

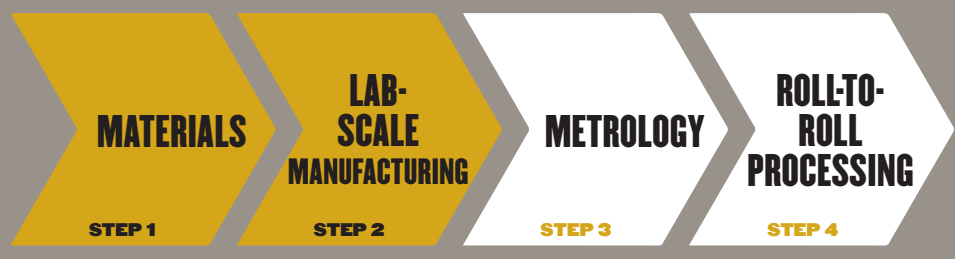
MANUFACTURING OF Z-ORIENTED FUNCTIONAL FILMS

OVERVIEW

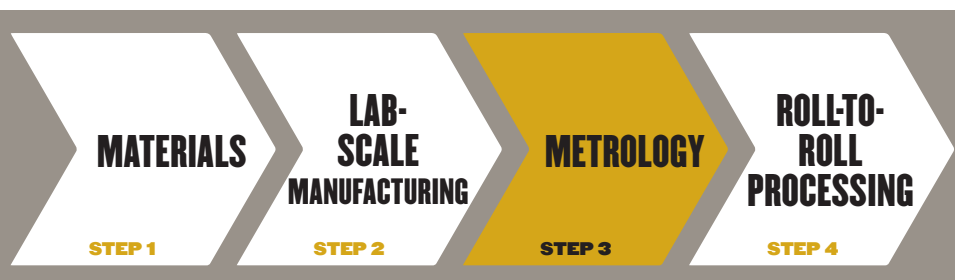
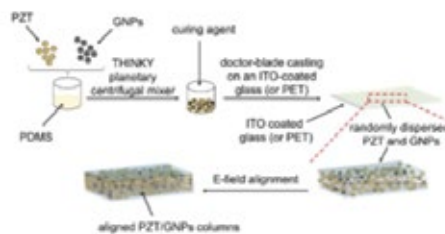
Functional films are processed such that they have unexpected or exceptional properties. Possible effects include directional dependence of mechanical, optical, or electrical properties, extreme responsiveness to external stimuli, or high performance properties unattainable by conventional processing techniques. The Birck Nanotechnology Center Roll-to-Roll laboratories provide all the tools necessary to develop raw materials into functional films and manufacture them in large scale roll-to-roll processes. As an example, we show how vertically aligning particles via electric field produces highly sensitive pressure sensitive films that are transparent, flexible, and large area.



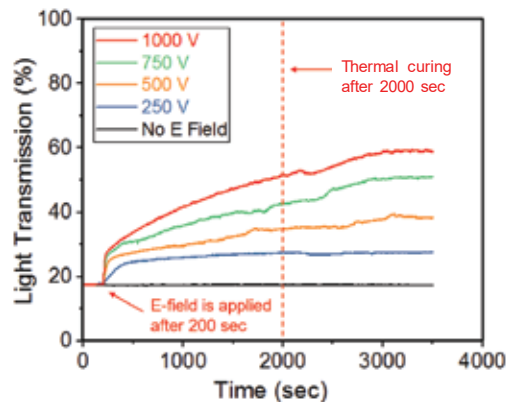
BIRCK NANOTECHNOLOGY CENTER ROLL-TO-ROLL PROCESS

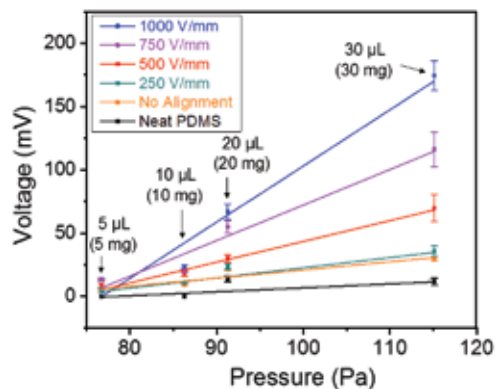
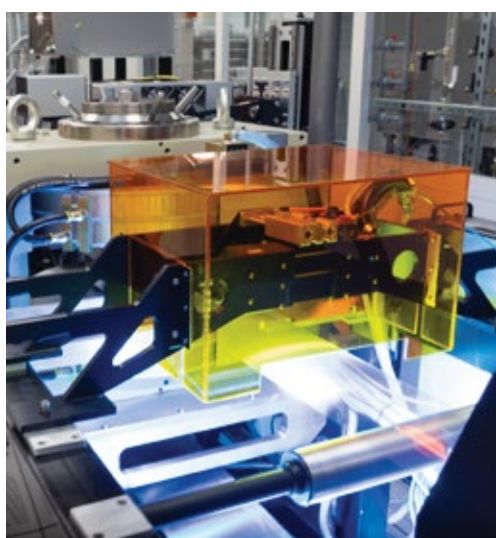


- Raw materials are prepared by milling particles and sieving to isolate desired size ranges.
- Mixing up to 300 g batches via Thinky planetary centrifugal mixer.
- Casting up lab-scale films (up to ~120 mm x 120 mm) via mechanically driven doctor blade.
- Electric field applied via signal generator while sample cures in heated oven.



