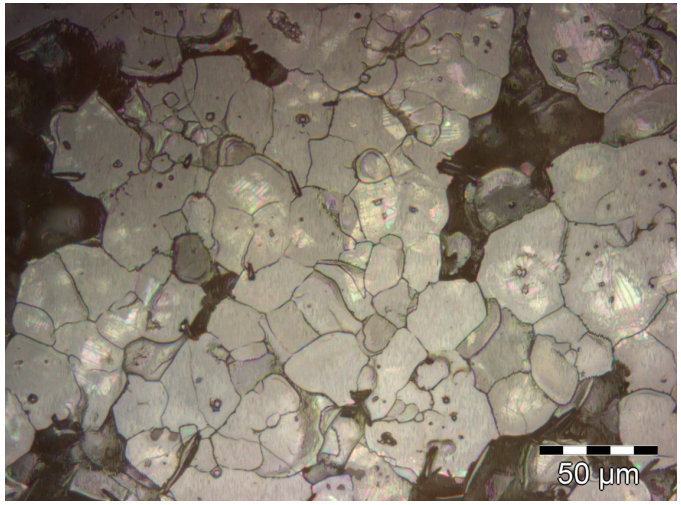
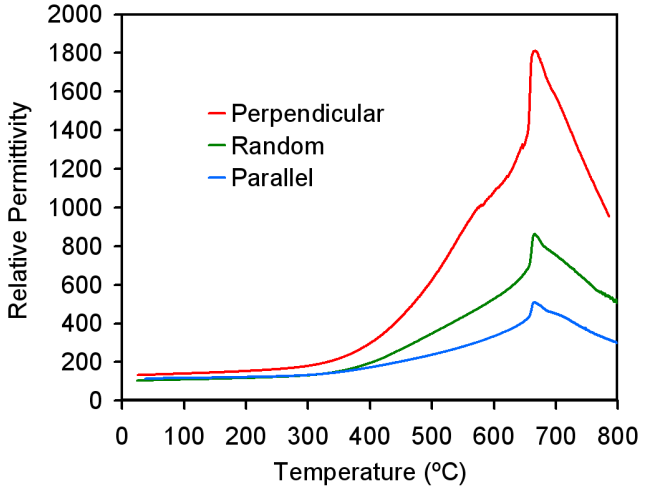
SAND2008-1249C

Thick Film Texturing to Enhance the Properties of Lead-Free Ferroelectric Materials





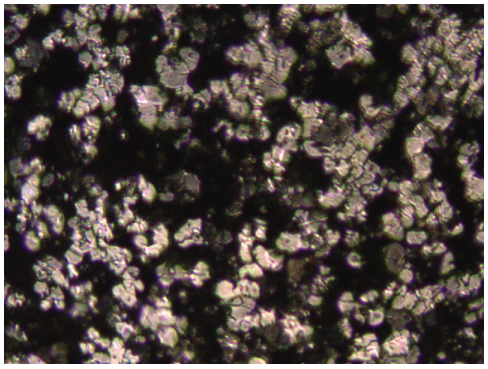
Michael R. Winter

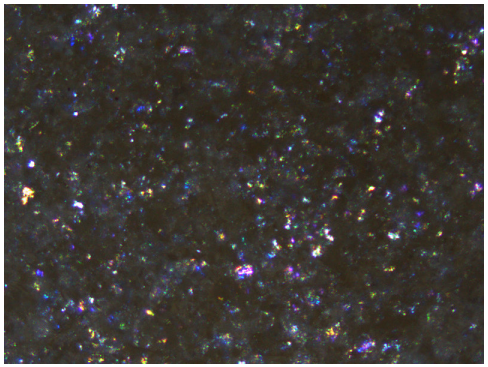
Christopher B. DiAntonio **Tom Chavez** **Mark Rodriguez**

Sandia National Laboratories

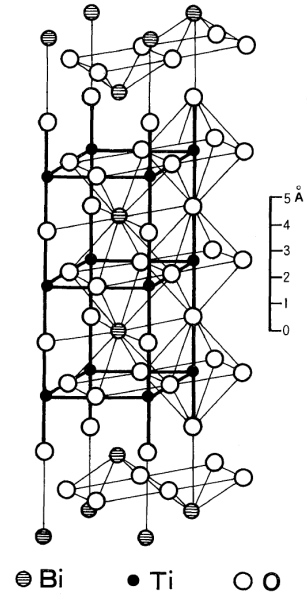
Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

This presentation focuses on improving the dielectric properties of lead-free materials textured by screen printing



