State College δ^+ PolyK δ^- PA, USA

PVDF-TrFE Copolymer

Best Summary From Professor Qiming Zhang's publications

We strongly recommend you read publications from Professor Zhang in 1998-2005, as well as publications from Dr. Andrew J. Lovinger and Takeo Furukawa in 1980's and 1990's.

PolyK Technologies, 2124 Old Gatesburg Rd, State College, PA 16803, USA

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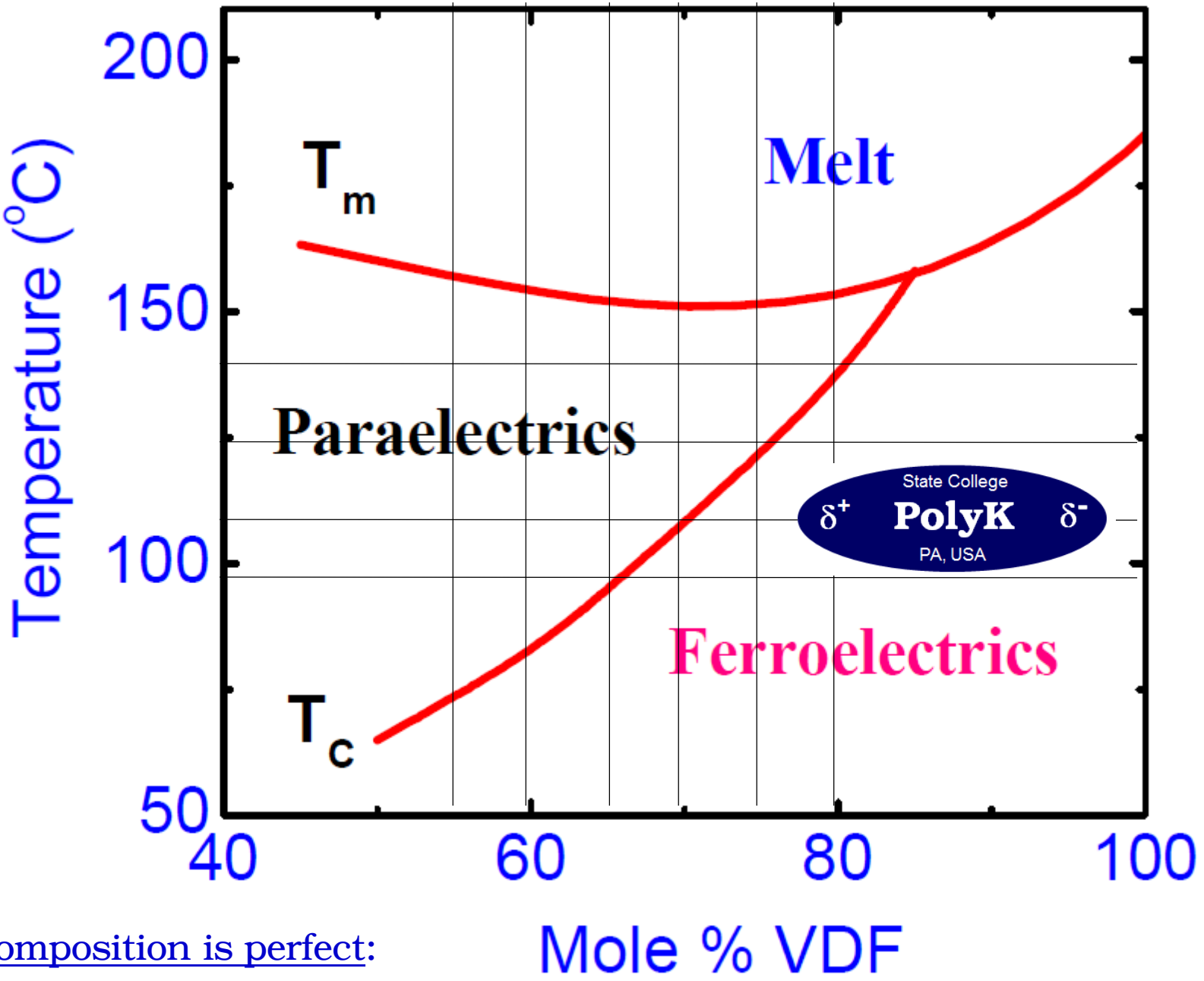
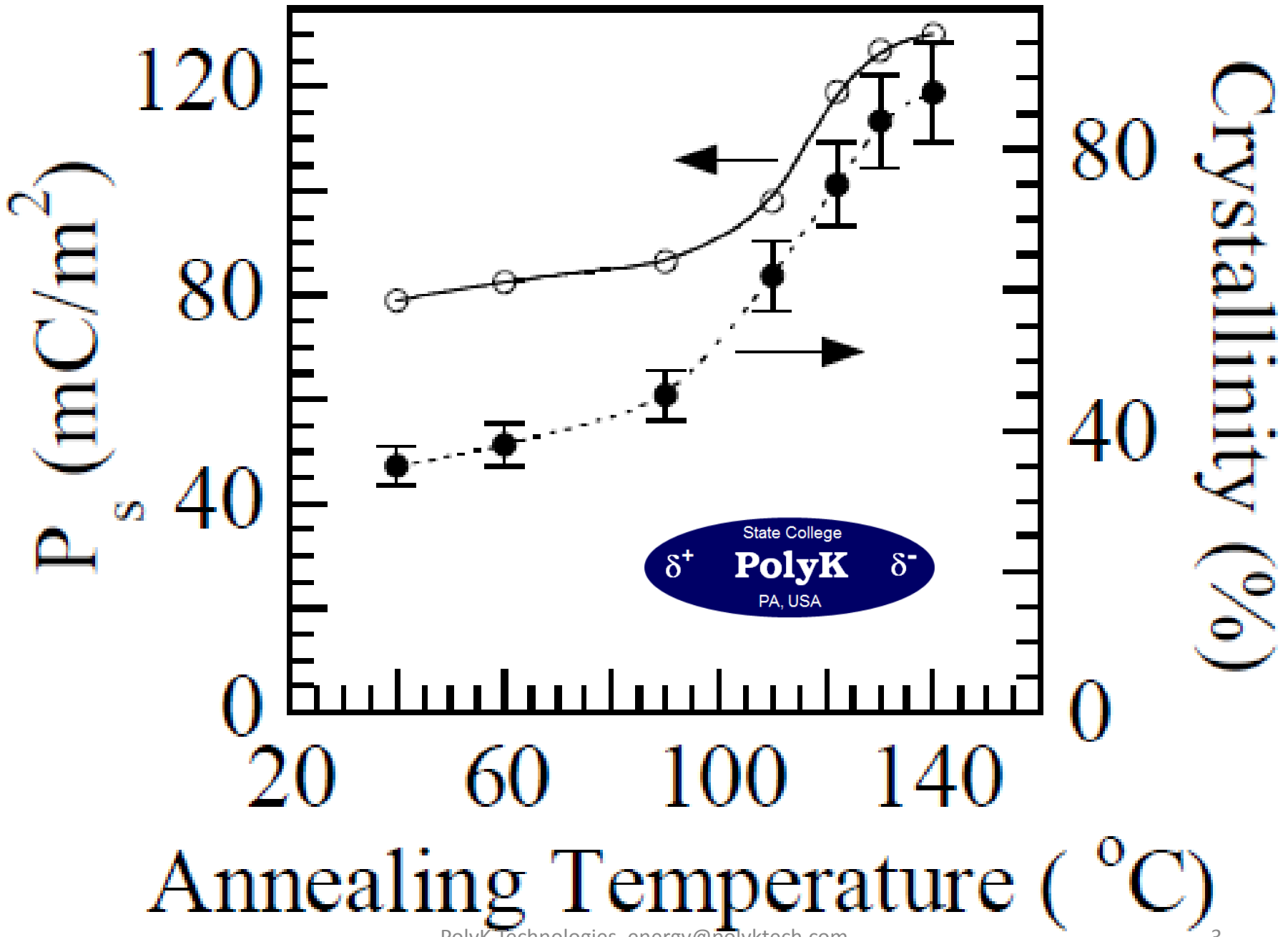
www.polyktech.com

www.polyk-lab.com



NO composition is perfect:

it is always a compromise. Select the composition based on your application.


