Thickness and from 20-30μm polarization direction is

Thickness = From Pco and T we can draw graphs to discuss the properties of copolymerD= Thermal diffusivity constantFor PVDF Film

D= 6. 2 x 10?? m²/s5. Results and Discussion: 5. 1 Thickness vs Pyroelectric coefficient of bilayer 21μm thick PVDFfilm Figure 7: Spatial distribution of the apparent pyroelectric coefficient of a 21μm thick PVDF bilayer film front side In the abovefigure,   X axis = Thickness (m)Y axis = Pyroelectriccoefficient (a.

u.)We can observe a breakin the curve this is because of sign changes. The polarization reaches maximumat 5μm. compared to single layer PVDF film polarization decreases if the thermalwave moves deep inside the sample   5. 2Thickness vs Pyroelectric coefficient of three layer 30μm thick PVDF film Figure 8: Spatial distribution of the apparent pyroelectric coefficient of a 30μm thick PVDF multilayer film front and back side   In the abovefigure,   X axis = Thickness (m)Y axis = Pyroelectriccoefficient (a.

u.)0-10μm polarization direction is upwards ? and polarization reachesmaximum value at 5 μm and decreases and from 10-20μm polarization direction isdownwards ? and polarization increases and from 20-30μm polarization directionis upwards ? and there is not much change in polarization. So I would say wecan measure better polarization until 20 μm. blue curve indicate front side ofthe film and the green curve indicate back side of the film. Figure 9 Combination of measurements from 2sides from figure 8 1. 3   Thickness vs Pyroelectric coefficient ofbilayer 23um thick P(VDF-TrFE)70/30 mol%, P(VDF-TrFE)50/50 mol%film In the belowfigure,   X axis = Thickness (m)Y axis = Pyroelectriccoefficient (a. u.

)blue curve indicates front side of the film and the green curveindicates back side of the film. Both sides of the filmpolarized in the same direction by applying a voltage. Blue curve reachesmaximum polarization faster than the green curve. This is because of theirdifferent mol%. We can observe curvechanges until 23um after that polarization coefficient shows a constant value. I would say green curve has maximum polarization so I expect it would be 70/30mol% and the blue curve has less polarization compared to green so I expect bluecurve is 50/50 mol%. Figure 10: Spatial distribution of the apparent pyroelectric coefficient of a 23um thick P(VDF-TrFE) bilayer film front 70/30 mol% front and 50/50 mol% back side Figure 11 Combination of measurements from 2sides from figure 10Started measuringpolarization at different temperatures from 40°C to 120°C to determine thepolarization changes of the film caused because of temperature deference. Figure 12: Spatial distribution of the apparent pyroelectric coefficient of a 23um thick P(VDF-TrFE) bilayer film front 70/30 mol% and 50/50 mol% back side Sample heated for 10minutes at 40°C and measured pyroeletricity at room temperatureIn the abovefigure X axis = Thickness (m)Y axis = Pyroelectriccoefficient (a.

u.)Blue curve reaches maximum polarization so I expect it would be 70/30mol% and the green curve has less polarization compared to green so I expectgreen curve is 50/50 mol%. Compared to Figure 12 there are no much changesexpect less decrease of maximum polarization Figure 13 Combination of measurements from 2sides from figure 12 Figure 14 Spatial distribution of theapparent pyroelectric coefficient of a 23um thick P(VDF-TrFE) bilayer film front 70/30 mol% and 50/50 mol% back sideX axis =

Thickness (m)Y axis = Pyroelectric coefficient (a. u.)Sample heated for 10 minutes at 45°C and measured pyroeletricity at roomtemperature.