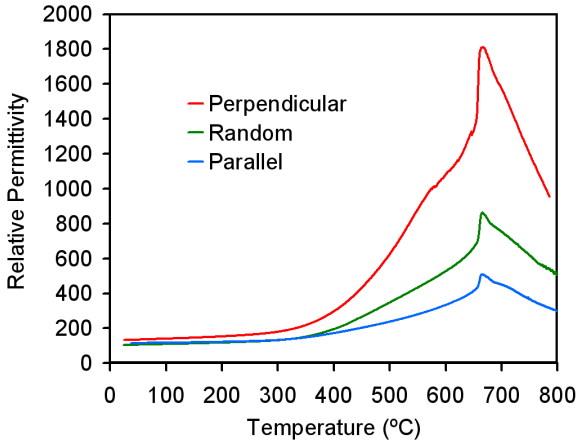


Lead-free dielectrics

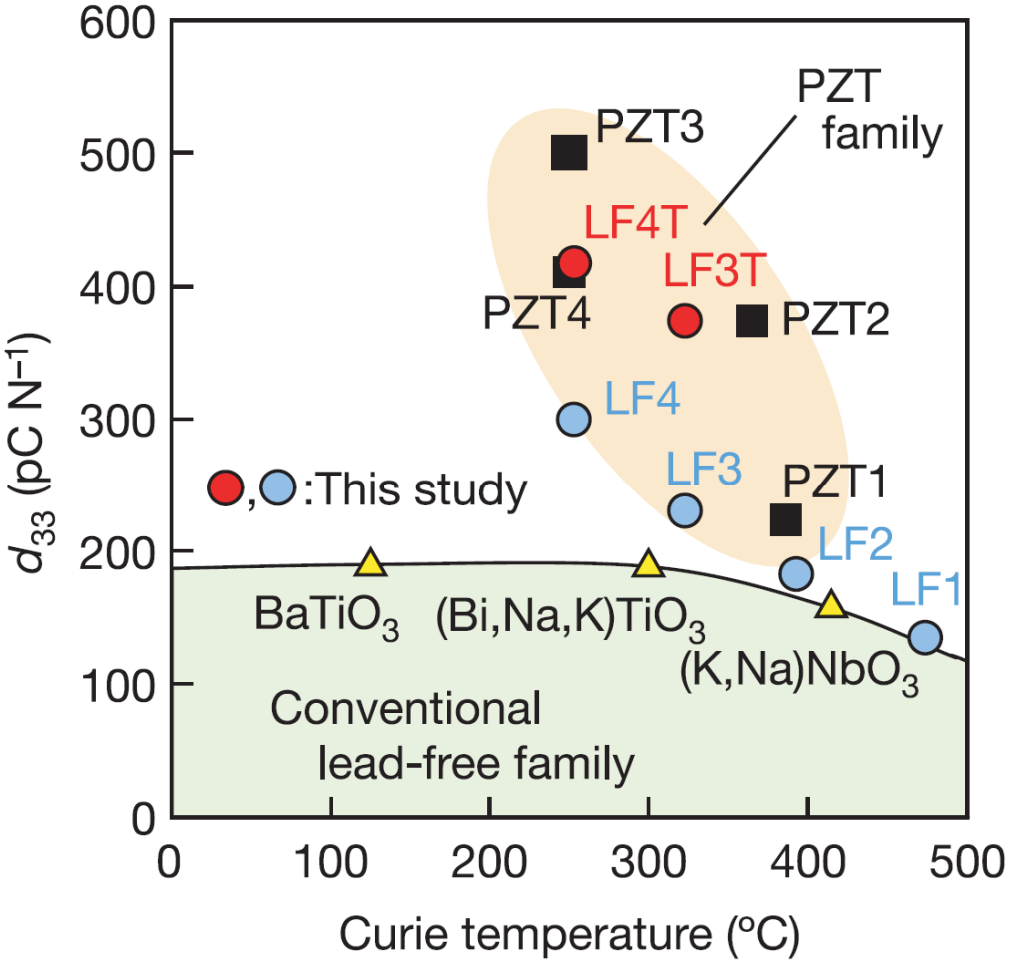


Scalable industrial techniques

Improved dielectric properties



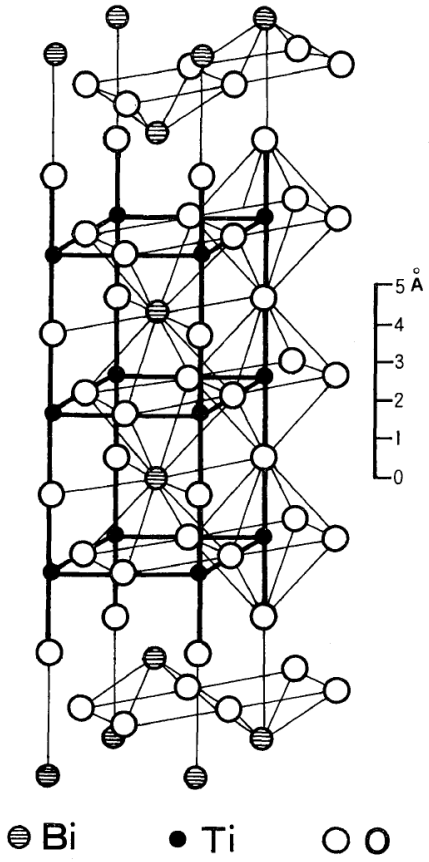
The motivation is to develop replacements for current lead-based systems that are rapidly scalable to industry



