Monolayer 2D material lasing from photoactivation-enhanced photoluminescence at room temperature

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In recent years, monolayer transition metal dichalcogenides (TMDs) with unique photoluminescence (PL) properties have received extensive attention [1]. However, the defects introduced during the fabrication and processing steps provide nonradiative recombination pathways. In addition, as the pump intensity increases, the generated high-density carriers in this atomic thickness enhance many-body interactions such as nonradiative exciton-exciton annihilation.

In this work, we first grow single-crystal monolayer MoS_2 on tapered silica MNFs (micro/nano fibers)[2]. We then use a simple photoactivation strategy to obtain strongly enhanced and highly stable PL quantum yields (QYs) in a wide pump dynamic range at room temperature.

Our work demonstrates substantially enhanced and stable room temperature PL QYs of monolayer MoS_2 grown on silica MNFs in a wide pump dynamic range, using a simple photoactivation method. The taper-drawing process greatly lowers the photoactivation energy and allows fast completion of the entire photoactivation process in a few minutes with a CW laser. The high-density oxygen dangling bonds released from the tapered micro/nanofiber surface are the key to this strong enhancement of QYs. As the pump intensity increases from 10^{-1} to 10^{4} W cm^{-2}, our photoactivated monolayer MoS2 exhibits QYs from ~30 to 1% while maintaining high environmental stability, allowing direct lasing with greatly reduced thresholds down to 5 W cm^{-2}. By using a monolayer/microbottle structure with an outer diameter of 5.5 µm, the lasing threshold around 5 W cm^{-2} (Fig 1.c) for a best fitted β of 0.5 is observed at a wavelength of 682.5 nm (TM^{1}_{31}).[3]

We foresee that our photoactivation method for single-crystal TMD monolayer/MNF structures provides an exciting direction for various integrated applications ranging from low-threshold coherent light sources and nonlinear optics to optoelectronics. Since microfiber and microbottle structures themselves can serve as good optical microcavities [3,4], the high-QY and stable emission make as-activated monolayers good choice for lasing generation at room temperature.

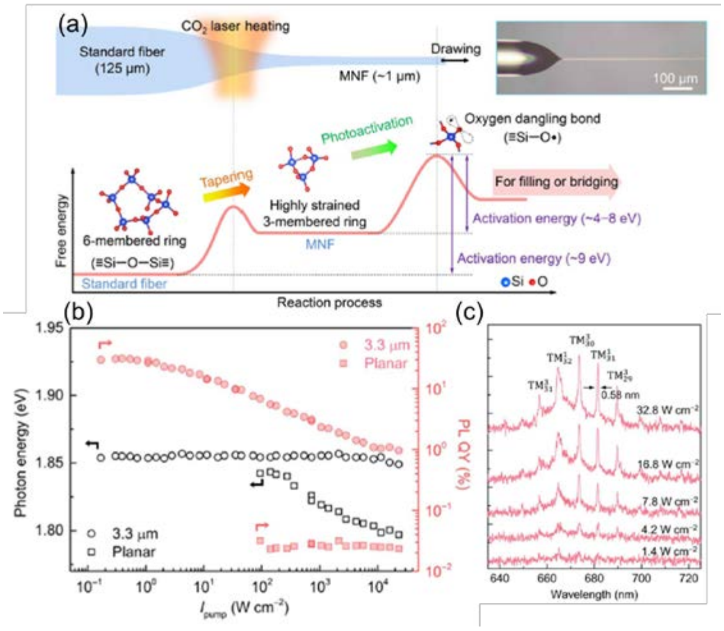

Fig.1 (a) Schematic illustration of generation of oxygen dangling bands from a tapered fiber. The tapering process greatly lowers the activation energy from ≡Si—O—Si≡ to ≡Si—O·. Inset: Optical image of a MNF tapered from a standard fiber. **(b)** Pump-dependent peak positions (black data) and PL QYs (red data) in the as-photoactivated monolayer MoS_2 (solid circles). A planar sample is also provided for reference (open squares). **(c)** Steady-state PL spectra in an as-photoactivated MoS_2 monolayer/microbottle (outer diameter,5.5 mm) with increasing $\mathbf{I}_{pump}$, in which WGM oscillations are observed.

References:

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