In the above figure full of noise due to missing connectionshappened during measurement. Figure 12: Spatial distribution of the apparent pyroelectric coefficient of a 23um thick P(VDF-TrFE) bilayer film front 70/30 mol% and 50/50 mol% back side Figure 15 Spatial distribution of the apparent pyroelectric coefficient of a 23um thick P(VDF-TrFE) bilayer film front 70/30 mol% and 50/50 mol% back side Xaxis = Thickness (m)Y axis = Pyroelectric coefficient (a. u.)Sample heated for 10 minutes at 50°C and measured pyroeletricity at roomtemperature. Missing connections continued from figure 14. There is no changein the graph noise continues. Figure 16 Spatial distribution of the apparent pyroelectric coefficient of a 23um thick P(VDF-TrFE) bilayer film front 70/30 mol% and 50/50 mol% back side X axis = Thickness (m)Y axis = Pyroelectriccoefficient (a.

u.)Sample heated for 10minutes at 55°C and measured pyroeletricity at room temperature Figure 17 Spatial distribution of theapparent pyroelectric coefficient of a 23um thick P(VDF-TrFE) bilayer film front70/30 mol% and 50/50 mol% back sideX axis = Thickness (m)Y axis = Pyroelectric coefficient (a. u.)Sample heated for 10 minutes at 65°C and measured pyroeletricity at roomtemperature Figure 18 Spatial distribution of theapparent pyroelectric coefficient of a 23um thick P(VDF-TrFE) bilayer filmfront 70/30 mol% and 50/50 mol% back sideX axis = Thickness (m)Y axis = Pyroelectric coefficient (a. u.)Sample heated for 10 minutes at 75°C and measured pyroeletricity at roomtemperature Figure 19 Spatial distribution of theapparent pyroelectric coefficient of a 23um thick P(VDF-TrFE) bilayer filmfront 70/30 mol% and

50/50 mol% back sideX axis = Thickness (m)Y axis = Pyroelectric coefficient (a.

u.)Sample heated for 10 minutes at 85°C and measured pyroeletricity at roomtemperature 5. 4 Thickness vs Pyroelectric coefficientof bilayer 25um thick P(VDF-TrFE)70/30 mol%, P(VDF-TrFE)50/50 mol%film Figure 20 Spatial distribution of the apparent pyroelectric coefficient of a 25um thick P(VDF-TrFE) bilayer film front 70/30 mol% and 50/50 mol% back side In the abovefigure, X axis = Thickness (m)Y axis = Pyroelectriccoefficient (a. u.)blue curve indicates front side of the film and the green curveindicates back side of the film.

Both curves show a disturbance in the startingof the curve is because of noise. In the above figure blue curve reaches maximumpolarization so I expect it would be 70/30 mol% and the green curve has lesspolarization compared to green so I expect green curve is 50/50 mol%. Figure 21 combination of measuremnts from 2sides of sample from figure 20 Figure 22 Spatial distribution of theapparent pyroelectric coefficient of a 25um thick P(VDF-TrFE) bilayer filmfront 70/30 mol% and 50/50 mol% back sideX axis = Thickness (m)Y axis = Pyroelectric coefficient (a. u.)Sample is annealed at 40°C and measured pyroeletricity at roomtemperature. Compared to Figure 20 has more noise starting of the curves andhaving less noise in the end but in figure 22 we can observe a change in noisethat is having less noise in the starting and more in the end of the curve. Figure 23 combination of measuremnts from 2sides of sample from figure 22 Figure 24 Spatial distribution of theapparent pyroelectric coefficient of a 25um thick P(VDF-

TrFE) bilayer filmfront 70/30 mol% and 50/50 mol% back sideX axis = Thickness (m)Y axis = Pyroelectric coefficient (a. u.

) Sample is annealed at 50°C and measured pyroeletricity at roomtemperature. In the above figure we can observe change in polarization comparedto figure 20 and figure 22 caused due to change in temperature. Figure 25 combination of measuremnts from 2sides of sample from figure 24 Figure 26 Spatial distribution of theapparent pyroelectric coefficient of a 25um thick P(VDF-TrFE) bilayer filmfront 70/30 mol% and 50/50 mol% back sideX axis = Thickness (m)Y axis = Pyroelectric coefficient (a. u.)Sample is annealed at 60°C and measured pyroeletricity at roomtemperature Figure 27 Spatial distribution of theapparent pyroelectric coefficient of a 25um thick P(VDF-TrFE) bilayer filmfront 70/30 mol% and 50/50 mol% back sideX axis = Thickness (m)Y axis = Pyroelectric coefficient (a. u.)Sample is annealed at 70°C and measured pyroeletricity at roomtemperatureCompared to figure 26 and figure 27 there is no change in thepolarization. Rather we can observe change in noise Figure 28 combination of measuremnts from 2sides of sample from figure 27 Figure 29 Spatial distribution of theapparent pyroelectric coefficient of a 25um thick P(VDF-TrFE) bilayer filmfront 70/30 mol% and 50/50 mol% back sideX axis = Thickness (m)Y axis = Pyroelectric coefficient (a.

