Develop a 3D Printable Nanodiamond Polymer Nanocomposite Resin towards Fabrication of Low Cost Thermally Conducting Devices

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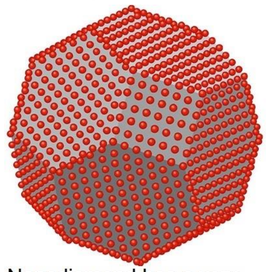
1) Solution to improving the Thermal Properties of DLP 3D printed synthesized Parts

Nanodiamond (ND) has an average size of 3-5 nm. It has one of the highest thermal conductivities and it has been incorporated into polymer-based structures to form nanocomposites (NC) & improve their thermal conductivity. Our research focuses on preparation of ND-Acrylate NC resin and study it's thermal property through DLP 3D printing.

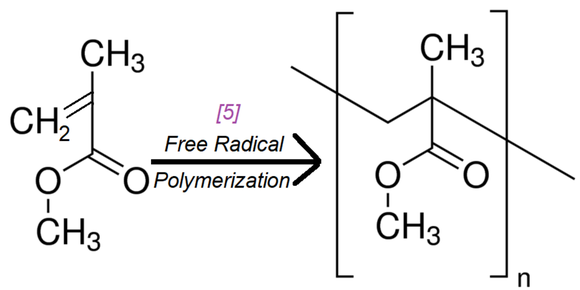


Nanodiamond has a very high thermal conductivity of 1100~1200 W/(m-K) which is roughly 4 times of that of Pure Copper *[1]*

1) Researchers have observed a 3.8-fold increase in Thermal conductivity at just 0.5 wt% of Methacrylate-Tethered-ND/polymer composite *[2]*
2) Other Researchers have also observed an 8.75-fold increase in Thermal Conductivity of Nano-Fibrillated Cellulose films at just 0.5 wt% loading of Nanodiamonds *[3]*
3) We plan to prepare and test Acrylate Nanocomposite samples at up to 30 wt% Nanodiamond loading to further improve the thermal conductivity *[4]*

2) Polymerization of Methyl Methacrylate (MMA) to Poly Methyl Methacrylate (PMMA)

Below figure illustrates how MMA which is the most common resin used in DLP 3D printing proceeds to polymerization. Upon exposure to a wavelength of light, a free radical is formed which ionizes the MMA monomer and creates a chain of reactions that ends with the formation of the Polymer (PMMA).

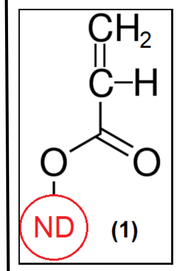


Methyl Methacrylate [Liquid Resin]

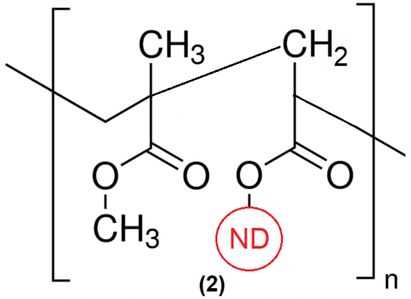
Poly-Methyl Methacrylate(PMMA) [Hard Compound]

3) What does the research aim to find?

Very few studies have been found in literature surrounding the 3D Printing of Nanodiamond Polymer Nanocomposites. And no study has been found in literature to the best of our knowledge that seeks to find the influence of covalently bonded ND into the polymer resin for 3D printing. We seek to synthesize a ND grafted Acrylate Monomer **(1)** that would be substituted into the Polymer Chain **(2)** upon polymerization. This makes this a first of its kind study in 3D printing of ND Polymer NC's.



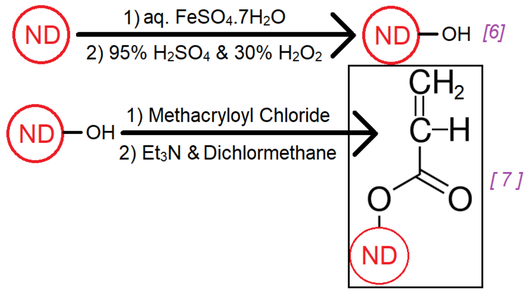
ND grafted Acrylate(ND-Ac) Monomer



ND-Ac substituted covalently into the polymeric chain of PMMA

4) How do we seek to synthesize the ND grafted Acrylate

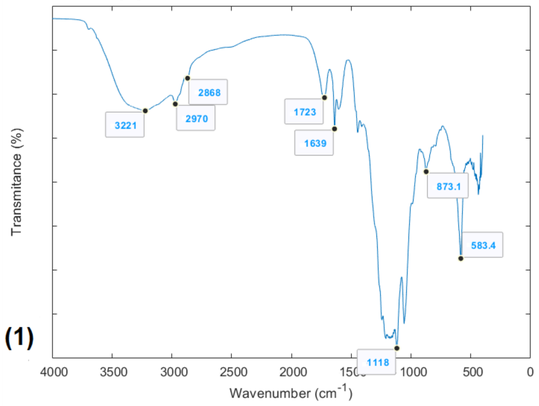
We have found the following two sets of reactions through literature survey suitable for synthesizing the ND-Ac we require.



The boxed thing is Methyl Methacrylate grafted with Nanodiamond and thus would be substituted in the polymer chain as shown above

5) Confirmation of –OH group attachment

We have successfully grafted the hydroxyl (-OH) group onto Nanodiamond or the first part of reaction as shown in 5th block *[6]*. The formation of ND-OH has been established by the comparison of our FT-IR results **(1)** with those of the researcher**(2)**.



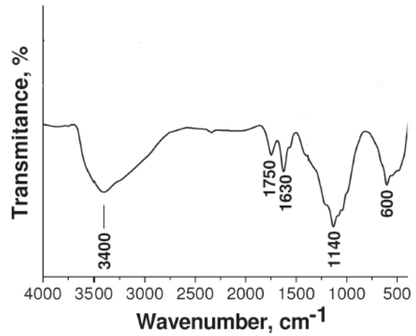
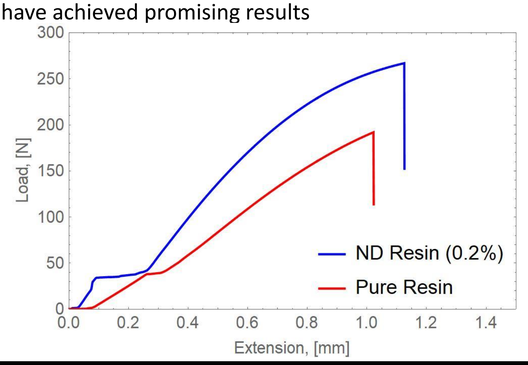


Figure 2: FT-IR spectra of NDp subjected to Deep Fenton Treatment (See Experimental Section for Conditions.

6) What have we achieved so far?

There were multiple safety concerns regarding the handling of Methacryloyl chloride. Thus we needed to purchase the necessary safety equipment to handle and process it. For now we mixed 0.2 W/V % ND in Polymer resin to print its strength characteristics and thus far have achieved promising results



7) Future work

i) Future work would be to further subject the ND-OH to the second reaction in order to form ND-Ac
ii) Once ND-Ac has been successfully synthesized, study the dispersion characteristics of ND-Ac in Acrylate Monomer resin to obtain uniform dispersion
iii) Study the printing parameters and obtain a stable print of the ND-Ac Nanocomposite
iv) Gauge performance of the produced sample for Thermal Conductivity

8) References

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[5] Bagheri, A., Jin, J., **Photopolymerization in 3D Printing,** *ACS Appl. Polym. Mater. 2019, 1, 593–611*
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