- Simultaneous electric field alignment and thermal curing can also be accomplished in a state of the art, custom instrumented apparatus designed to monitor curing and drying processes.
- Real time light transmission monitoring indicates the degree of particle alignment.

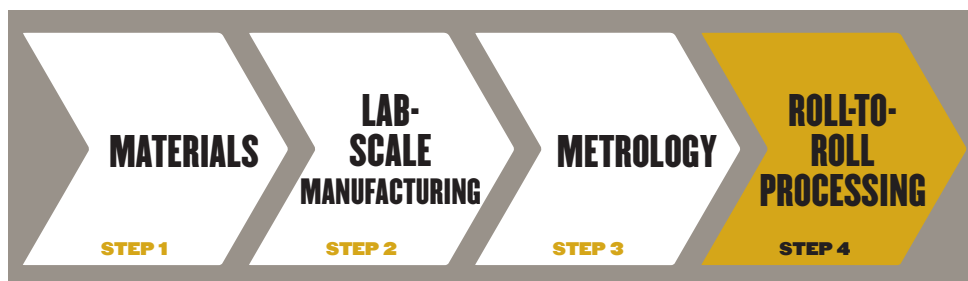




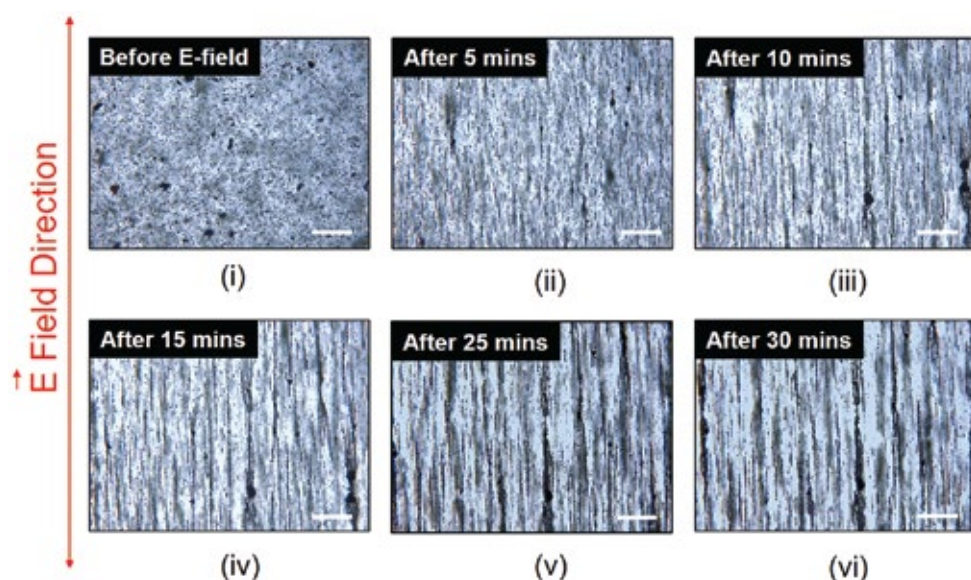
1. Mukerrem Cakmak, Armen Yildirim, Rahim Rahimi, "Piezoelectric Transducers Based on Vertically Aligned PZT and Graphene Nanoplatelets", U.S. Provisional Patent Application S/N 62/772,144, 2018.

2. Mukerrem Cakmak, Armen Yildirim, Rahim Rahimi, Saeed Mohammadi, Ali Shakouri, "MACHINES AND PROCESSES FOR PRODUCING POLYMER FILMS AND FILMS PRODUCED THEREBY" U.S. Non-Provisional Patent Application S/N 16/571,794, 2019.

PURDUE UNIVERSITY
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- Roll-to-roll production is achieved via the MAXWELL custom coating and particle alignment machine.
- Using electric field and thermal settings as well as the coating materials developed in laboratory processes, the casting, particle alignment, and curing processes are scaled up to fully continuous, roll-to-roll operations.
- Other deposition (extrusion casting, electrospinning), alignment (magnetic), and curing (UV light, Novacentrix PulseForge UV/Vis flashlamp) options are available on the same tool, suitable for other types of materials or processes.



- The result is a meters-long continuous cast film of aligned PZT/graphene particles in a PDMS matrix.
- Because PZT is a piezoelectric material, this film is ultrasensitive to pressure in the direction normal to the plane of the film. All that is required is to attach electrodes to sense the voltage that is generated by the application of pressure.
- Microscopic examination shows how the particle alignment evolves with time under electric field at varying field strength, as shown below.

CONTACT INFORMATION

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