120
80
40
0
P_s (mC/m^2)
80
40
0
Crystallinity (%)
20
60
100
140
Annealing Temperature (°C)
State College
δ+ PolyK δ-
PA, USA

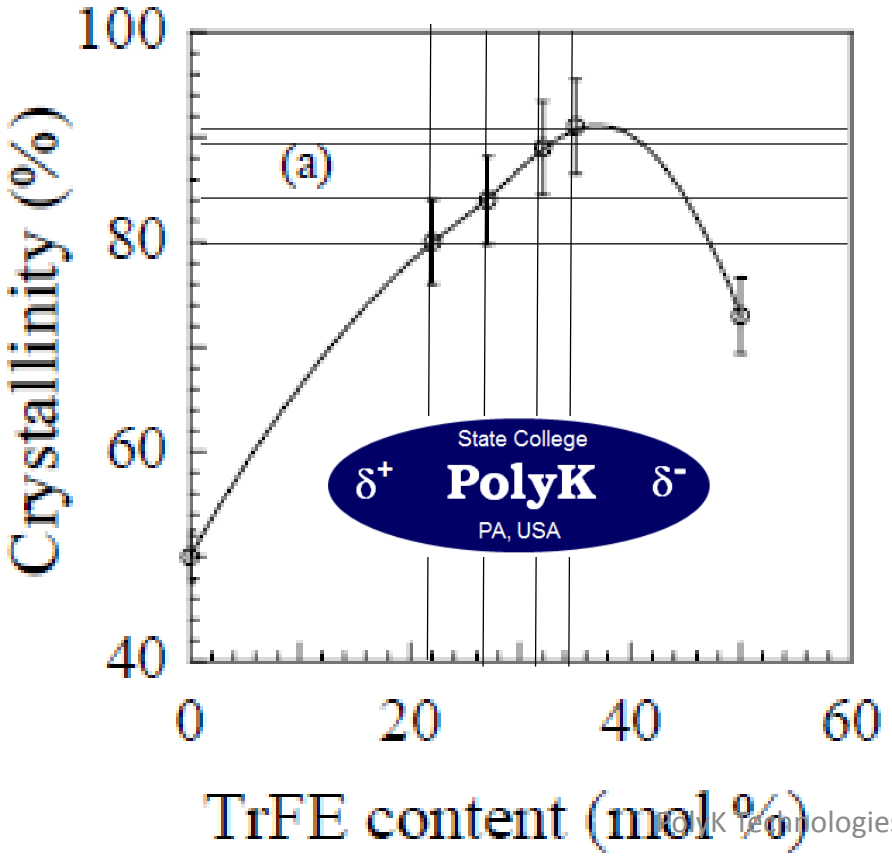
PolyK Technologies, 2124 Old Gatesburg Rd, State College, PA 16803, USA

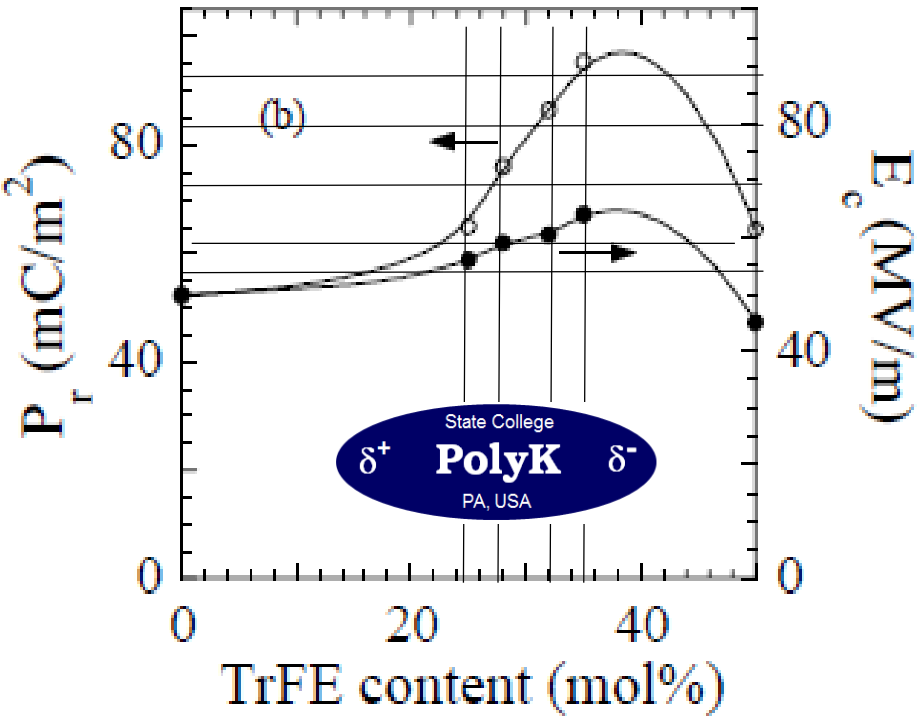
energy@polyktech.com

We specialized in PVDF-related polymers and their applications, test, and manufacturing.

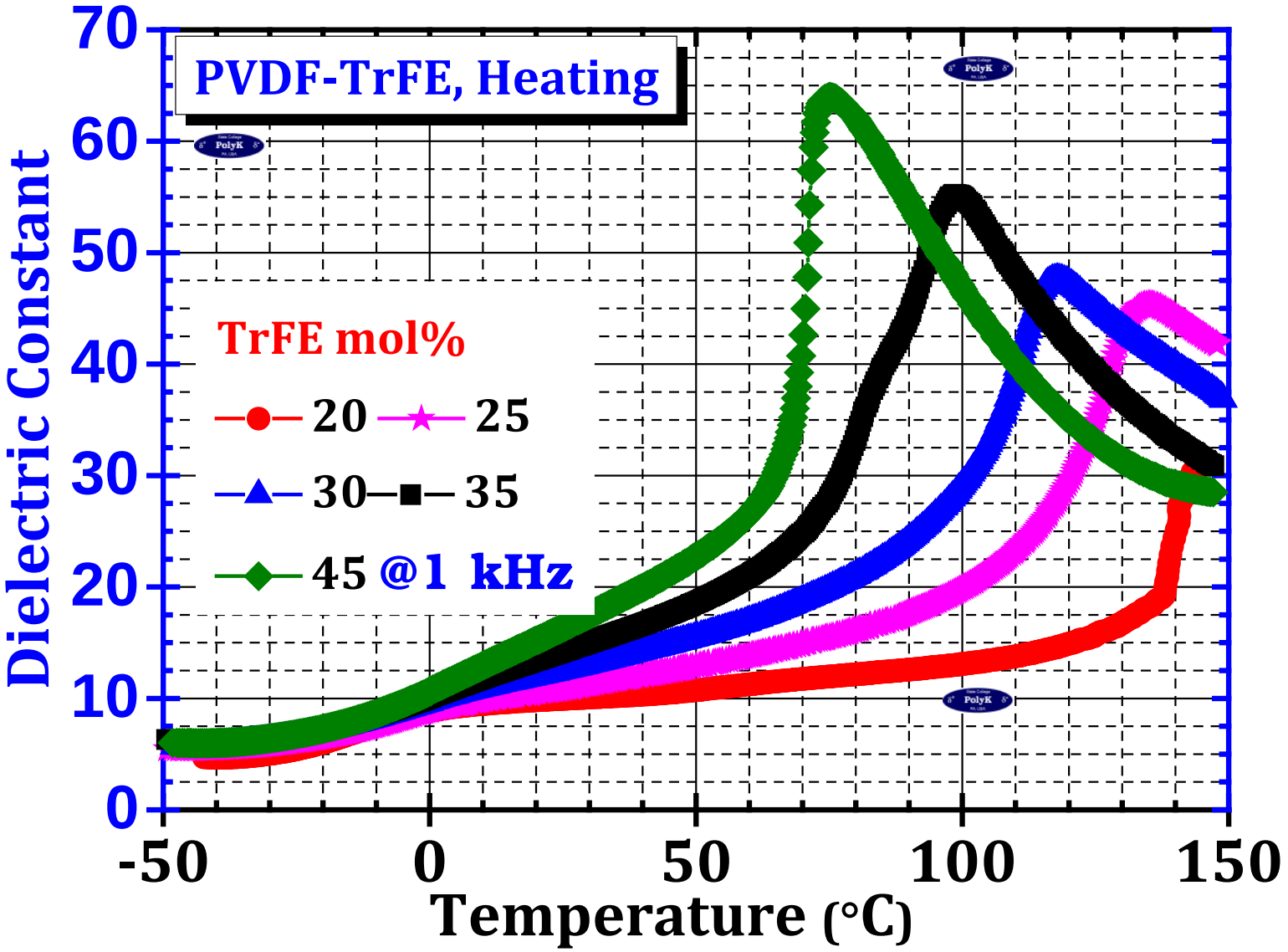
Manufacturers: Arkema, 3M, Solvay, Kureha

Production Process: suspension, emulsion, micro-emulsion, …. Similar price, but different properties

