EFFECTS OF ELECTRON BEAM IRRADIATION ON CARBON FIBER TENSILE PROPERTIES

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OBJECTIVE

To evaluate the effects of EB radiation on the tensile properties of resin-impregnated specimens obtained from two commercial carbon fibers used for structural applications in two conditions: on the carbon fiber itself before preparing resin-impregnated specimens for mechanical testing and directly on the final test specimens.

INTRODUCTION

- Carbon fibers are used associated to epoxy matrix in advanced composites. These materials are frequently used for structural purposes in conditions of high mechanical loads;

- An important factor to assure the good performance of carbon fiber based composite materials is the adhesion between the surface of the carbon fiber and the epoxy matrix;

- Commercial carbon fibers present a sizing material on their surfaces in order to protect the filaments and to improve the adhesion with polymeric matrixes;

INTRODUCTION

- Electron beam (EB) radiation processing is being applied to composite materials for cross-linking polymeric matrices;

- For the studied material, EB radiation was used in order to promote excitation reactions on the fiber/matrix interface resulting in improved adhesion properties.

EXPERIMENTAL

- **Samples**

Two different commercial carbon fibers roving of high tensile strength were studied. One carbon fiber roving contained 6 000 elementary filaments (6k) and the other one with 12 000 filaments (12k);

- **EB irradiation conditions**

EB irradiation was carried out at the IPEN facilities using a 1.5 MeV and 37.5 kW Dynamitron Electron Accelerator model JOB-188. Irradiation conditions were: energy 0.555 MeV, electron-current 6.43 mA and dose rate 44.81 kGy s^{-1}. Overall doses applied were 50, 100, 200 and 300 kGy;

EXPERIMENTAL

- **Mechanical tests**

Tensile properties of the carbon fiber rovings were determined as resin-impregnated thermal cured specimens according to ASTM D4018. This procedure is used to evaluate tensile strength (TS) and Young's modulus (E) in continuo filament carbon fiber due to the difficulties to perform mechanical tests directly with filaments;

- **Scanning Electron Microscopy (SEM)**

SEM micrographs of the fiber surfaces from fractured samples were obtained using a scanning electron microscope model JXA-6400 (JEOL).

RESULTS AND DISCUSSION

IBP: samples prepared from carbon fiber irradiated before preparing test specimens;

IAP: samples irradiated only after preparing test specimens;

Blank: samples prepared from non-irradiated carbon fibers.

RESULTS AND DISCUSSION

TABLE I: TENSILE PROPERTIES DATA FOR 6k AND 12k CARBON FIBERS IRRADIATED BEFORE PREPARING TEST SPECIMENS (IBP).

	6k		12k	
Sample	TS (MPa)	E (GPa)	TS (MPa)	E (GPa)
blank	3230	223	4425	232
50 kGy IBP	3472	221	4781	227
100 kGy IBP	3582	223	4608	230
200 kGy IBP	3373	212	4662	238
300 kGy IBP	3490	222	4747	226

RESULTS AND DISCUSSION

TABLE II: TENSILE PROPERTIES DATA FOR 6k AND 12k CARBON FIBERS IRRADIATED AFTER PREPARING TEST SPECIMENS (IAP).

	6k		12k	
Sample	TS (MPa)	E (GPa)	TS (MPa)	E (GPa)
blank	3230	223	4425	232
50 kGy IAP	3184	215	4457	229
100 kGy IAP	3285	216	4520	232
200 kGy IAP	3323	224	4385	227
300 kGy IAP	3320	222	4404	228

