# Three-dimensional carbon fiber networks with multiple self-orienting laser-induced periodic surface structures enabled by ultrafast laser processing

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While 3D-networks of nano-textured carbon fibers (CFs) are highly promising materials for electrochemical energy storage and tissue engineering applications, it is extremely difficult to perform wide-area nano-texturing using conventional methods without damaging the bulk structure. Therefore, nano-texturing is generally performed on delicate fibers by chemical processing, which relies on the use of highly toxic chemicals that are environmentally unfriendly and may cause unexpected reactions upon application (i.e., explosions for energy storage or cell-death for tissue engineering) unless carefully cleaned. Here, we demonstrate the fabrication of an interconnected 3D network of CFs possessing periodic nano-scaled ripples, or laser-induced periodic surface structures (LIPSS) via femtosecond (fs) laser processing [1]. For the fs-laser-processed CFs, we observed the coexistence of two distinct types of LIPSS with different spatial periodicities of ~800 nm (low-spatial-frequency LIPSS, LSFL) and ~100 nm (high-spatial-frequency LIPSS, HSFL). Furthermore, it was indicated that the orientation of the LSFL was highly dependent on the structural-morphology and propagation direction of the fibers, while the orientation of the HSFL was solely dependent on the fundamental laser polarization direction. This suggests that the two LIPSS formed through different interference mechanisms; specifically, LSFL formed through the interference with Fresnel diffraction patterns projected by the fiber edges, while HSFL formed through the interference of surface plasmons leading to LSFL-splitting. The current findings not only open a new route for the preparation of nano-textured carbon materials for future energy and regenerative-medicine applications, but also reveals important fundamental insights into the underlining physical phenomena of LIPSS.

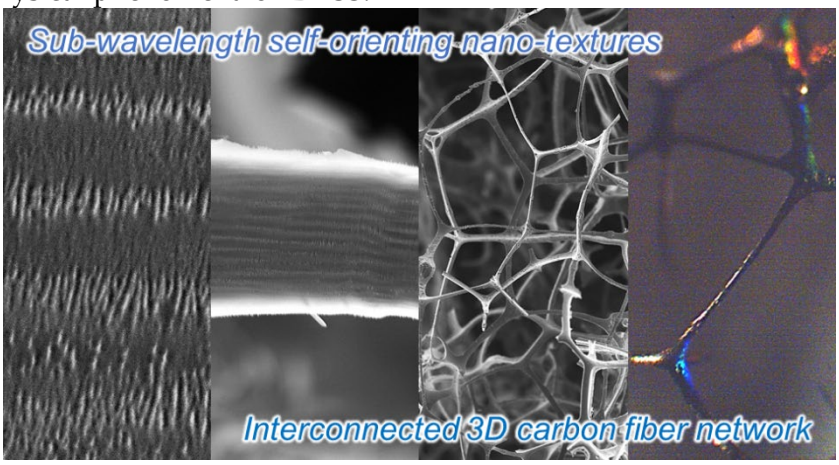


Figure 1: From left to right are the high-resolution SEM images of the nano-scaled LIPSS, single CF showing LIPSS orienting according to the fiber propagation orientation, interconnected 3D CF network, and a photograph of the CF network showing structural coloration owing to LIPSS formation.

[1] S. Hayashi, A. Sanchirico, A. Das, and C. B. Arnold, *Under Review* (2024).