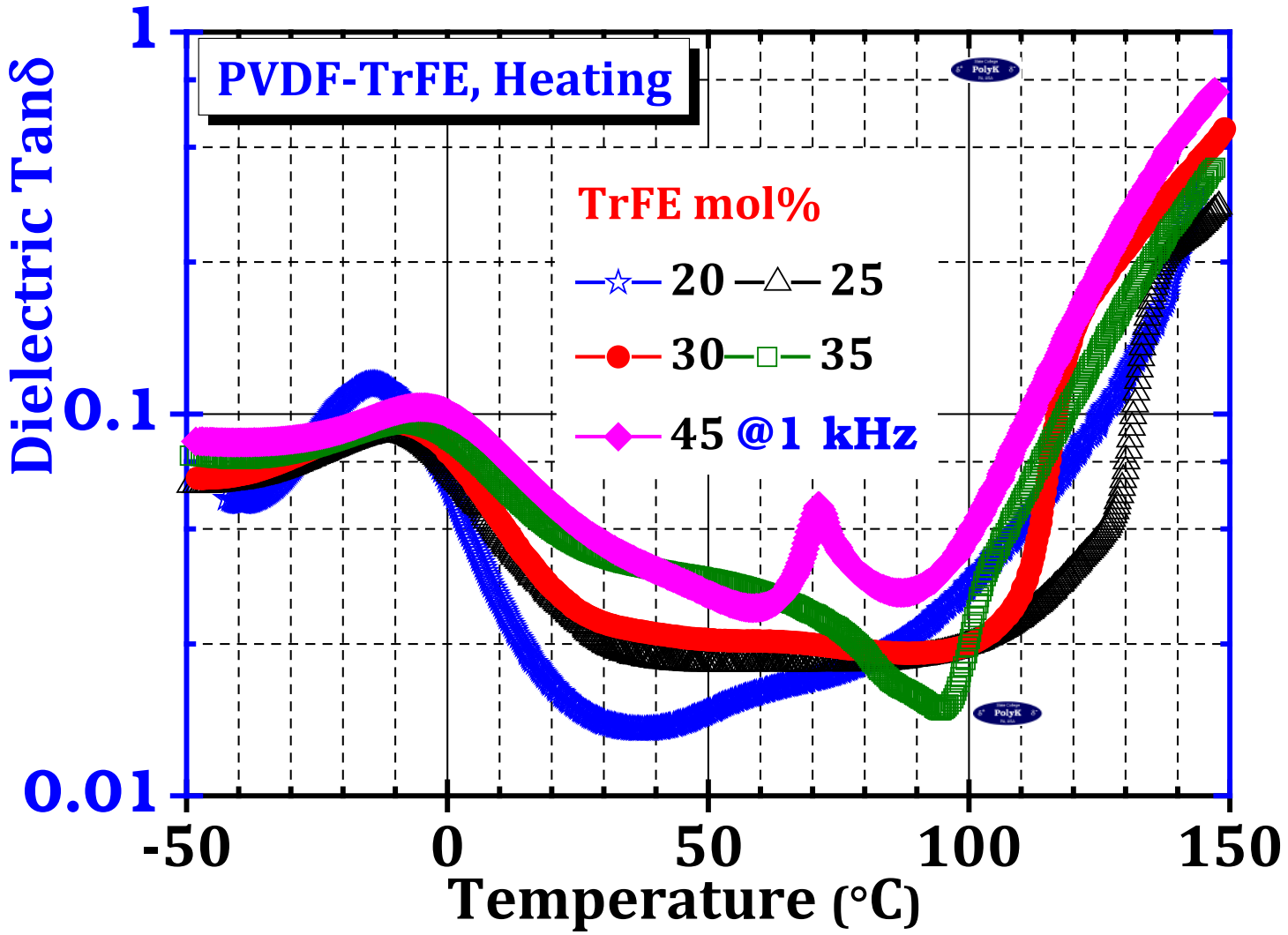




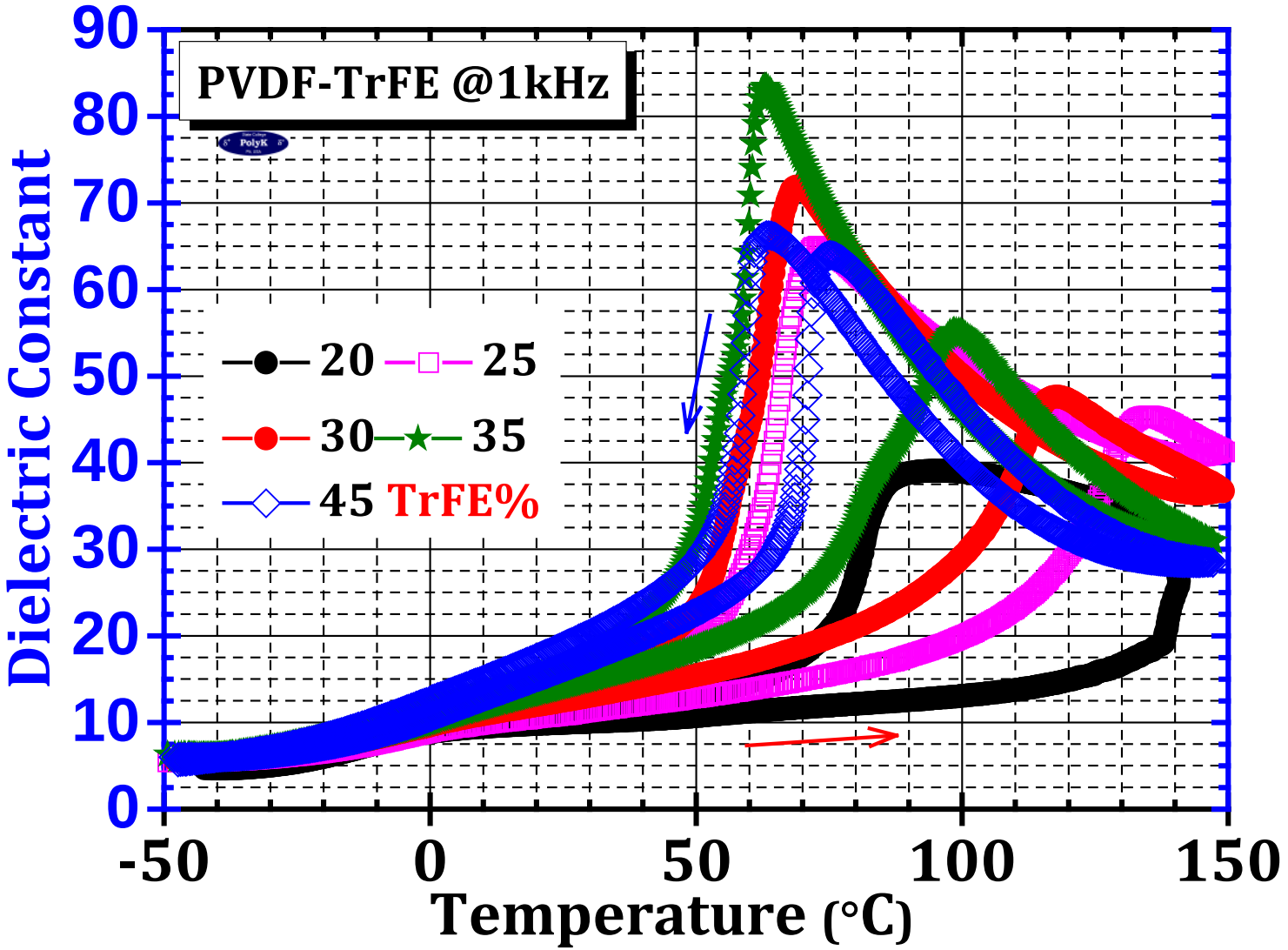
Dielectric, 1 kHz, Heating 2 C/min



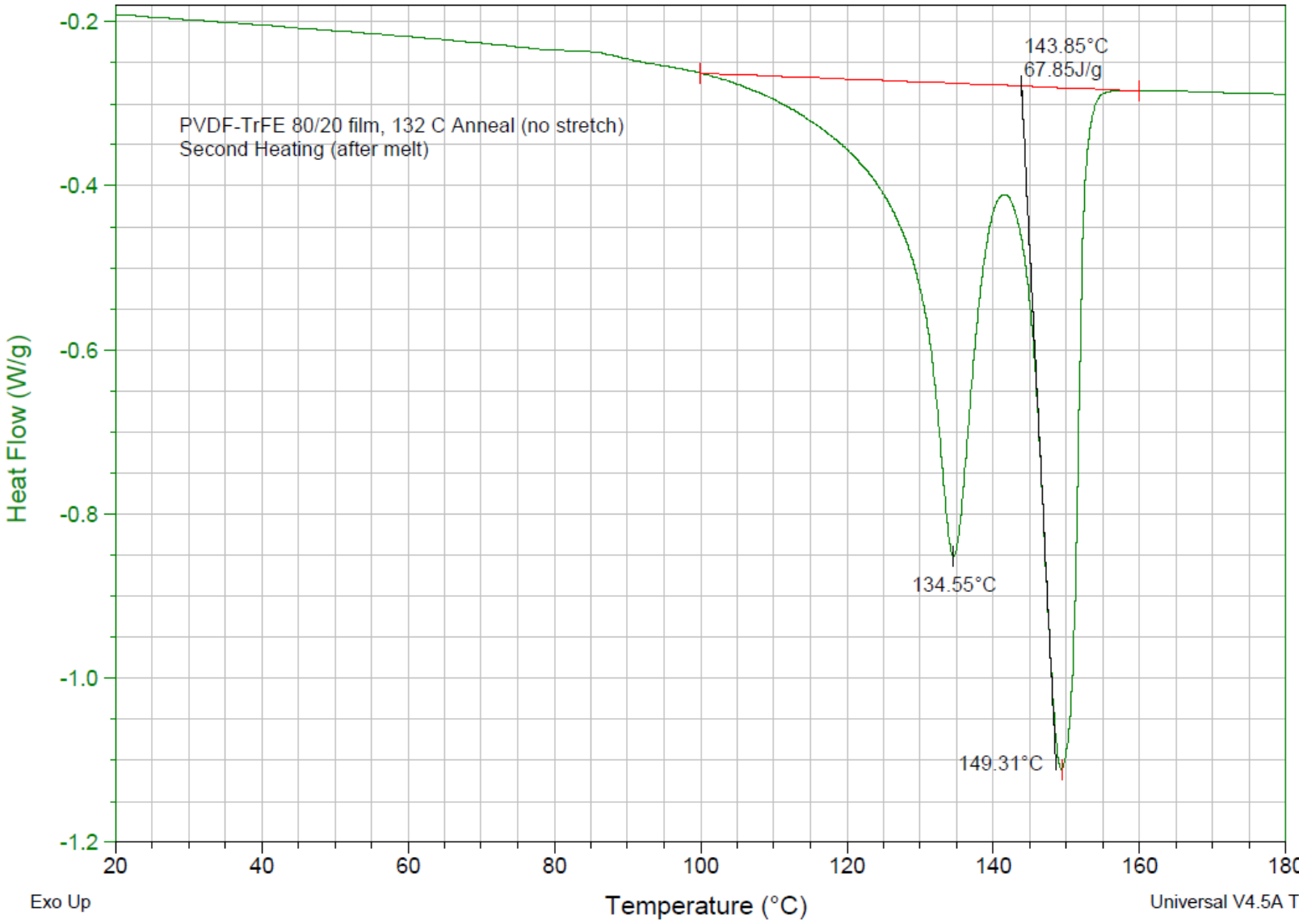
