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Microcavity Enhanced Amorphous Silicon Photoluminescence

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A Fabry-Perot microcavity is used for the enhancement of photoluminescence in hydrogenated amorphous silicon. The enhancement is understood by the modified density of photon states. The a-Si:H microcavity has potential for becoming a novel source in optoelectronics.

Due to their unique optical properties, microcavities attract the attention of the optoelectronic engineers.[1] In a microcavity, two electromagnetic effects occur. The microcavity acts as a resonator for light rays with specific wavelengths. The emission at the cavity resonances is larger than the bulk emission because of the modified density of photon states.[2] These two advantages of microcavities are used in resonant cavity enhanced (RCE) photonic devices, which are wavelength selective and ideal for wavelength division multiplexing.[3] In diode lasers,[4] RCE light emitting diodes (LED's),[5] and RCE photodiodes,[6] the mode linewidth is narrowed, the efficiency, brightness, and directivity, finesse and quality factor are enhanced.

Interest in silicon as an optoelectronic material is also increasing. With modern process techniques, it will be possible to integrate lasers, photodetectors and waveguides on silicon motherboards. Hydrogenated amorphous silicon (a-Si:H)[7] has been proposed as a suitable material for the realization of these waveguides. a-Si:H can be deposited by plasma enhanced chemical vapor deposition (PECVD). The other advantage of the a-Si:H[8] as well as porous silicon[9] is that they also attract the interest of optoelectronic engineers as a potential optical gain medium, because of their room temperature visible luminescence. Recently, we have observed visible room temperature photoluminescence (PL) from a-Si:H.[10] Microcavity effects on porous silicon has also been reported.[11]

In this paper, we report, the microcavity enhancement of room temperature PL of a-Si:H. The microcavity was realized by a Au back mirror and an a-Si:H-air front mirror. The substrates were coated with Au, and a thin layer of a-Si:H was deposited on the substrates by PECVD. While the exact mechanism of the occurrence of the PL in bulk a-Si:H is still under discussion, we suggest the use of a quantum confinement model.[12] We propose that, our samples consist of small a-Si clusters in a matrix of a-Si:H. The regions with Si-H, having larger energy gaps due to strong Si-H bonds, isolate these a-Si clusters, and form barrier regions around them. The PL originates from these a-Si clusters.

Figure 1 shows the PL of the a-Si:H microcavity with (X1) and without (X2) the Au mirror. The PL of the microcavity without the Au mirror was multiplied by a factor of 2 to compare it with the PL of the microcavity with the Au mirror. When comparing the spectra, the microcavity with the Au mirror has several noteworthy features: (1) there is a 2X increase of the overall spectrum average (i.e., averaging out the resonances), (2) there is a 4X enhancement of the PL peaks, and (3) the PL dips have similar amplitude. The 2X increase is due to the "round trip" of the excitation Ar^+ laser in the microcavity due to the back Au mirror. Since the wavelength of the Ar^+ laser is not on a resonance, the input laser light doesn't

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resonate in the cavity, which would have enhanced the PL further. The 4X enhancement at the resonances, are clearly due to the combined effect of the enhancement of the PL with that of the input laser reflecting from the back Au mirror. The PL dips having the same amplitude in both spectra is due to the inhibition of the PL in between the resonances.

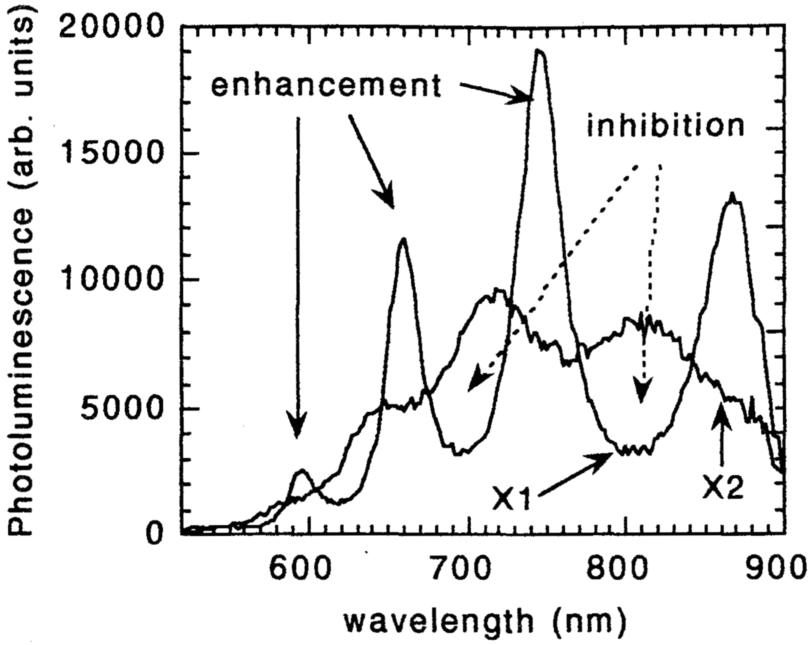

Figure 1. PL of the a-Si:H microcavity with (X1) and without (X2) the Au back mirror.

In conclusion, a microcavity is used for resonant cavity enhancement and of a-Si:H PL. The PL enhancement is understood by the modified density of EM states. This enhancement opens up a variety of optoelectronic applications, such as tunable light sources, RCE LED's and a-Si:H lasers. We would like to acknowledge the support of this research by the TUBITAK Grant No: TBAG-1368 and ICTP Grant No: 95-500 RG/PHYS/AS.

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