO_2 interface. TEM analysis also reveals that there is also formation of some features in Si substrate, suggesting a possible silicide formation. The distribution of Co nanoparticles also becomes bimodal with nanoparticles with average size of ~17.5nm closer to the surface and ~8nm closer to the Si/SiO_2 interface. By increasing the annealing time (900°C - 2 hours) the growth of nanoparticles is further increased. Also the diffusion of Co both towards the surface and Si/SiO_2 is more prominent. Larger nanoparticles are formed both closer to the surface and Si/SiO_2 interface and also Co diffusing out of surface and into the Si substrate. The distribution of nanoparticles still remains bimodal with the exception of larger nanoparticles.

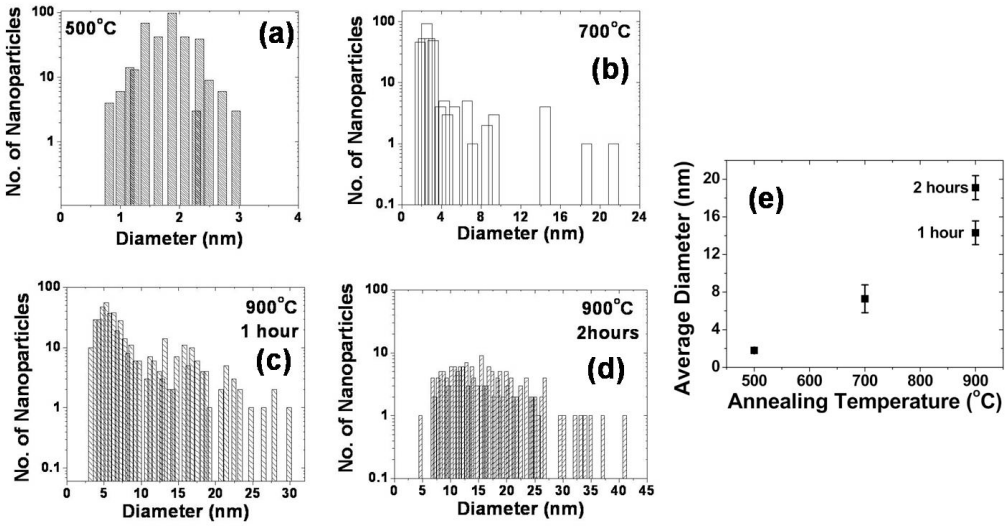

Fig. 2 Sizes distribution of Co nanoparticles at (a) 500°C, (b) 700°C, (c) 900°C for 1 hour and (d) 900°C for 2 hours annealed in N_2 samples. The increase in average diameter of nanoparticles with annealing time is also shown in (e).

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