Dielectric, 1 kHz, Heating 2 C/min



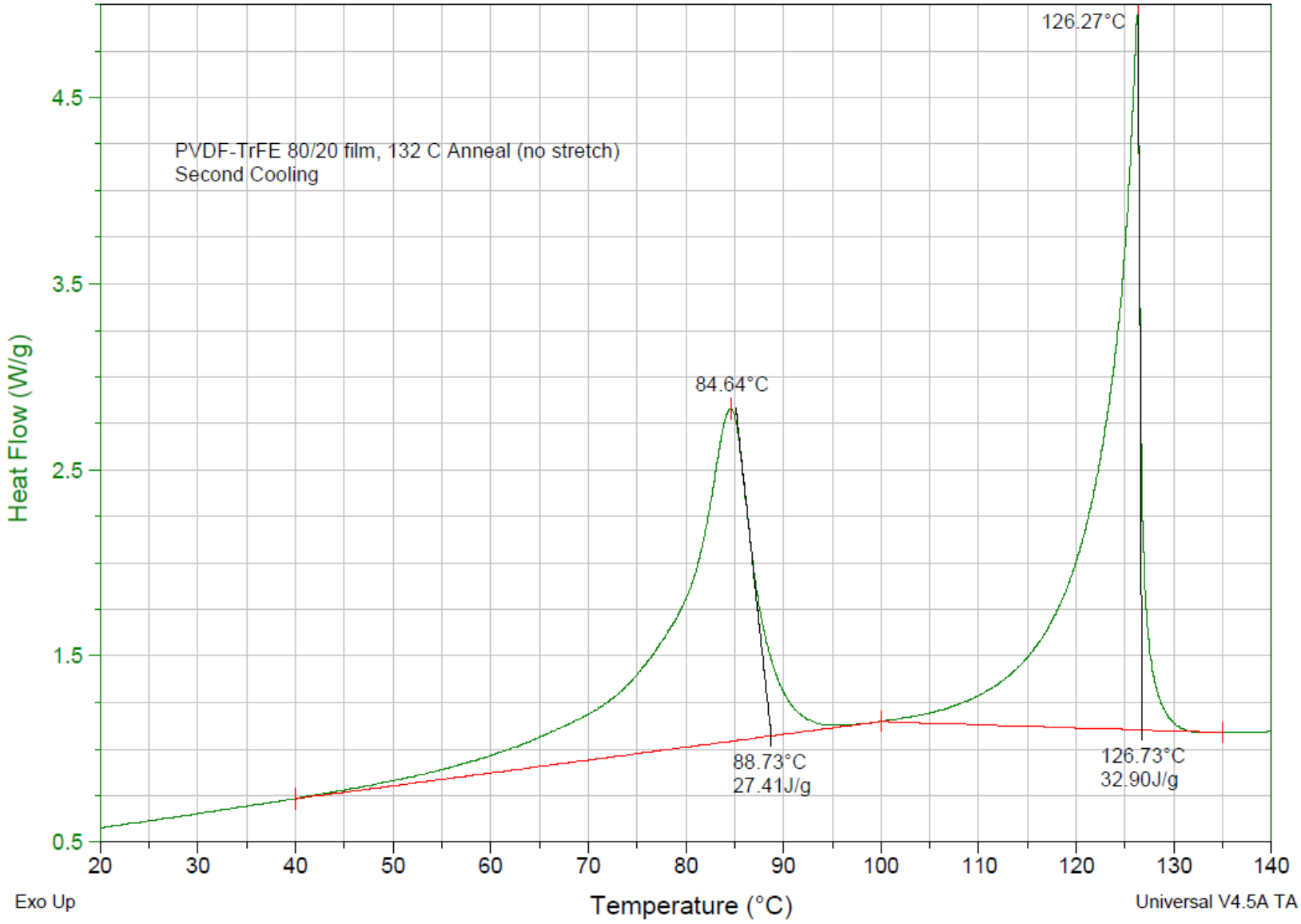
Dielectric, 1 kHz, Heating – Cooling 2 C/min



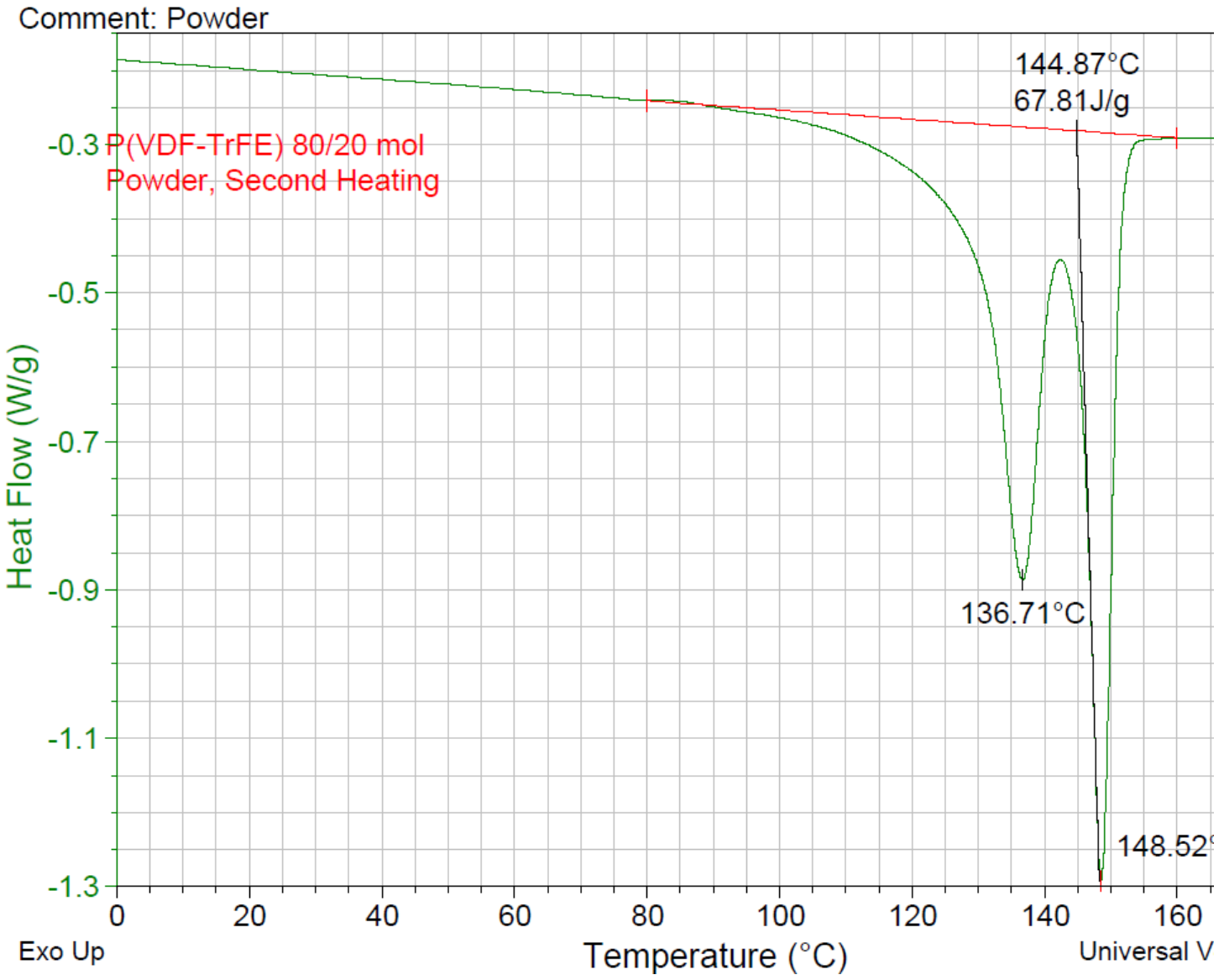
PVDF-TrFE 80/20 mol (2016 Film)