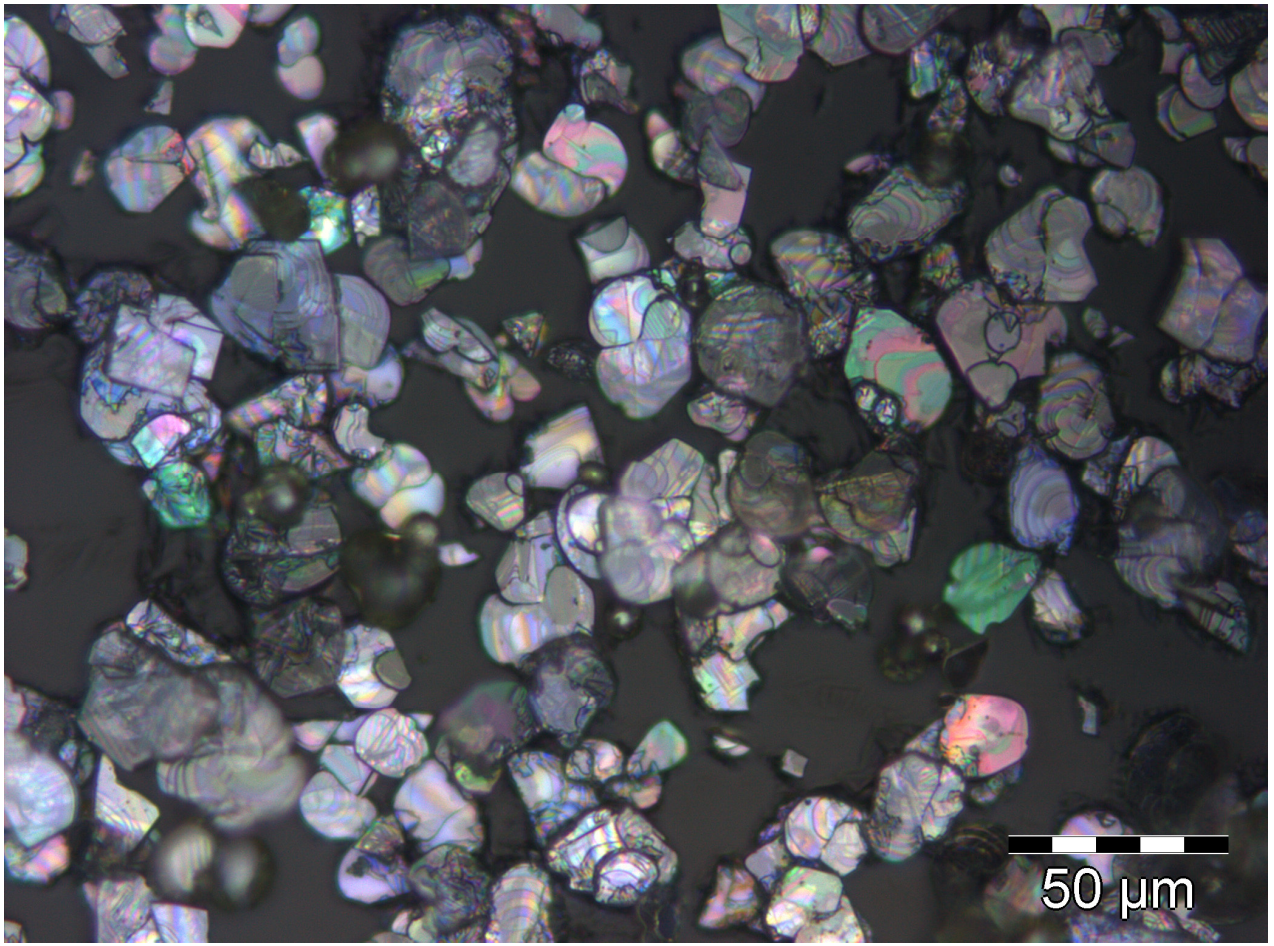
Y. Saito, Nature (2004)

When textured by tape casting, materials in the alkali niobate-based perovskite system have excellent dielectric properties

Layer-structure materials are excellent candidates for crystallographic texturing

