Laser direct writing of carbon complexes from polymeric precursors by laser-induced graphitization

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Carbon complexes, such as layered graphite, porous graphite, and monolithic carbon aerogels, possess unique material properties distinctive of their structure, and have been applied towards a wide range of applications [1]. Laser-induced graphitization is a direct write technique which offers the simultaneous synthesis and patterning of carbon complexes by simply scanning a laser beam over a polymeric precursor. By simply scanning the laser beam in three dimensions such materials can be rapidly structured into desired architectures, offering the laser direct writing (LDW) of various key applications, including sensors, unique identification tags, and energy devices [2-4]. Despite the versatility and scalability of this technique, a deeper understanding of the underlying photothermal mechanisms is required to exquisitely control the resulting morphology and properties. The specific formation mechanism of the carbon complexes has been an issue of debate for many years with the prevailing notion of a simple photothermal conversion reaction that mainly depends on the laser fluence. In this study, we reveal that structural formation is a highly complex, temporally- and spatially-dependent phenomena which cannot be explained solely by the laser fluence, and further propose and validate a mechanism based on the formation of laser-induced defects [5]. Our proposed formation mechanism is composed of 3 phases, (1) nucleation of laser-induced defects, (2) slow growth of defects and increase in defect number, and (3) the sudden growth of defects due to graphitization (Figure 1). The model is further validated by intentionally introducing controlled defects by femtosecond laser irradiation, and indicate the implications of a two-laser laser direct writing technique to go beyond the current processing limits.

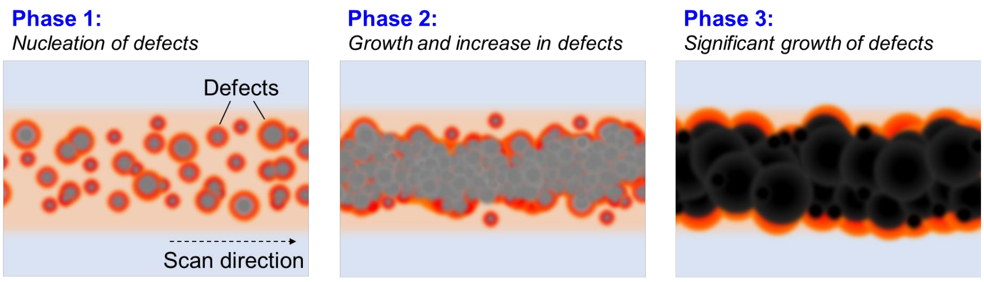

Figure 1: Schematic of the proposed formation mechanism is composed of 3 phases.

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