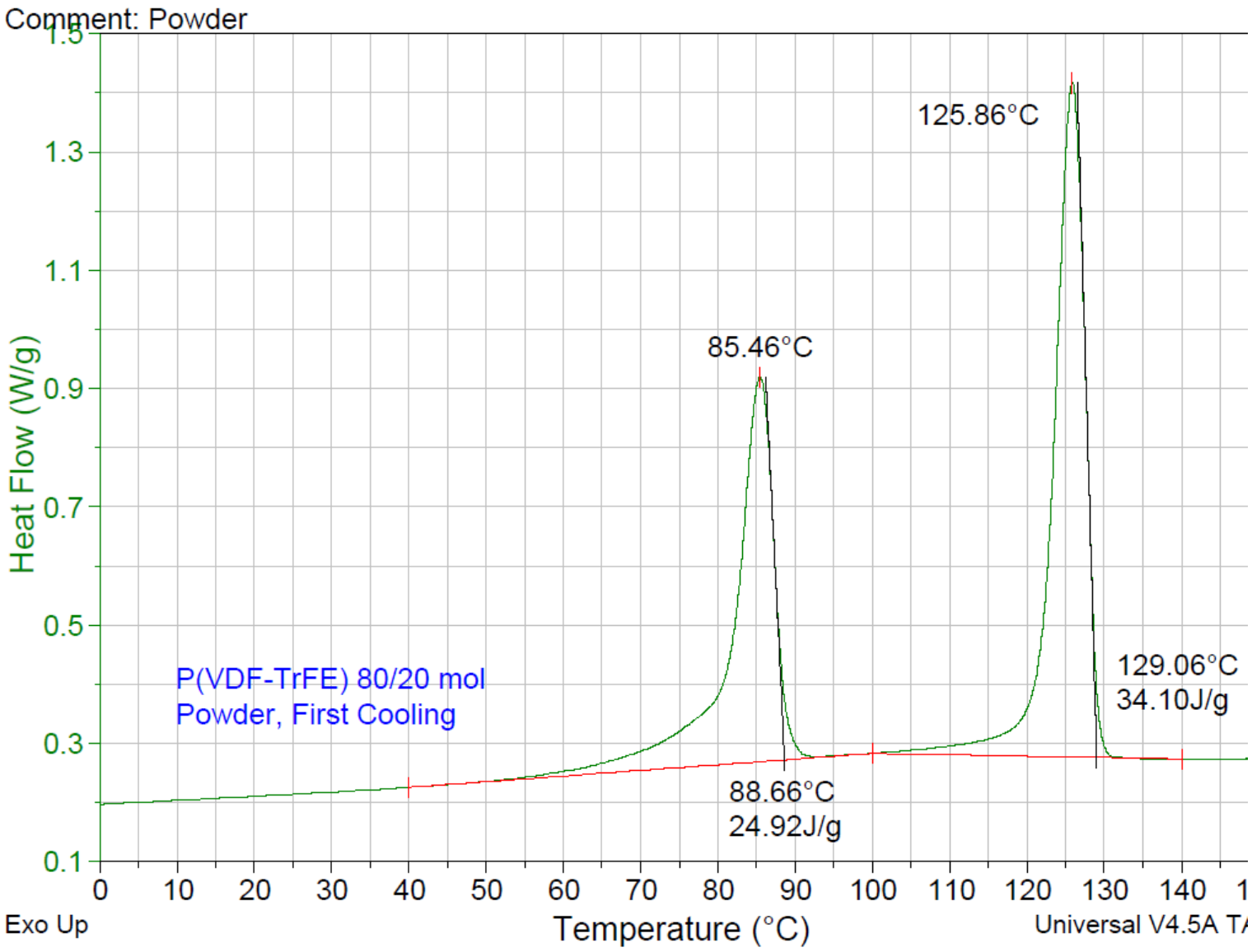
PVDF-TrFE 80/20 mol, Film



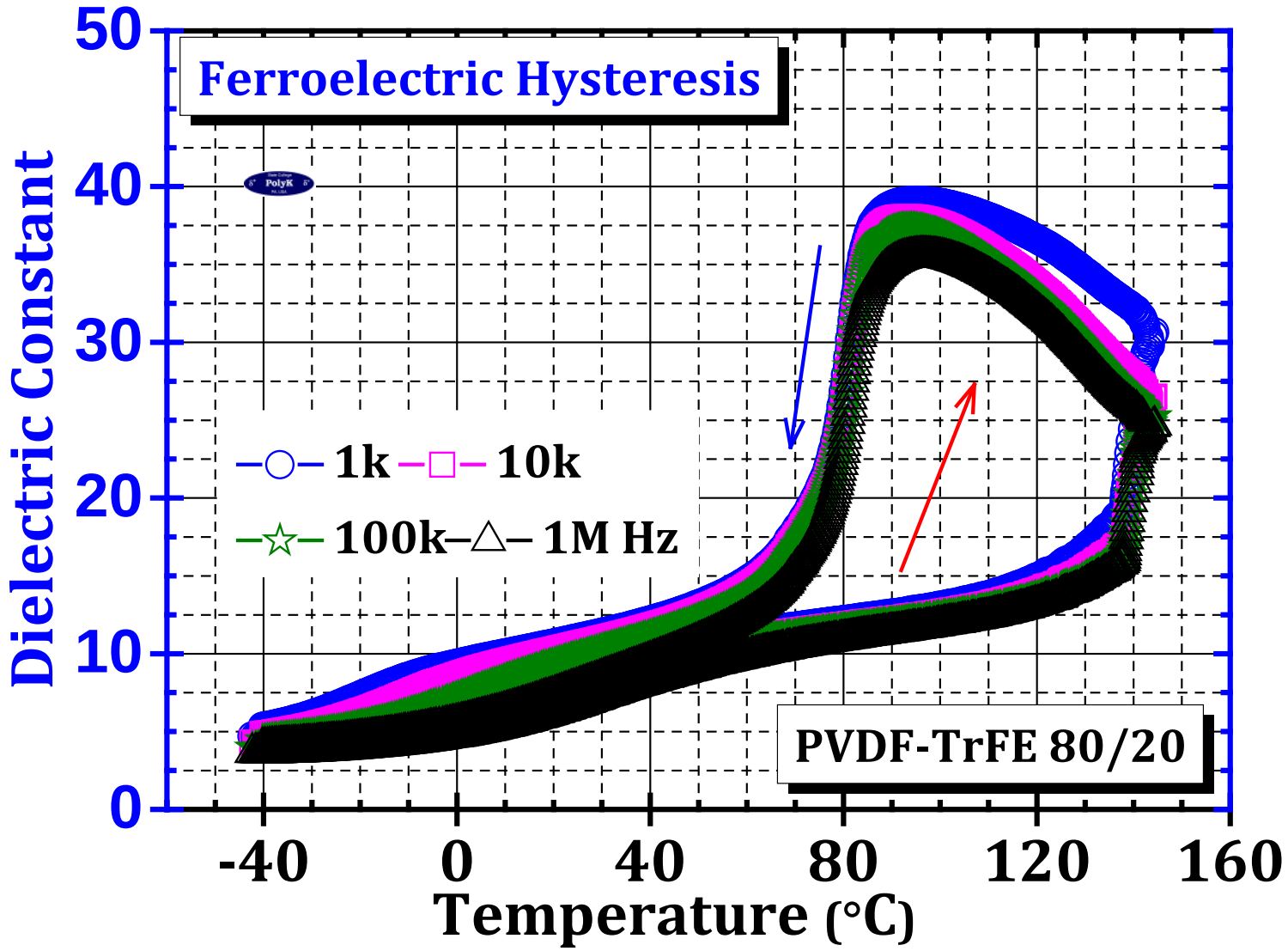
PVDF-TrFE 80/20 mol, Powder



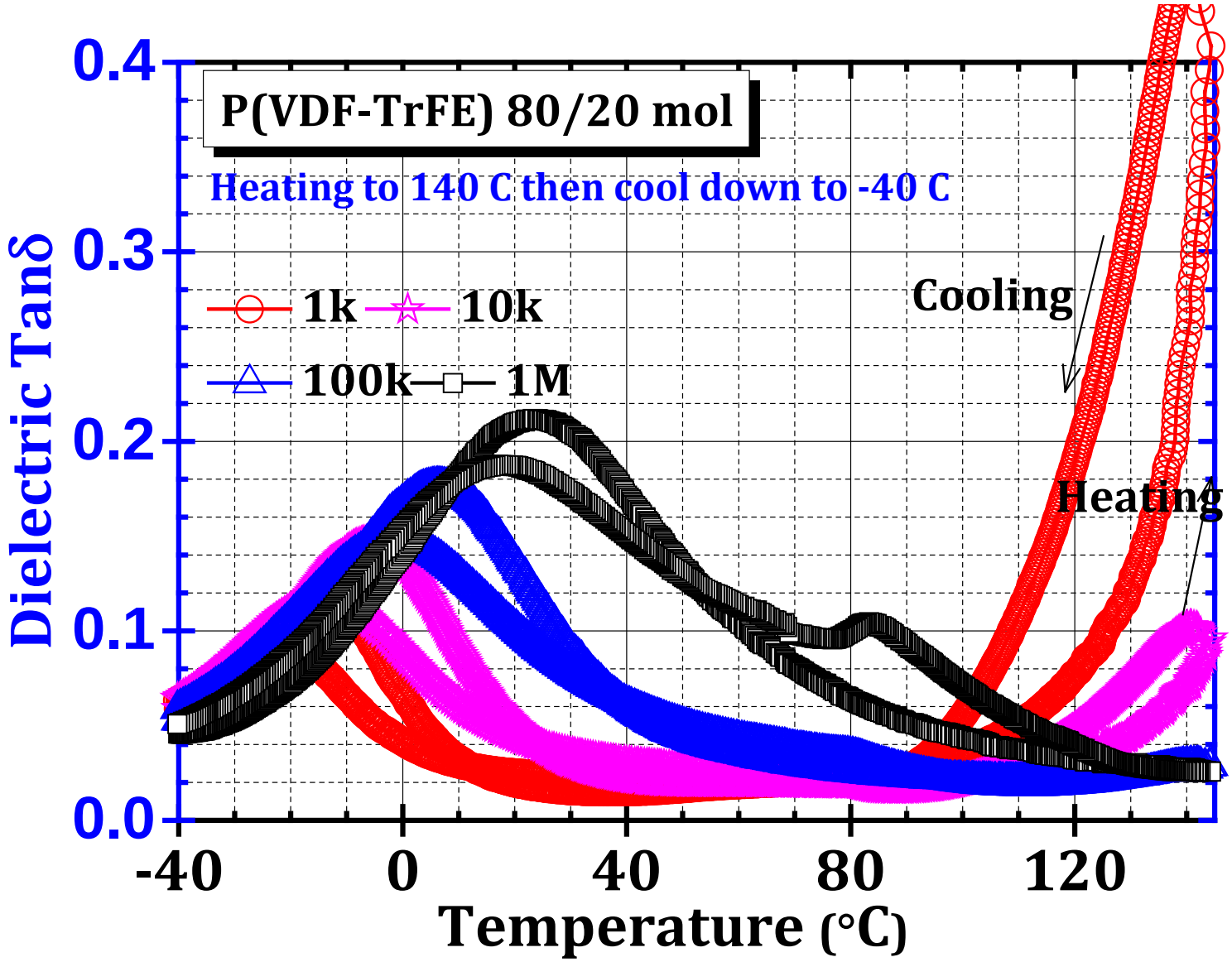