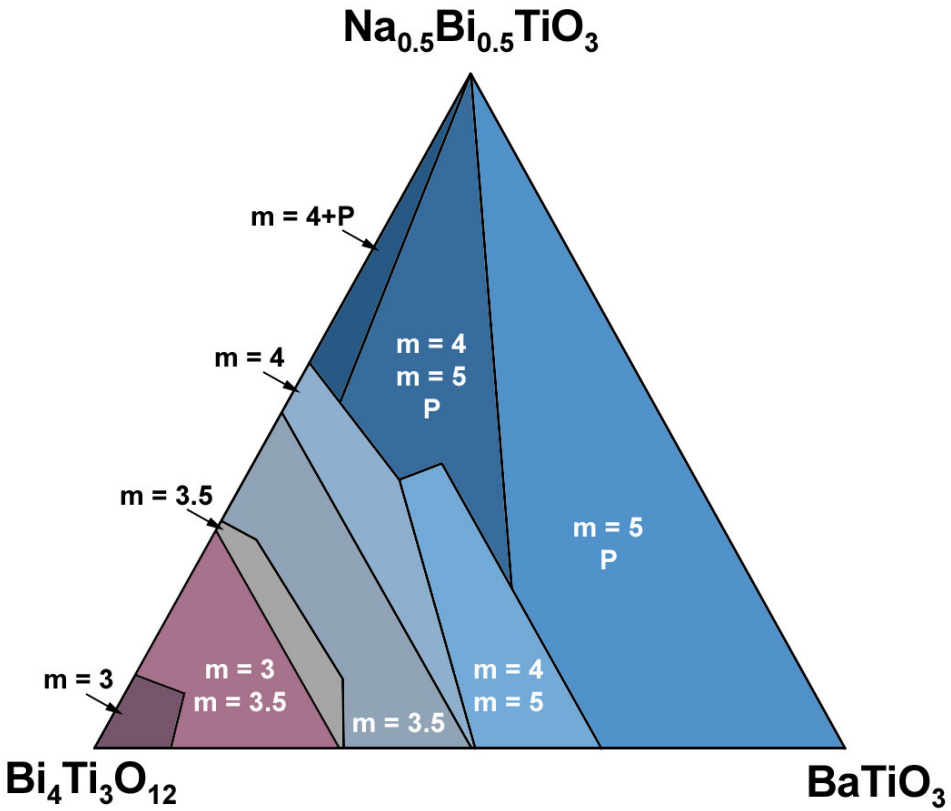


T. Takenaka, JJAP (1980)



High aspect ratio (~200:1) seeds of $Bi_4Ti_3O_{12}$ can be grown through molten salt synthesis

Several compositions in the ternary are potential lead-free dielectrics

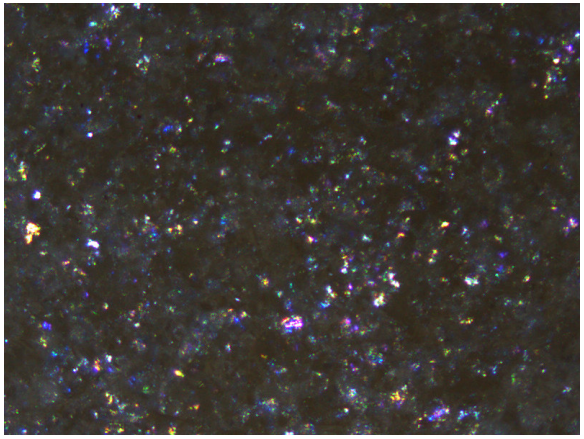


A. Sanson, JACS (2005)

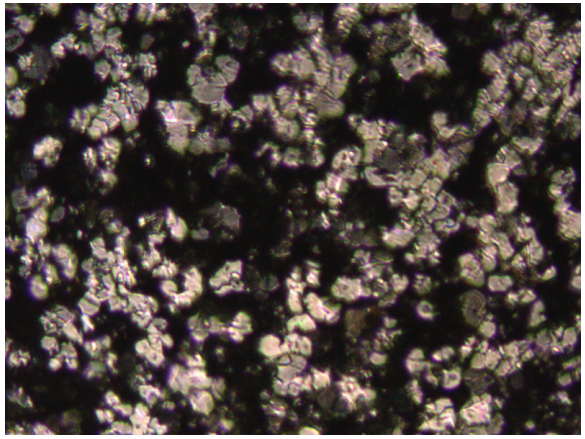
