Aminated Nanodiamond Powder as a Novel Material for Advanced Composites

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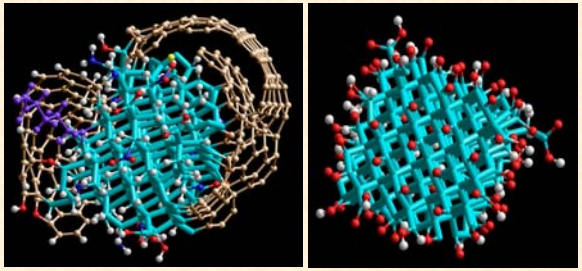
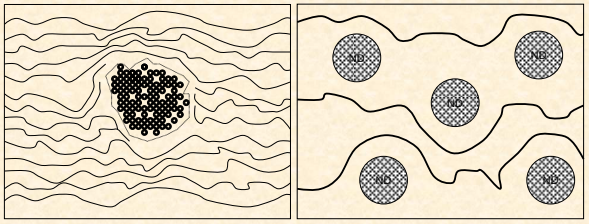
Motivation

Nanosized diamond powders (nanodiamond - ND) produced by detonation synthesis in large volumes represent a novel and relatively inexpensive carbon nanomaterial with a high potential for use in nanocomposites due to superior mechanical and thermal properties of diamond combined with nanometer particle size and rich tunable surface chemistry.



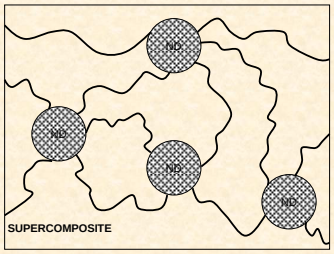
As-produced ND | ND after air oxidation

In literature, there are examples of both improvement in mechanical strength, wear resistance and ageing characteristics of polymer matrices (mainly natural and synthetic rubbers) upon ND addition, and decrease in strength of epoxy/ND composites. These discrepancies can be attributed to:

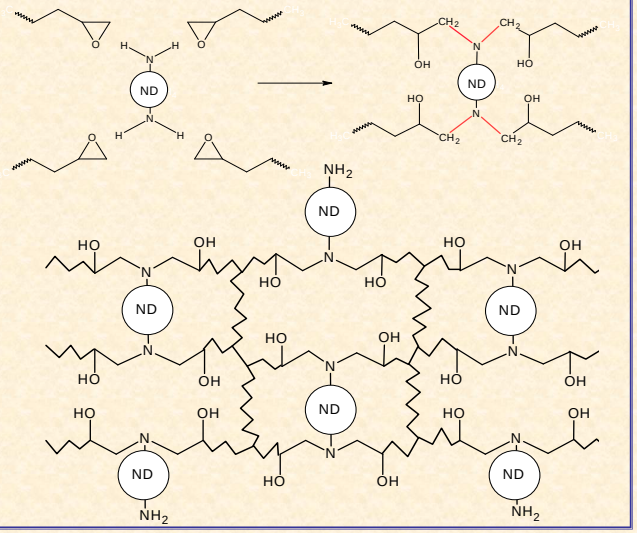


poor dispersion | weak non-covalent bonding at the interface

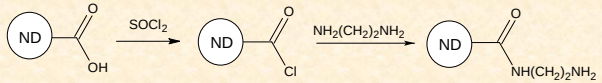
SOLUTION:
Improve dispersion (no agglomerates) and form strong covalent bonding between the matrix and the filler



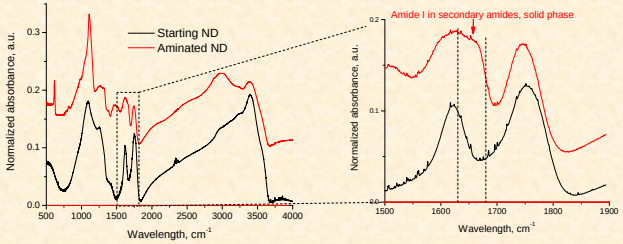
Incorporation of aminated ND into epoxy network



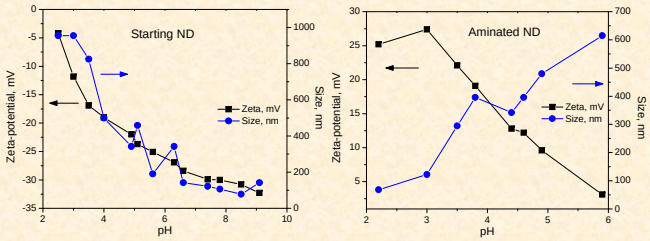
Synthesis and characterization of aminated ND



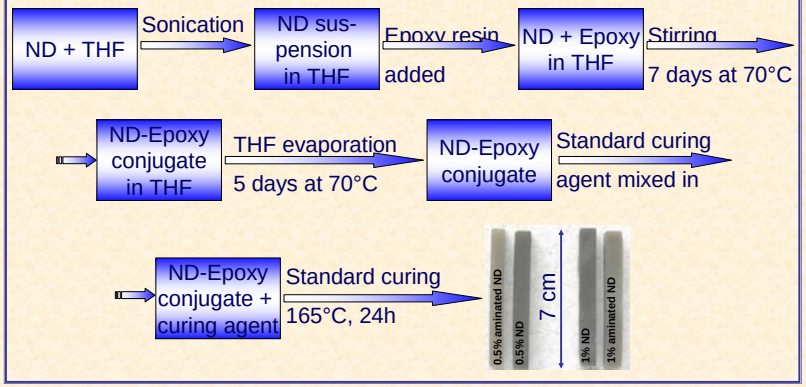
IR spectroscopy



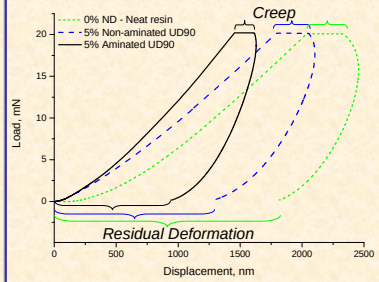
Aqueous suspension stability



Manufacturing of covalently bonded ND-epoxy nanocomposites



Mechanical tests on the covalently bonded ND-epoxy nanocomposites



Sample	Young's modulus, GPa	Hardness, GPa
0% ND	2.7	0.17
5% wt. non-aminated ND	5.0	0.18
5% wt. aminated ND	6.3	0.23

Compared to the neat epoxy samples (0%ND) the samples with the aminated ND demonstrate a higher Young's modulus and a higher hardness. Especially notable is an almost two times decrease in creep rate and a significant increase in hardness which were only observed for composites with aminated nanodiamond. These results provide a clear indication of improvement in mechanical properties of the composites with ND covalently bonded to polymer chains.

Conclusions

- Nanodiamond powders terminated with aminogroups have been produced through grafting ethylenediamine to their surface. Covalent linking of ethylenediamine has been verified by detection of amide vibration in IR spectra of aminated material. In contrast to non-modified nanodiamond, the aminated powders demonstrate higher aqueous dispersion stability at basic pH.
- Aminated nanodiamond has been used to produce covalently bonded nanodiamond-epoxy composites. The covalently bonded nanodiamond–epoxy composites show enhanced Young's modulus, hardness, and reduced creep as compared to neat epoxy and non-aminated nanodiamond-epoxy composites.

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