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14. ABSTRACT
Toughness is one of the most critical parameters for aviation materials. Its maximization requires reaching high values of strain, Young's modulus, and ultimate strength, simultaneously, which makes the design and manufacturing of high-toughness materials quite challenging. Review of the current achievements and failures in this field give strongest possible indications that high performance materials with record toughness will require multiscale control of the structure of composites. This puts strict requirements on the composite processing technologies, but also opens the opportunities for the development of new class of practically and fundamentally important materials. In this proposal, we are taking advantage of the unique toolset provided by LBL deposition and dramatically increase toughness of composites working at the molecular, micro- and macro-scale levels of organization.

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Program Title: **ENGINEERING OF HIGH-TOUGHNESS CARBON NANOTUBES HIERARCHICALLY LAMINATED COMPOSITES**

Project Number: **FA9550-08-1-0382**

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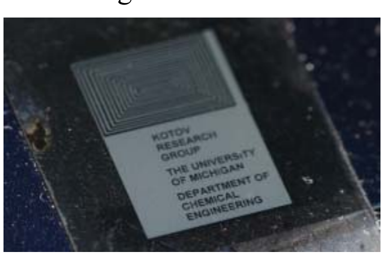
1. Brief Description of the Program and Research Approach

Toughness is one of the most critical parameters for aviation materials. Its maximization requires reaching high values of strain, Young's modulus, and ultimate strength, simultaneously, which makes the design and manufacturing of high-toughness materials quite challenging. Review of the current achievements and failures in this field give strongest possible indications that high performance materials with record toughness will require ***multiscale control*** of the structure of composites. This puts strict requirements on the composite processing technologies, but also opens the opportunities for the development of new class of practically and fundamentally important materials. In this proposal, we are taking advantage of the unique toolset provided by LBL deposition and dramatically increase toughness of composites working at the molecular, micro- and macro-scale levels of organization.

2. Major Goals and Objectives.

Our goal is to produce material with record properties using novel methods of structural control of the composites. Our focus will be on reaching high toughness values for the SWNT and other composite materials. In order to achieve that we set the following objectives. (1) Realization of LBL assembly with polyurethanes (PUs). (2) Evaluation and optimization of toughness of individual free-standing LBL films with PUs. (3) Preparation of the hierarchical laminates made from individual LBL sheets consolidated in a composite stack. (4) Incorporation of nano/microscale corrugations in the SWNT sheets and investigation of their effect on toughness (Figure 1).



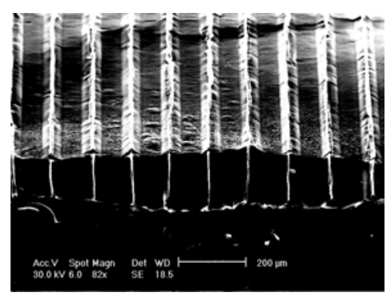
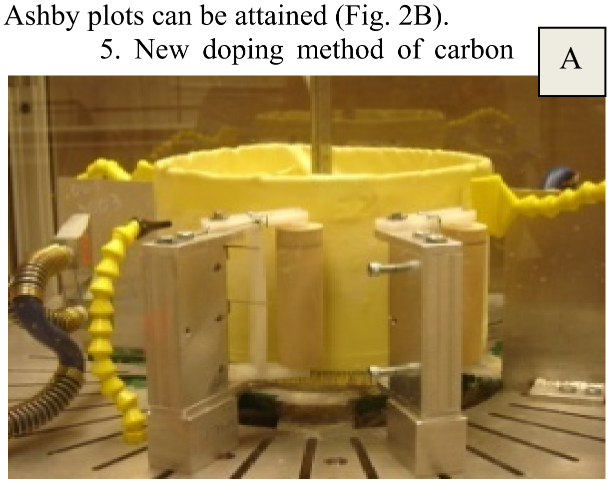


Figure 1. Schematics of three-dimensional LBL composites made in this project.

Significant Accomplishments

1. A new scaled up metho of LBL deposition was developed. (Fig.2).
2. The record toughness materials were obtained from **PU/PAA** is **65 N/mm.**
3. The matrix of properties for different compositions and inorganic loadings in the composites was obtained (Fig. 2A). It significantly extends the range of property variability for traditional composites.
4. The mechanical properties of the prepared composites demonstrate that the "blank" spots on Ashby plots can be attained (Fig. 2B).
5. New doping method of carbon nanotubes was developed.



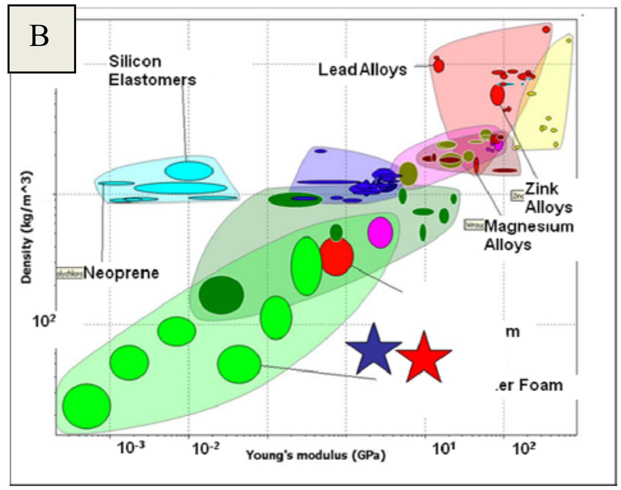


Figure 2. Results with high toughness hierarchical laminates; (A) Scaled-up version of LBL robot. (E-F) micrographs of consolidated LBL films. (G) largest LBL sample produced.

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