$Bi_4Ti_3O_{12}$	$Na_{0.5}Bi_{0.5}TiO_3$	$BaTiO_3$
100%	0%	0%
0%	100%	0%
0%	0%	100%
33%	33%	33%
50%	50%	0%
8.55%	43.30%	48.15%

Materials in the $Bi_4Ti_3O_{12}$ - $Na_{0.5}Bi_{0.5}TiO_3$ - $BaTiO_3$ ternary have a variety of layer structures for different compositions

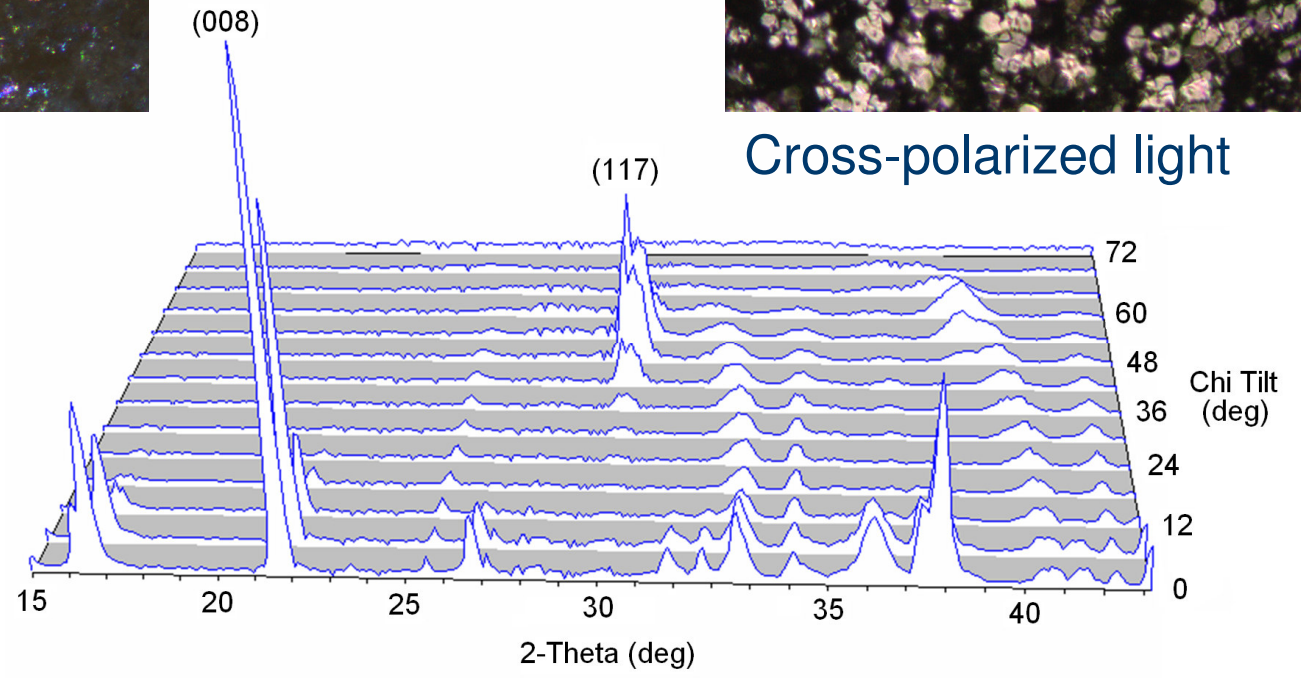
Texture induced by high shear processing



