MoS$_2$/Carbon Nanotube Core–Shell Nanocomposites for Enhanced Nonlinear Optical Performance

Over the last decade, tube-like carbon nanotubes (CNTs) have been widely investigated as a versatile third-order nonlinear optical (NLO) material in a range of applications, such as optical limiting (OL) for laser protection and saturable absorber for ultra-short pulsed lasers owing to their low saturation intensity, fast recovery time, and wide operating bandwidth.\cite{1-3} It has been reported that both single-walled nanotubes and multi-walled nanotubes possess ultrafast relaxation time (ca. 1 ps).\cite{4} On the other hand, two dimensional (2D) layered transition metal dichalcogenides (TMDs) semiconducting materials, such as MoS$_2$ and WS$_2$, have also been reported to have excellent NLO performances.\cite{5}

For the sake of developing nanomaterials with higher NLO performance, we successfully synthesized nanocomposites of few-layer MoS$_2$ and CNTs with core–shell structure by wrapping MoS$_2$ nanosheets on the surface of coaxial CNTs via a simple solvothermal method (Figure 1), and systematically investigated the third-order NLO performances by Z-scan technique over a broad temporal (ns-fs) and spectral (Vis-NIR) range. Enhanced third-order nonlinear optical performances were observed for both fs and ns laser pulses over a broad wavelength range from the visible to the near infrared, compared to those of MoS$_2$ and CNTs alone (Figure 2). The enhancement can be ascribed to the strong coupling effect and the photoinduced charge transfer between MoS$_2$ and CNTs. The versatile nonlinear properties imply a huge potential of the nanocomposites in the development of nanophotonic devices, such as mode-lockers, optical limiters, or optical switches.

References

Figure 1: SEM images of a) pristine CNTs and b) the MoS2-L/CNTs. c)–e) Element mapping of C, S, and Mo. f),g) TEM images of a single CNTs wrapped by layered MoS2 nanosheets. h),i) Photographs of the samples in dispersions and PVA films.

Figure 2: SEM Normalized transmission as functions of input laser fluence for pure CNTs and MoS2/CNTs in a) high transmission dispersions, and b) PVA thin films under fs laser pulses at 1030 nm, and (c–d) MoS2, CNTs, and MoS2/CNTs dispersions with the transmission of about 80% for ns pulses at 532 nm and 1064 nm, respectively.