u.)Sample is annealed at 80°C and measured pyroeletricity at roomtemperature Figure 30 combination of measuremnts from 2sides of sample from figure 29 Figure 31 Spatial distribution of the apparentpyroelectric coefficient of a 25um thick P(VDF-TrFE) bilayer film front 70/30mol% and 50/50 mol% back sideX axis = Thickness (m)Y axis = Pyroelectric coefficient (a. u.

)Sample is annealed at 90°C and measured pyroeletricity at roomtemperature Figure 32 combination of measuremnts from 2sides of sample from figure 31 Even at 80°C and 90°C also we didn’t get a change in polarization Iwould say this is because of measurement error Figure 33 Spatial distribution of theapparent pyroelectric coefficient of a 25um thick P(VDF-TrFE) bilayer filmfront 70/30 mol% and 50/50 mol% back sideX axis = Thickness (m)Y axis = Pyroelectric coefficient (a. u.)Sample is annealed at 100°C and measured pyroeletricity at roomtemperature Figure 34 combination of measuremnts from 2sides of sample from figure 33 Figure 35 Spatial distribution of theapparent pyroelectric coefficient of a 25um thick P(VDF-TrFE) bilayer filmfront 70/30 mol% and 50/50 mol% back sideSample is annealed at 110°C and measured pyroeletricity at roomtemperature. X axis = Thickness (m)Y axis = Pyroelectric coefficient (a. u.

) Figure 36 combination of measuremnts from 2sides of sample from figure 35 From Figure 20, 22, 24, 26, 27, 29, 31, 33 and 35 we can observe thereis no change in the graphs. Mostly it is because of sample not get polarized at50/50 mol% side. If we measure at 120°C we may have seen a change at 70/30mol%, because it gets depolarized at 120°C.   So we proceed to prepare nextfilm and measured with different amplification factors to know about where theproblem is occurred. 5.

5 Thickness vs Pyroelectric coefficientof bilayer 30um thick P(VDF-TrFE)70/30 mol%, P(VDF-TrFE)50/50 mol%film Figure 37 Spatial distribution of

theapparent pyroelectric coefficient of a 30um thick P(VDF-TrFE) bilayer filmfront 70/30 mol% and 50/50 mol% back sideX axis = Thickness (m)Y axis = Pyroelectric coefficient (a. u.)The above figure results are not good. We thoughtproblem is with the amplification factor. So we measured polarization withdifferent amplification factors. Here it follows Figure 38 Spatial distribution of theapparent pyroelectric coefficient of a 30um thick P(VDF-TrFE) bilayer filmsoldering side at 10^6 high amplificationX axis = Thickness (m)Y axis = Pyroelectric coefficient (a. u.

)In the above figure measured polarizationof soldering side sample at high amplification factor 10^6. Figure 39 Spatial distribution of theapparent pyroelectric coefficient of a 30um thick P(VDF-TrFE) bilayer filmfront 70/30 pin side at 10^5 high amplification factorX axis = Thickness(m)Y axis = Pyroelectric coefficient (a. u.)Measured polarization of pin side of the sample athigh amplification factor 10^5. Compared to Figure 38 and Figure 39, I would say thatsoldering side of the film at 10? high amplification factors and pin side ofthe film is at 10? high amplification factors got good results compared to sameamplification factor. We can observe less noise.

Figure 40 Spatial distribution of theapparent pyroelectric coefficient of a 30um thick P(VDF-TrFE) bilayer filmfront 70/30 mol% and 50/50 mol% back side at 140°CX axis = Thickness (m)Y axis = Pyroelectric coefficient (a. u.)Sample is annealed at 140°C and measured pyroeletricity at roomtemperature. We can observe full of noise due to measurement error.

Next wewill measure polarization at low and high amplification factors to know aboutwhere the problem exists. Figure 41 Spatial distribution of the apparent pyroelectric coefficient of a 30um thick P(VDF-TrFE) bilayer film front 70/30 mol% and 50/50 mol% back side at 10^5 high amplification factor X axis = Thickness (m)Y axis = Pyroelectric coefficient (a. u.