Polarized light

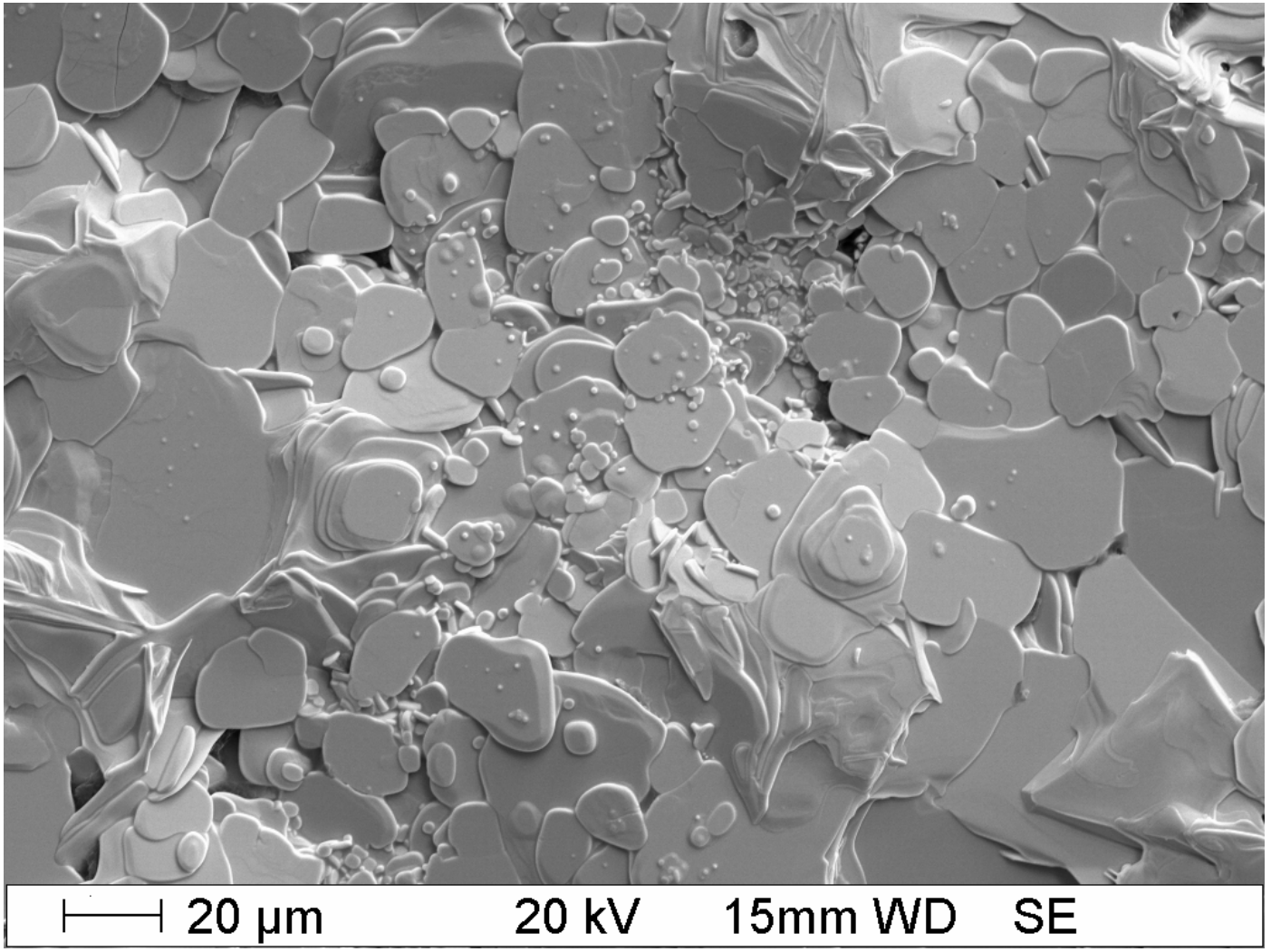


Cross-polarized light



The Lotgering factor is 0.93 for the green screen printed sample

Upon sintering, seeds grow at the expense of the equi-axial powder matrix