PVDF-TrFE 80/20 mol, Powder



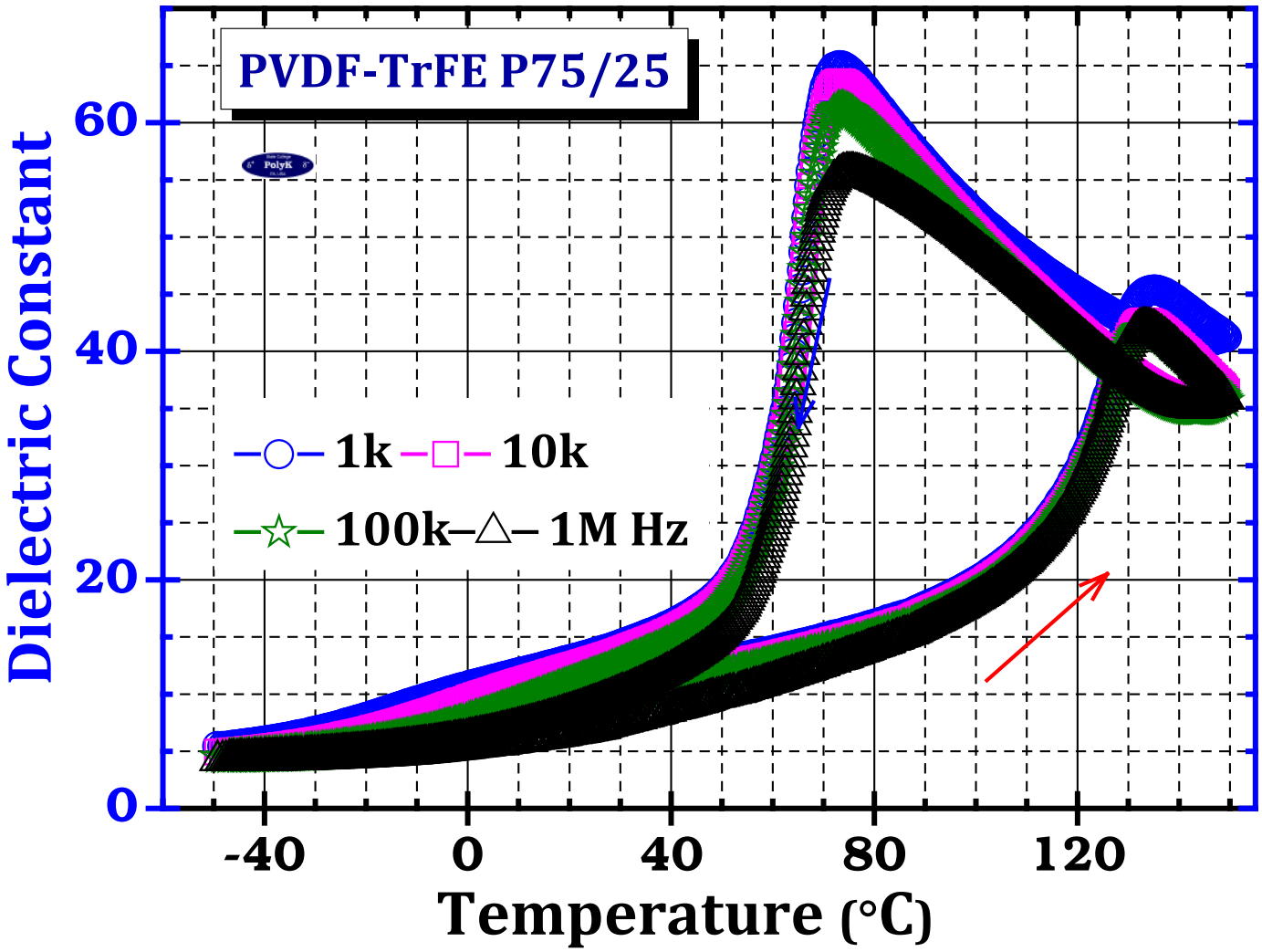
PVDF-TrFE 80/20 mol



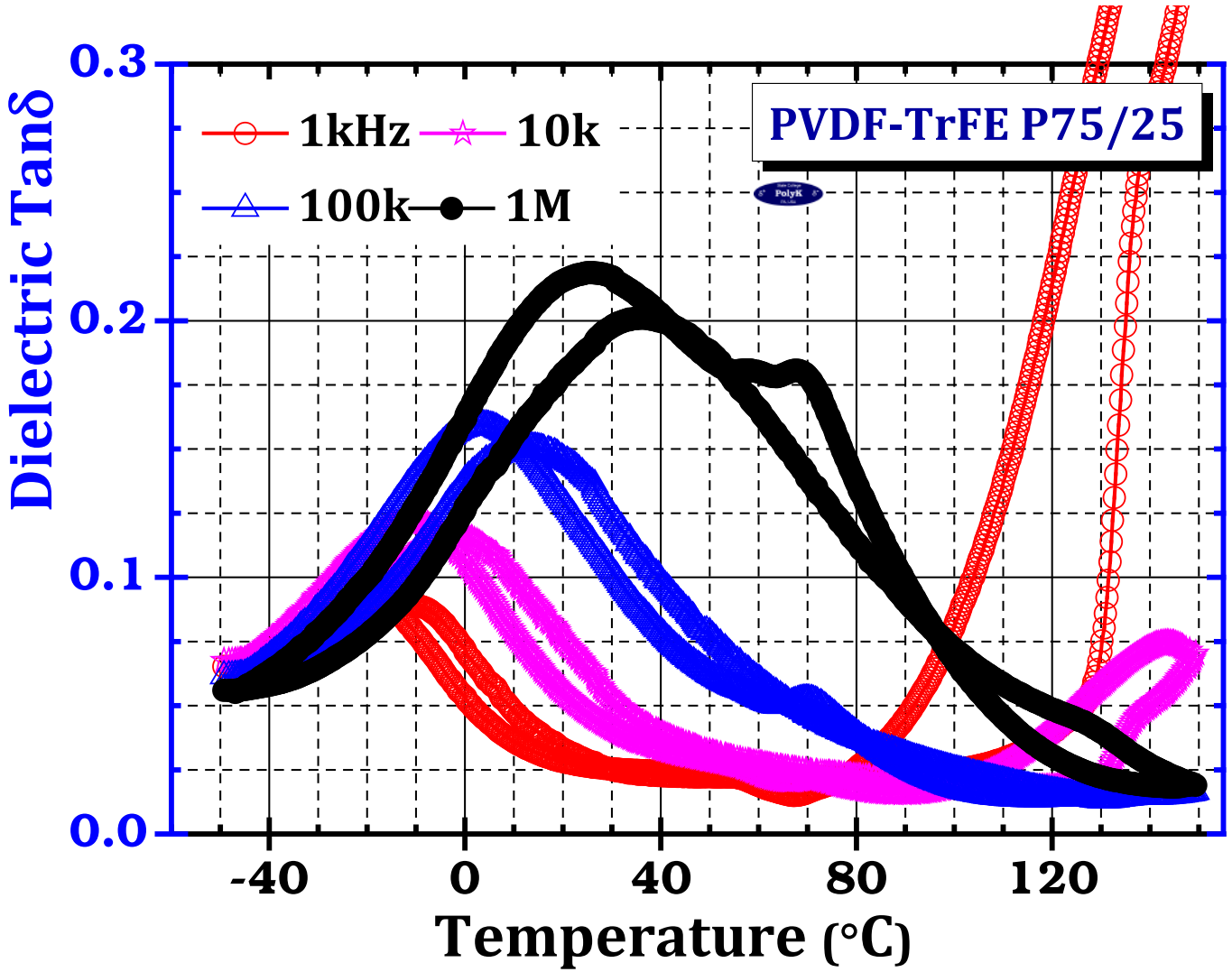
PVDF-TrFE 80/20 mol



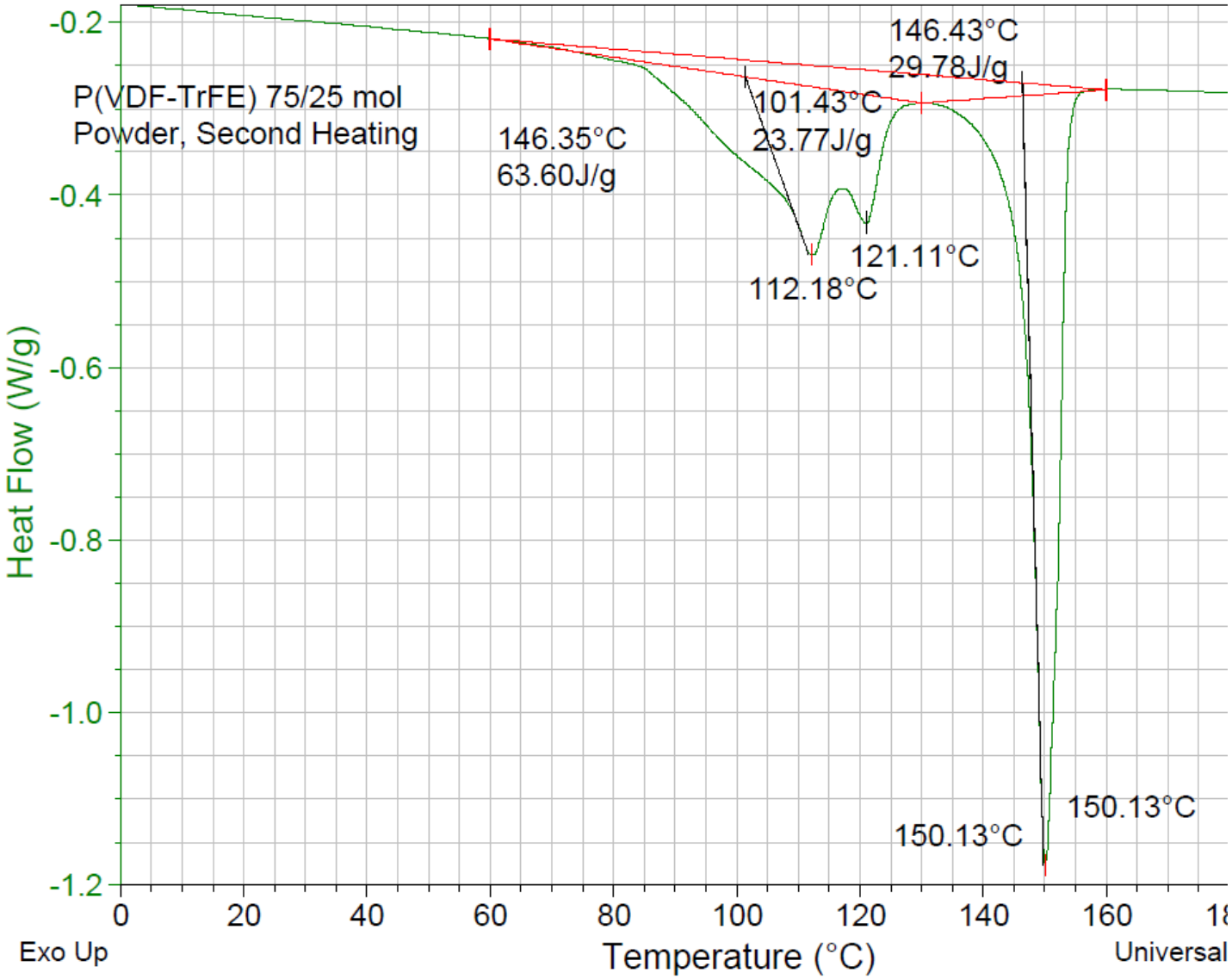
