Si29 nanoparticles: A highly fluorescent new form of silicon

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We electrochemically dispersed bulk crystalline Si into a colloid of ultrasmall Si nanoparticles (Si29, $\approx$ 1 nm diameter) with novel optical, electronic and biological characteristics, and reconstituted them into micro crystallites or uniform films on device quality Si, or silicon oxide. The particles are ultrabright blue luminescent particles, two-fold brighter than fluorescein, and most efficient under single UV or near-infrared two photon excitation processes. The blue emission from single particles in colloids or frozen in a gel or on a quartz substrate are readily detectable with a high degree of photostability. The particles are produced with hydrogen, oxygen, or biopolymer termination. In addition to being ultrabright, reconstituted films exhibit stimulated blue emission, directed blue beam emission between faces micro crystallites with a high gain coefficient, and second harmonic generation (forbidden in bulk due to the centrosymmetry). I-V spectroscopy using scanning tunneling microscopy and spectroscopic ellipsometry suggest a large drop in the dielectric constant, and a breakdown of the effective mass. Monte Carlo quantum theory shows that the particle is a filled fullerene, at the edge of the sp3 diamond-like and the sp2 graphite-like structures. Five atoms constitute a tetrahedral core. The remaining 24 atoms constitute a highly, puckered (wrinkled) cage with highly radiative quantum confinement-induced Si-Si reconstructed phase, found only in ultrasmall nanoparticles.