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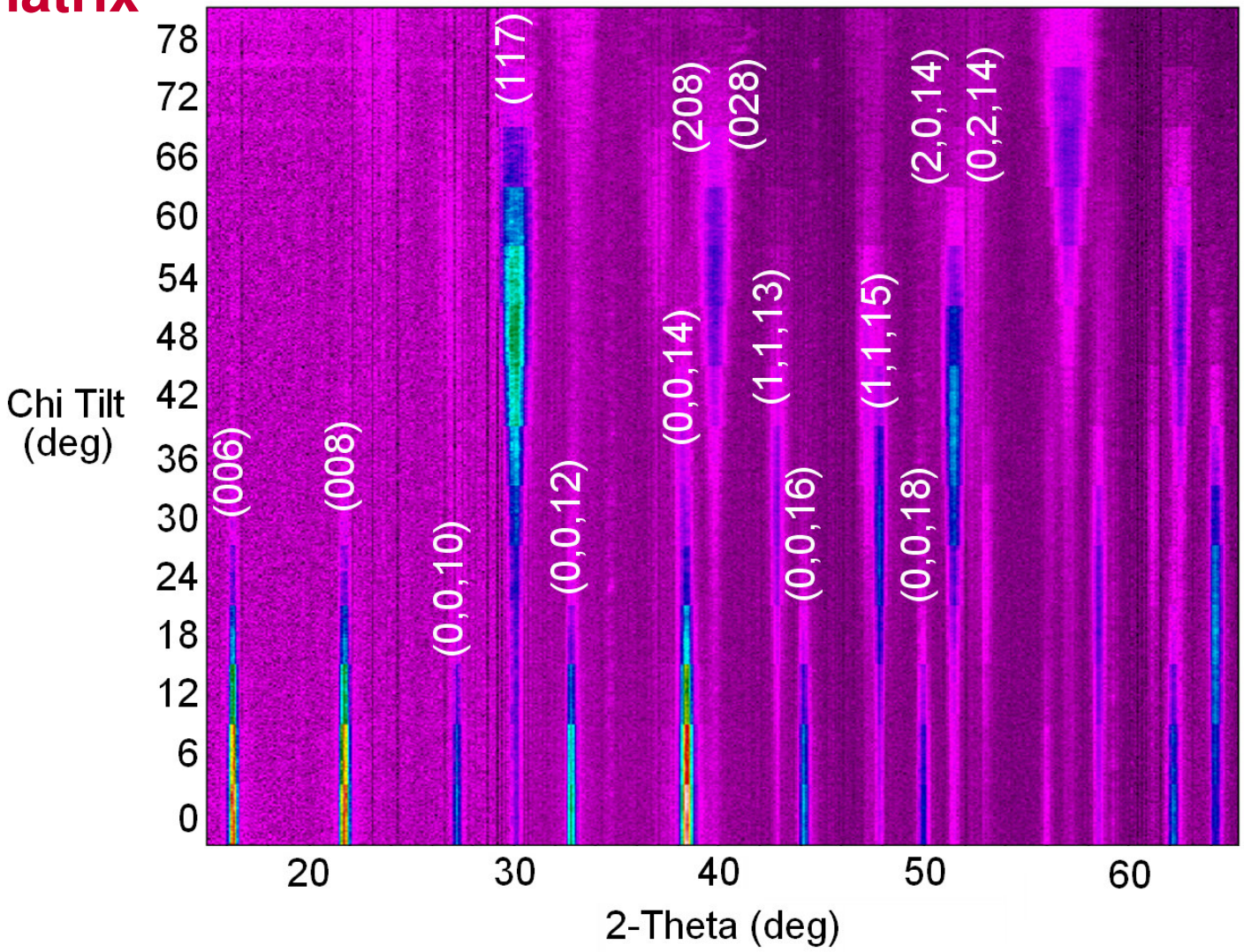
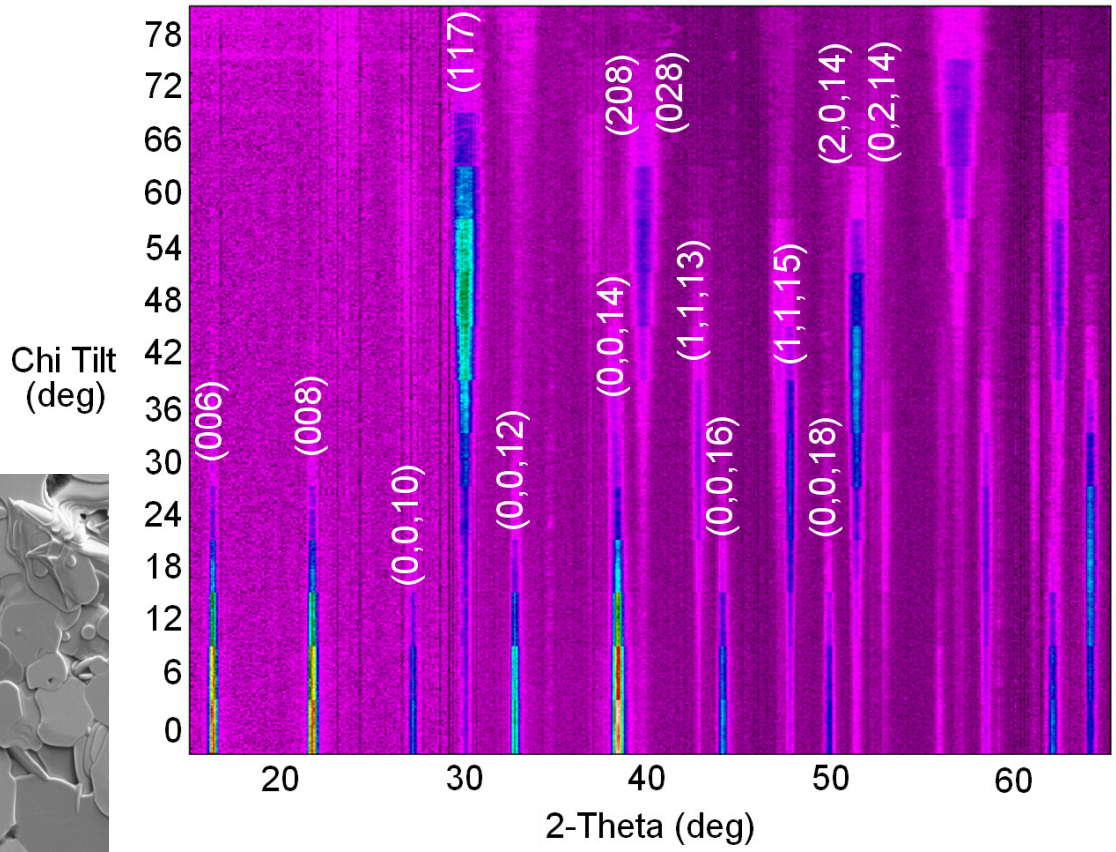
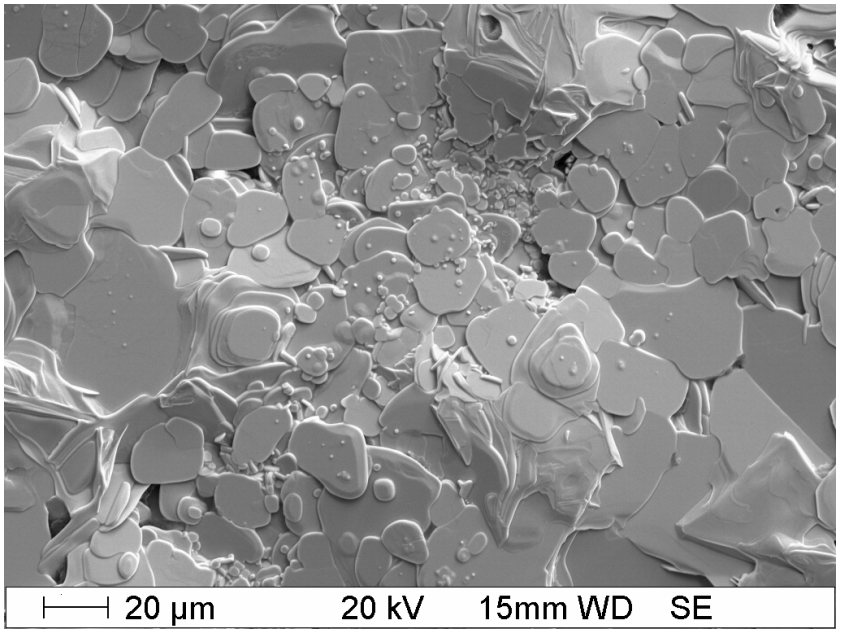


