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# Metro/access 광통신망을 위한 실리콘 나노결정 sensitized Er-doped 실리카 광도파로 광증폭기

# Si nanocrystal sensitized Er-doped silica waveguide optical amplifiers for optical metro/access networks

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Optical telecommunication has been growing at a rate that exceeds even the "Moore's Law". However, while the electronic revolution has allowed everyone to have his/her own PC, the optical revolution is still confined to the long-haul netowork such that the individual end users are still connected to an electronic metro/access networks. However, given the rapid increase in the data traffic (e.g., multimedia), the optical edge that separates the individual end users from optical networks will eventually have to include the metro/acces networks.

One essential technology for such an optical metro/access network is optical amplifiers. All-optical networks became possible only with Er-doped fiber amplifiers (EDFA) capable of amplifying the optical signal transparently without having to convert to an electronic form. This fact, plus the low-noise and WDM capability of EDFAs, has led the National Research Council of America to identify EDFAs as the enabling technology for establishing an information society in its report "Condensed Matter Physics: Basic Research for Tomorrow's Technology"

However, EDFAs are fairly large, very expensive, and are produced as self-contained, stand-alone units. This does not present a problem for long-haul networks for which an EDFA is needed every tens or hundreds of km. However, an metro/access network requires components such as splitters, switches, and filters every tens or hundres of meters, and each time requires a small amplet to compensate for losses. In such a case, conventional EDFAs are unpractical to be used widely. Therefore, in order to realize an all-optical metro/access network, we must 1) reduce the cost of an amplifier from several thousands of dollars to several tens/hundreds of dollars, and 2) reduce the footprint of an amplifier from several tens of $cm^2$ to several $cm^2$. Furthermore, since such an amplet is most likely to be used in conjunction with other optical components, we must 3) increase the integrability of an amplifier with other optical components.

A device that has been touted for some time as a possible solution is Erbium doped waveguide amplifier (EDWA). This has the advantage of reproducing the proven EDFA technology on a planar device. Yet this very advantage can also be its critical weakness. For example, EDWAs require the same expensive pump laser and packaging steps as EDFAs. However, since the pump LD and packaging cost constitutes the major fraction of the final cost of an EDFA, the cost advantage of an EDWA over and EDFA can at most be incremental. Furthermore, EDWA requires co-propagation of pump and signal beams, such as an EDFA. Therefore, the advantage of EDWAs over EDFAs in terms of footprint and integrability is also expected to be incremental at best.

In this talk, we will introduce nanocrystal Si (nc-Si) sensitization as a possible solution for developing optical amplifiers for all-optical metro/access networks. In such nc-Si sensitized, Er-doped silica, Er ions are excited via photocarriers generated inside nc-Si. The following picture shows, schematically, the structure of such a film and the excitation process of Er.

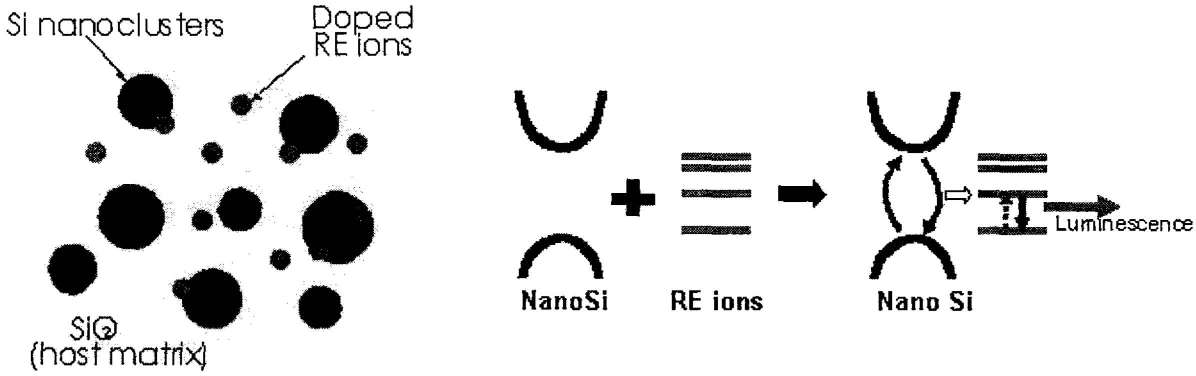


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그림 1 : A schematic of nc-Si senstized, Er-doped silica thin films and the excitation process of Er in such a film. Excitation of Er is mediated via photocarriers inside nc-Si.

nc-Si sensitization is operationally similar to the well-known Yb sensitization, excpet for the following crucial differences. 1) The absorption cross section of nc-Si is $10^{17}$ - $10^{16}$ cm$^{2}$, which is $10^4$ - $10^5$ times larger than that of Er in silica. This reduces the necessary interaction distance between the pump beam and the waveguide from tens of cm to several microns, thereby enabling top-pumping of the waveguide. 2) The absorption cross section of nc-Si is continuous. This allows use of low-cost broadband light source (e.g., Flashlamps, LEDs) instead of wavelength-stabilized lasers, significantly reducing the cost.

Such nc-Si sensitized, Er-doped silica thin film was deposited using electron-cyclotron plasma enhanced chemical vapor deposition (ECR-PECVD) of $SiH_4$ and $O_2$ with concurrent sputtering of Er, followed by an high temperature anneal. Single-mode, ridge-type waveguides were fabricated using chemical etching. Photoluminescence measurements demonstrate the excellent Er luminescence properties of the film. By top-pumping the waveguide with the 477 nm line of an Ar laser, we demonstrate a signal enhancement of 14 dB/cm, indicating that optical gain of up to 7 dB/cm should be possible with this material. Such results indicate that it is possible to reduce the pump cost and the footprint of an amplifier by 90% or more. Detailed experimental procedures and the possible applications of such amplifiers will be discussed.

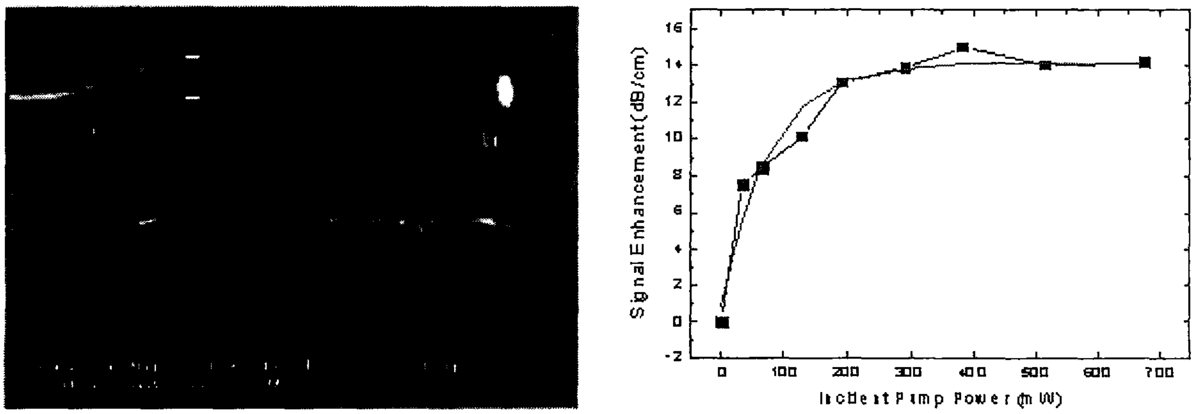


그림 2 : SEM image of the fabricated waveguide and measured signal enhancement