RESULTS AND DISCUSSION

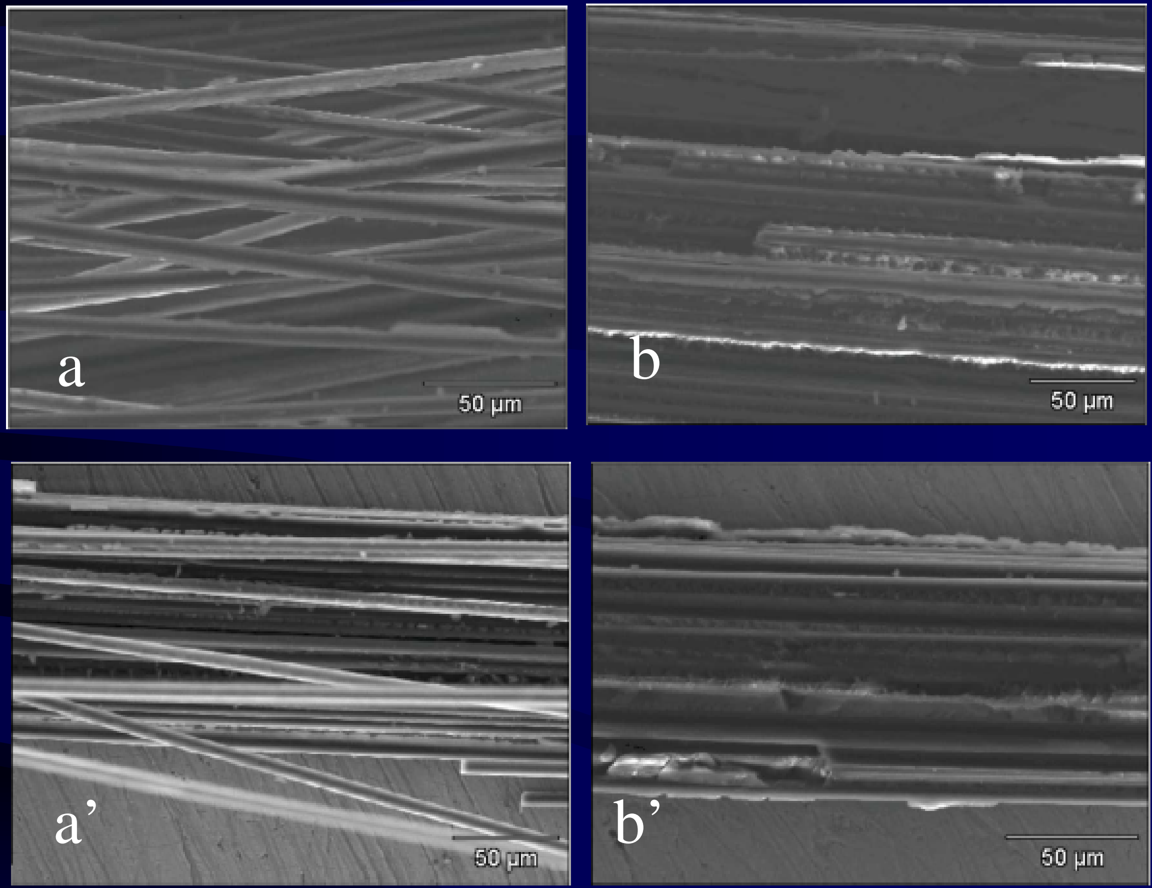

FIG. 1. SEM micrographs of 6k and 12k carbon fibers after breakage for non-irradiated (a, a') and irradiated before preparing test specimens (b, b') samples, respectively.

RESULTS AND DISCUSSION

- The visual aspect of test specimens after breakage prepared from irradiated carbon fibers (IBP) and non-irradiated carbon fibers (blank and IAP) was completely different. Test specimens after breakage prepared from non-irradiated carbon fibers present a fiber distribution with many separated filaments giving to them a very disordered aspect. On the other hand, test specimens prepared from irradiated carbon fibers present a high number of fragments containing some bonded filaments, which gives to them a very organized aspect.

CONCLUSIONS

- Tensile strength improvements and test specimens aspect after breakage for IBP samples suggest that the modifications induced by EB irradiation promote changes on the fiber surface or sizing or both, resulting in a better adhesion between the carbon fibers and the resin used to prepare test specimens;

- The improvement obtained was very similar in the range of applied doses, from 50 kGy to 300 kGy. However, it was only observed for test specimens prepared from irradiated carbon fibers. This behavior was observed for both carbon fibers studied;

CONCLUSIONS

• The fact that it was not observed changes for IAP test specimens after breakage probably means that in order to increase the degree of reticulation of the thermal cured matrix it is necessary to apply a high dose of radiation. On the other hand, to induce modifications on the carbon fiber surface or sizing or both low doses are enough.

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