)Measured pyroelectricity of the sample at highamplification factor 10^5. Figure 42 Spatial distribution of theapparent pyroelectric coefficient of a 30um thick P(VDF-TrFE) bilayer filmfront 70/30 mol% and 50/50 mol% back side at 10^4 high amplification factor X axis = Thickness (m)Y axis = Pyroelectric coefficient (a. u.)Measuredpyroelectricity of the sample at high amplification factor 10^4. In the abovefigure, we can observe full of noise. So compared to 10?, 10?, 10? amplification factors, from figure 38, figure 41, figure 42 we can sayit's good to measure polarization at 10? amplification factor. We will get lessnoise and more clear results.

Figure 43 Spatial distribution of theapparent pyroelectric coefficient of a 30um thick P(VDF-TrFE) bilayer filmfront 70/30 mol% and 50/50 mol% back side at high amplification factor X axis = Thickness (m)Y axis = Pyroelectric coefficient (a. u.)Measured pyroelectricity of the sample at high amplification factor. Figure 44 Spatial distribution of theapparent pyroelectric coefficient of a 30um thick P(VDF-TrFE) bilayer filmfront 70/30 mol% and 50/50 mol% back side at low amplification factor X axis = Thickness (m)Y axis = Pyroelectric coefficient (a. u.)Measured pyroelectricity of the sample at Lowamplification factor 10^5.

Compared to figure 43and figure 44, we can clearly observe at high amplification factor shows less noisecompared to low amplification factor. So I would recommend to measure at highamplification factor based on these results. To measure high frequencies itwould be better to measure at low amplification factor. And also for lowfrequencies use high amplification factor5. 6 Thickness vs Pyroelectric coefficientof bilayer 33um thick P(VDF-TrFE)70/30 mol%, P(VDF-TrFE)50/50 mol%film Figure 45 Spatial distribution of theapparent pyroelectric coefficient of a 33um thick P(VDF-TrFE) bilayer filmfront 70/30 mol% and 50/50 mol% back sideX axis = Thickness (m)Y axis = Pyroelectric coefficient (a. u.)Blue curve reachesmaximum polarization so I expect it would be 70/30 mol% and the green curve is50/50mol%.

both sides of the film poled in the same direction. A little bit ofnoise is presented at the starting of the green curve. Figure 46 combination of measuremnts from 2sides of sample from figure 45 Figure 47 Spatial distribution of the apparentpyroelectric coefficient of a 33um thick P(VDF-TrFE) bilayer film front 70/30mol% and 50/50 mol% back sideX axis = Thickness (m)Y axis = Pyroelectric coefficient (a. u.)Compared tofigure 33 in the above figure green curve 50/50 mol% lost its polarizationcaused due to increase in temperature of the film. I would say green curvereaches its curie temperature. In 70/30 mol% Blue curve less decrease ofpolarization. To confirm this we polarized the film again by applying voltageand we get results figure 49 and figure 51 Figure 48 combination of measuremnts from 2sides of sample from figure 47 Figure 49 Spatial distribution of theapparent pyroelectric coefficient of a 33um thick P(VDF-TrFE) bilayer filmfront 70/30 mol% and 50/50 mol% back sideX axis = Thickness (m)Y axis = Pyroelectric coefficient (a.

u.)In theabove figure, we tried to polarize the film by applying voltage but we canclearly see that green curve 50/50mol% not get polarized. To confirm this weagain increased the temperature of the film to 70°C. We can seeif any changes happened or not in figure 51. Figure 50 combination of measuremnts from 2sides of sample from figure 49 Figure 51 Spatial distribution of theapparent pyroelectric coefficient of a 33um thick P(VDF-TrFE) bilayer filmfront 70/30 mol% and 50/50 mol% back sideX axis = Thickness (m)Y axis = Pyroelectric coefficient (a. u.)There is no change in figure 51 and figure 49.

That means film not get polarized completely. So for next time we have toincrease the temperature of the film till 120°C then both thesides of the film lose its polarization. After that we can apply voltages toget polarize the sample then I would say the film get polarized completely andafter that without any disturbances we can measure pyroelectricity. Figure 52 combination of measuremnts from 2sides of sample from figure 51