PVDF-TrFE 75/25 mol (2017, Powder)



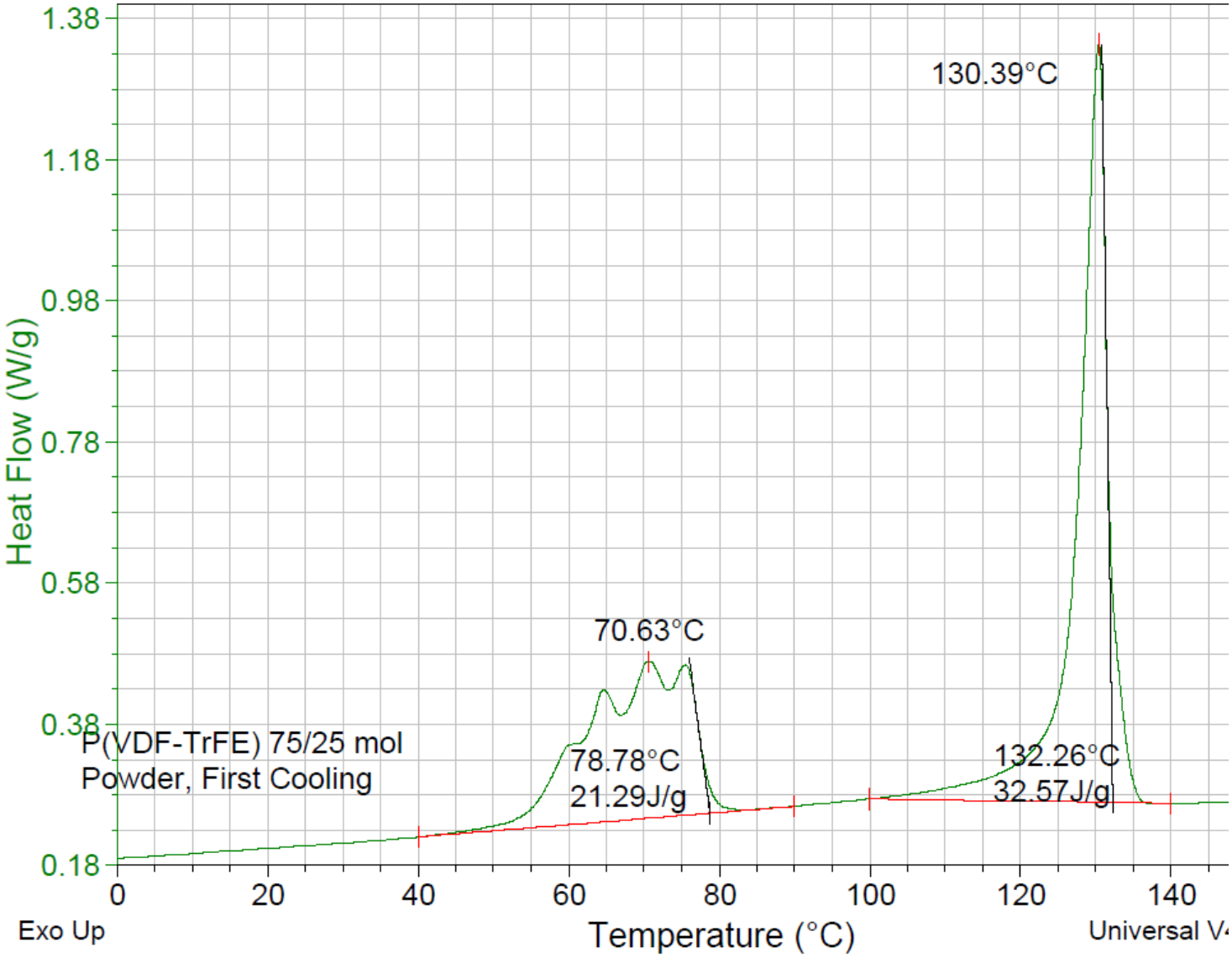
PVDF-TrFE 75/25 mol (2017, Powder)



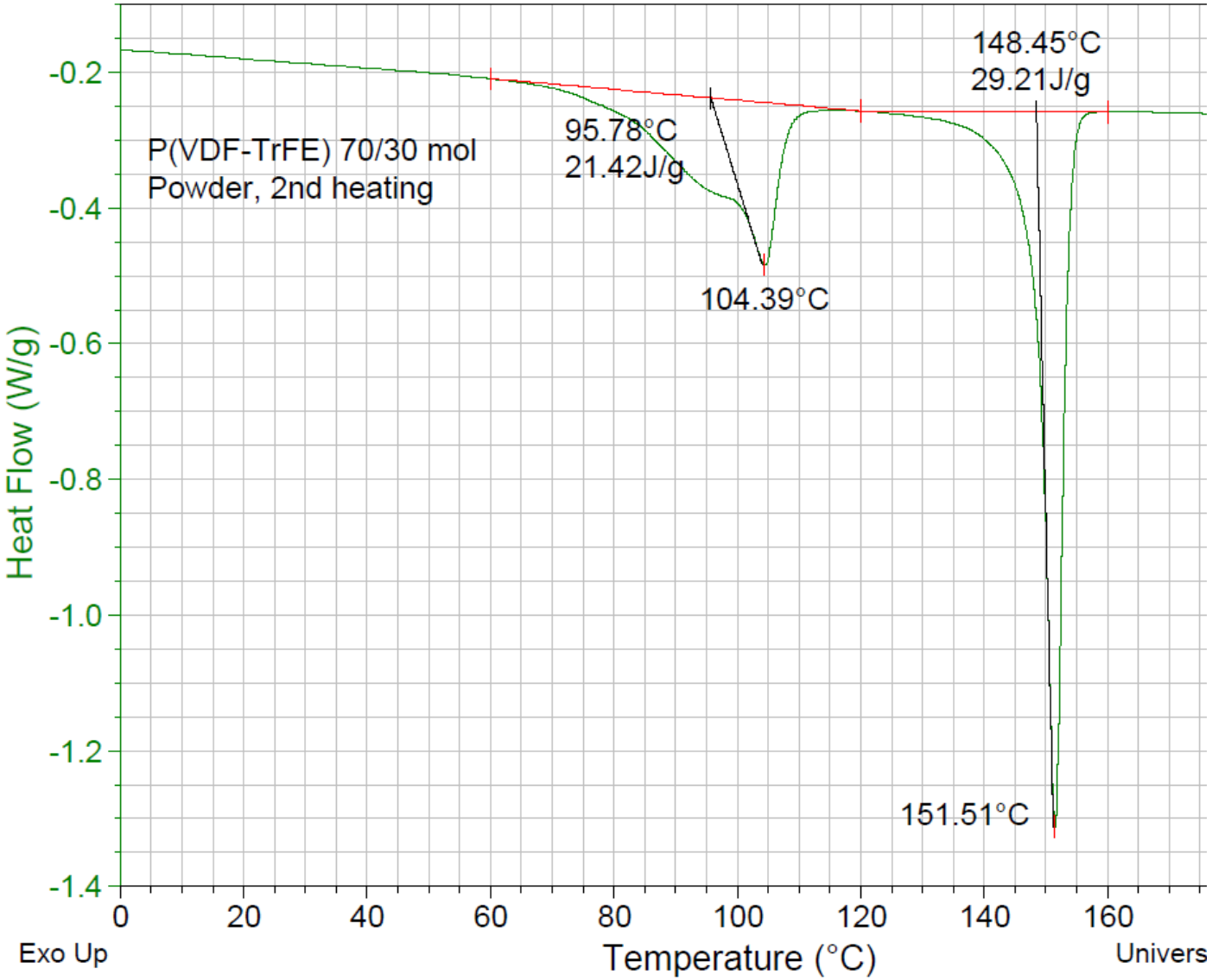
PVDF-TrFE 75/25 mol (2017, Powder)



