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Photoluminescences of SiO_2 Irradiated by Heavy Ion*

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Abstract: A novel method, high energy heavy ion irradiation, was proposed to produce light-emitting structures. It was used in studying photoluminescence properties from C-doped SiO_2 films.

Key words: high energy heavy ion irradiation; photoluminescence; SiO_2 films
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Since the discovery of intense visible photoluminescence (PL) from porous Si at room temperature, there has been a great interest in the structural and optical properties of Si nanocrystals[1]. A number of methods including chemical etching, CVD, co-sputtering, ion implantation have been used to produce light-emitting structures. However, most of them are not suitable for modern microelectronics application.

In this letter, a novel method, high energy heavy ion irradiation, was proposed to fabricate light-emitting materials with sufficient and special luminescent centers. The base of this method is that a very energetic heavy ion can induce defect production, ion latent track formation as well as phase change in a nanosized region along the ion path in a solid (see a review paper[2]). According to the effects of quantum confinement, chemical compounds and crystalline defects, quantum dots (point defects, nanosized ion track or new phase) created by high energy heavy ion irradiation will be light-emitting centers. Indeed, it is evidenced by the following experiments.

SiO_2 films were thermally-grown on (111) facet of p-type single crystalline silicon by use of wet oxidation at high temperature. The oxide thickness was about 500 nm. They were implanted at room temperature (RT) with 120 keV C-ions to 5×10^{17} ions/cm^2, and then irradiated at RT with 335 or 855 MeV ^{40}Ar ions or 1.98 GeV ^{86}Kr ions to 1×10^{12} ions/cm^2. After implantation and irradiation, spectra of PL excited by 320 nm monochromatic ultra-violet were measured at RT.

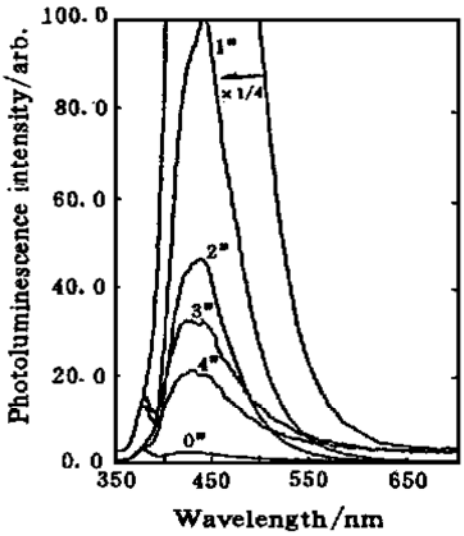

Fig. 1 Spectra of photoluminescence from SiO_2 samples. 0# as implanted; 1# as implanted and 855 MeV Ar ion-irradiated: 2# as implanted and 335 MeV Ar ion-irradiated; 3# as implanted and 1.98 GeV Kr ion-irradiated; 4# 1.98 GeV Kr ion-irradiated.

Fig. 1 shows the measured PL spectra. It is clear that blue-violet PL bands formed in the heavy ion irradiated samples (1# - 4#). The most intense

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PL bands are centred at the region from 441 to 430 nm (2.81 to 2.88 eV). There is also a relative weak but detectable violet PL from 3# (peak centred at 384 nm, 3.23 eV) and 4# (380 nm, 3.26 eV) samples. For unirradiated C-doped SiO_2 thin film (0#), no blue PL peak but a weak violet PL peak centred at 380 nm (3.26 eV) was observed. For 1.98 GeV Kr-ion irradiations, the PL from the C-doped SiO_2 film (3#) is stronger than that from the thermally-grown SiO_2 film (4#).

These may be interpreted by ion latent track formation and new phase separation in SiO_2 films under high energy heavy ion irradiations. Meftah et al[3] have found that there is a threshold electronic energy loss (S_e) value ($S_{et} \approx 1.6$ keV/nm) for ion track formation in SiO_2. If $S_e < S_{et}$, the incident ion could only produce point defects in SiO_2. When $S_e > S_{et}$, ion track could be produced and its size increases with increasing the S_e value. For 855 MeV Ar-ion irradiation (1#, $S_e = 1.48$ keV/nm $< S_{et}$), the PL band centred at ~ 440 nm is due to defect formation or bond sessions[4]. For 335 MeV Ar or 1.98 GeV Kr ion irradiations ($S_e > S_{et}$), nanosized ion track (new phase) can form. At this condition, the measured PL band and its peak position are determined by the competition of PL from the ion track and the point defects outside the track. The appearance of ion track results in shift of blue PL peak position towards to the short-wavelength direction and weakeness of the PL intensity from the samples. Taking into account the energy of the Si—Si, Si—C and C—C bands (2.36, 3.21 and 3.70 eV) and the maximum atomic concentration of implanted C-ions (~ 4×10^{22} C-atoms/cm^3) at the projected range, the relative weak PL bands (peak centred at about 380 nm) may be due to phase separation into SiC and carbon aggregates along the ion path. Moreover, the existence of doped C-atoms will stabilize the produced point defects and enhance the luminescence yield.

Experimental results let us make the conclusion that the high energy heavy ion irradiation is a useful and effective technique for fabricating luminescence materials and, in our knowledge, it is the first time to be proposed and used to obtain PL materials. PL from ion irradiated C-doped SiO_2 films may mainly due to the quantum-confined effect and crystalline defects.

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重离子辐照 SiO_2 的光致发光*

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摘　要: 基于荷能离子与固体相互作用特点, 提出了一种新的制备光致发光材料的方法—— 高能重离子辐照. 用这种方法研究了 SiO_2 薄膜的光致发光特性, 发现高能^{84}Kr 和^{40}Ar 离子辐照可在注碳 SiO_2 薄膜样品中产生强的蓝-紫光发射带, 掺杂碳增强了辐照样品的发光特性.

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