Epoxies for high-stability superconducting magnets: Capabilities at LBNL and program goals

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With thanks to many other colleagues for getting this program started and supporting it, including Diego Arbelaez, Jim Swanson, John Wirdzek, Ken Tokunaga, Charles Swenson, LBNL molecular foundry, and Chiara Tarantini at NHMFL. We also thank Bernhard Auchmann and Giuseppe Montenero at PSI, Steve Krave at FNAL, and Andrea Haight at CTD for useful general discussions, Joe Minervini at MIT for providing the results of the ITER insulation program, and Nicolai Martovetsky for the ITER central solenoid epoxy formulation.

Instruments to characterize potting characteristics and developing new resin formulations

Brookfield DV2T viscometer (@BCMT/SMP)

- Small sample adapter with circulating water bath for temperature control.
- Gel-timer instrument

- *Viscosity and pot life*
- *Gel-time*

TA instruments DSC1000
(@LBNL molecular foundry)

- *Glass transition temperature T_g*

XRD, TGA and FTIR also available
(@LBNL molecular foundry)

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Mechanical testing and microstructure observations

@ BCMT/SMP, ***RT and 77 K.***

- ***Tensile test (ASTM D-638)***
- ***Compression test (ASTM D-695)***
- ***Short-beam shear test (ASTM2344)***
- ***Shear/Compression tests (ITER program)***

- **Table-top SEM,** SEM, and FE-SEM (@molecular foundry)
- **Digital optical microscope** (@engineering division)

- *Mechanical testing at 77 K still being improved.*

Conventional VPI facilities regularly in use for potting magnets and samples for mechanical tests

Vacuum chamber
~26” dia x 84” height

Jim Swanson

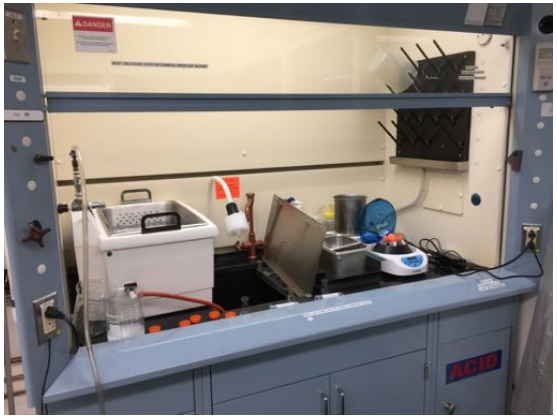
- *Potted RC1-6 coils*
- *Potted CCT3, CCT4, and CCT5.*

Advanced VPI facilities: Autoclave for VPI under pressure

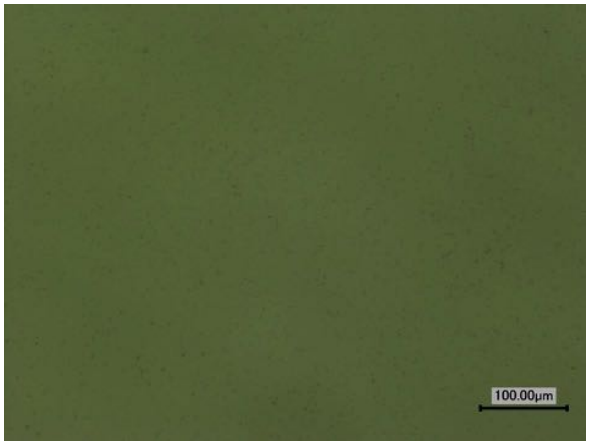
Eric Anderssen

- **<u>Existing</u>: 5’ dia x 10’ long, 450 F and 150 psi maximum, process Cyanate Esters, epoxies, and some Bismal-imides (BMI)**
- **<u>Incoming</u> (2020): 3' dia x 16' long, 850 F at 500 psi maximum, process Polyimide, Phenolics, BMI's, and can also melt and process PEEK.**

Nano-epoxy composites for wet-winding of superconducting coils – can we create a better epoxy than Stycast 2850?



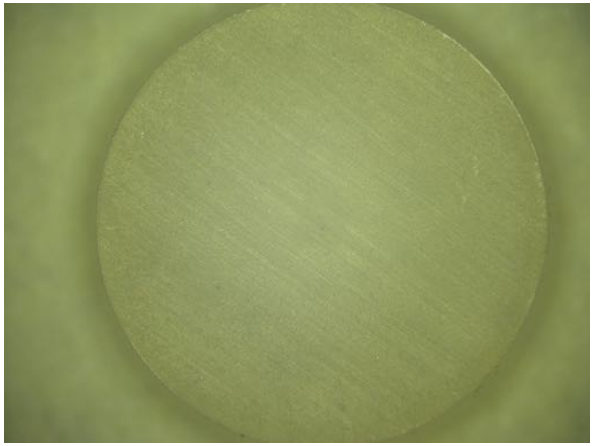
Fume hood for working with nano-matters
(w/ ultrasonic bath mixer, centrifuge, magnetic stirrer and hot plate)



Functionalized BNNS dispersing in CTD101K

Centrifugal Mixer

Centrifugal mixer for degassing and mixing fillers into epoxy (@Anderssen lab)



Nano-epoxy composite samples sent to C. Tarantini (NHMFL) for specific measurements (1.8 – 300 K) using PPMS. One with Gd_2O_3.

Program goals – with some good retults but still shaping up

- Search, develop, and characterize high toughness and radiation hard impregnating resin systems.
  - Low viscosity and long pot life.
  - Some interesting results so far (Shijian Yin)
  - Radiation hard not needed for the main ring dipoles.
- Develop high specific heat and/or high thermoconductivity nano composite epoxy for wet-winding high-stability superconducting magnets.
  - High viscosity.
  - Started.
- Characterize signature cracking and debonding signals under tensile, compression, and shear conditions using AE systems, and add into Maxim Martchevskii's database of what occur inside superconducting magnets.
  - With Maxim Martchevskii. Not yet started but can move fast.
- Correlate to magnet behaviors with a fast-turn-around small-sample, high-field experiment.
  - With Charlie Sanabria. Work just started.

Summary

- **Various lab capabilities to develop and characterize epoxy resins including viscosity and pot life, mechanical properties, conventional VPI and pressure VPI, with complimentary facilities from LBNL molecular foundry.**

- **Program still being shaped and support, collaboration, and help are welcomed, especially with**
  - **Mechanical testing at LT**
  - **Specific heat and thermoconductivity testing at LT.**