The Lotgering factor is 0.96 for the sintered screen printed sample

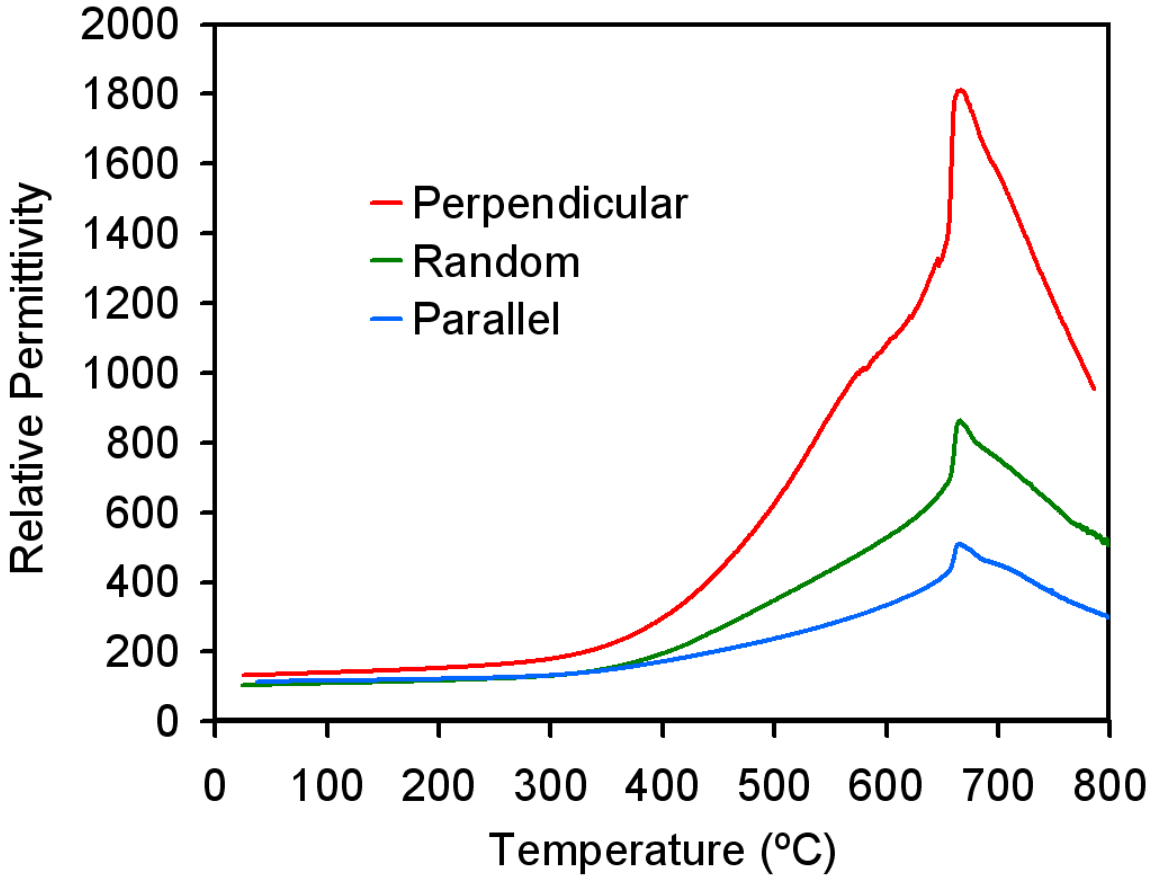
Upon sintering, seeds grow at the expense of the equi-axial powder matrix





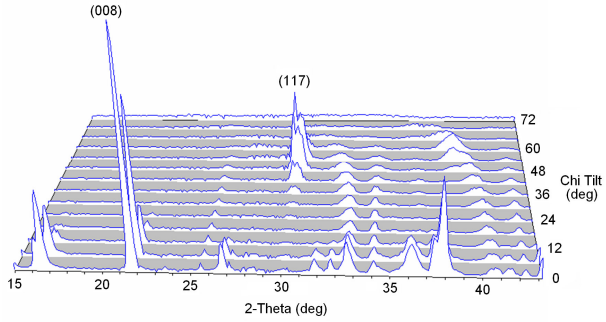
The Lotgering factor is 0.96 for the sintered screen printed sample

The relative permittivity of the textured material is significantly better than that of the non-textured material

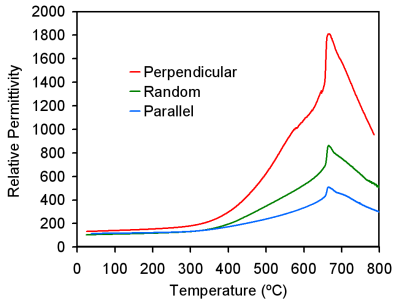


Tape cast material with a similar Lotgering factor shows very different relative permittivity values dependent on orientation

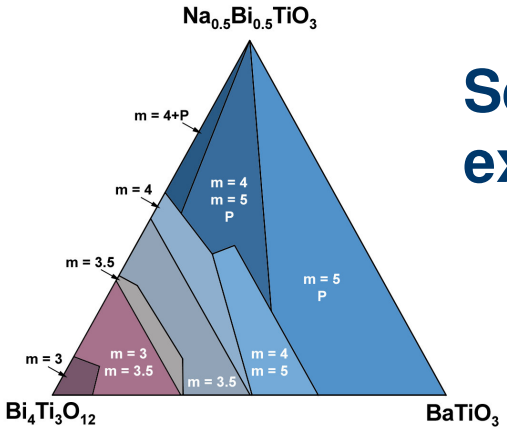
Textured layer-structure, lead-free materials show considerable promise to replace lead-based dielectrics



Screen printing has been shown to result in highly textured layer-structure materials



Similarly textured materials result in a significant improvement in dielectric properties



Several layer-structure materials have yet to be examined as lead-free dielectrics

Questions?

Lotgering Factor is calculated from the powder diffraction pattern

$$F = \frac{P - P_0}{1 - P_0}$$

$$P = \frac{\sum I\,(h00)}{\sum I\,(hkl)}, P_0 = \frac{\sum I_0\,(h00)}{\sum I_0\,(hkl)}$$

Processing conditions are continuously modified to achieve optimum density and microstructure

Seed Growth - 1100ºC for 16 hours → slow cool at 10ºC/h to 940ºC

Ink - texanol-based ink with 30-50 v/o powder (10-50 w/o seeds)

Substrate - Pt barrier layer or Bi soaked alumina substrate

Drying - 120ºC for 15 minutes

Sintering - 1100ºC for 1 hour in a sealed bismuth atmosphere