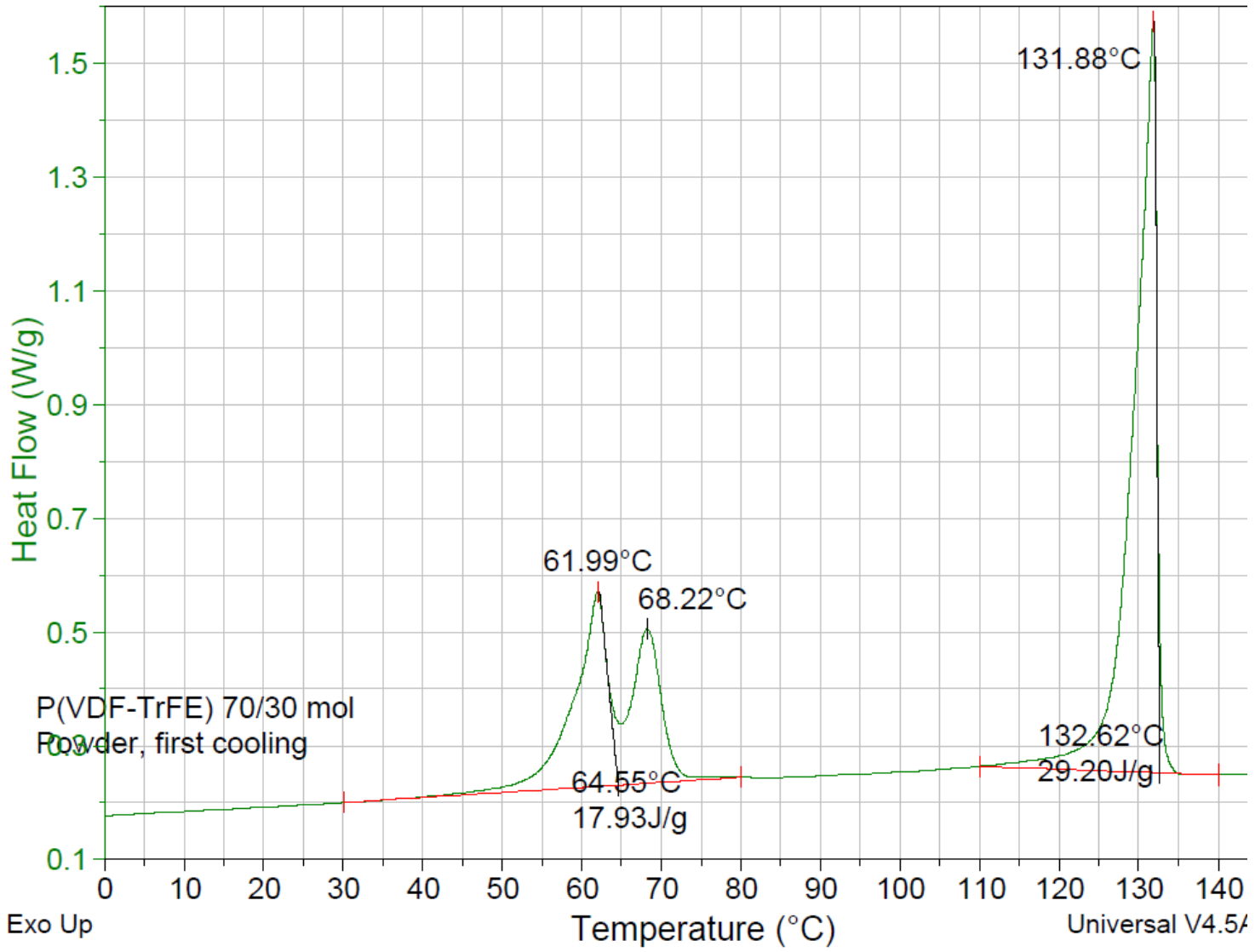
PVDF-TrFE 75/25 mol (2017, Powder)



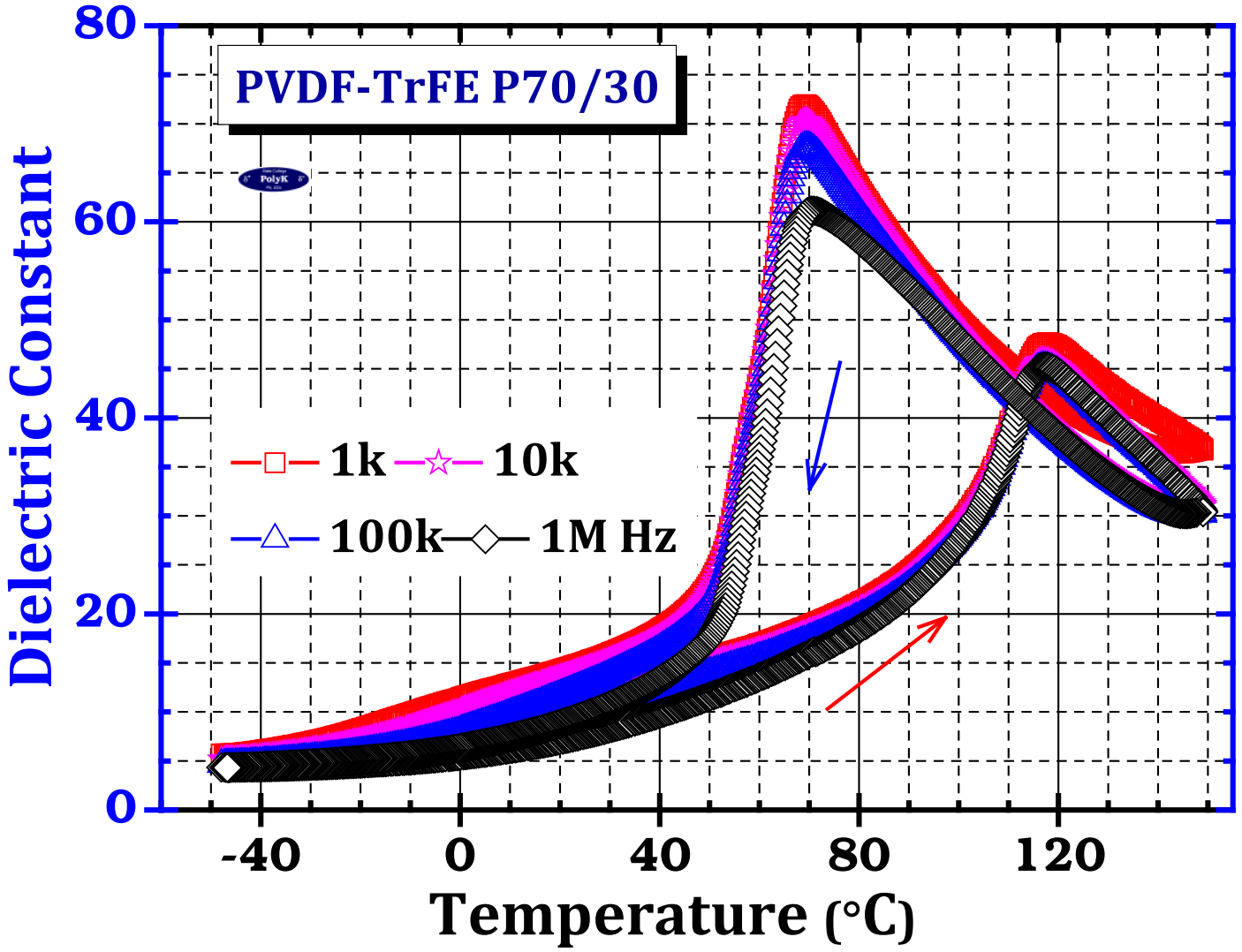
PVDF-TrFE 70/30 mol (2017, Powder)



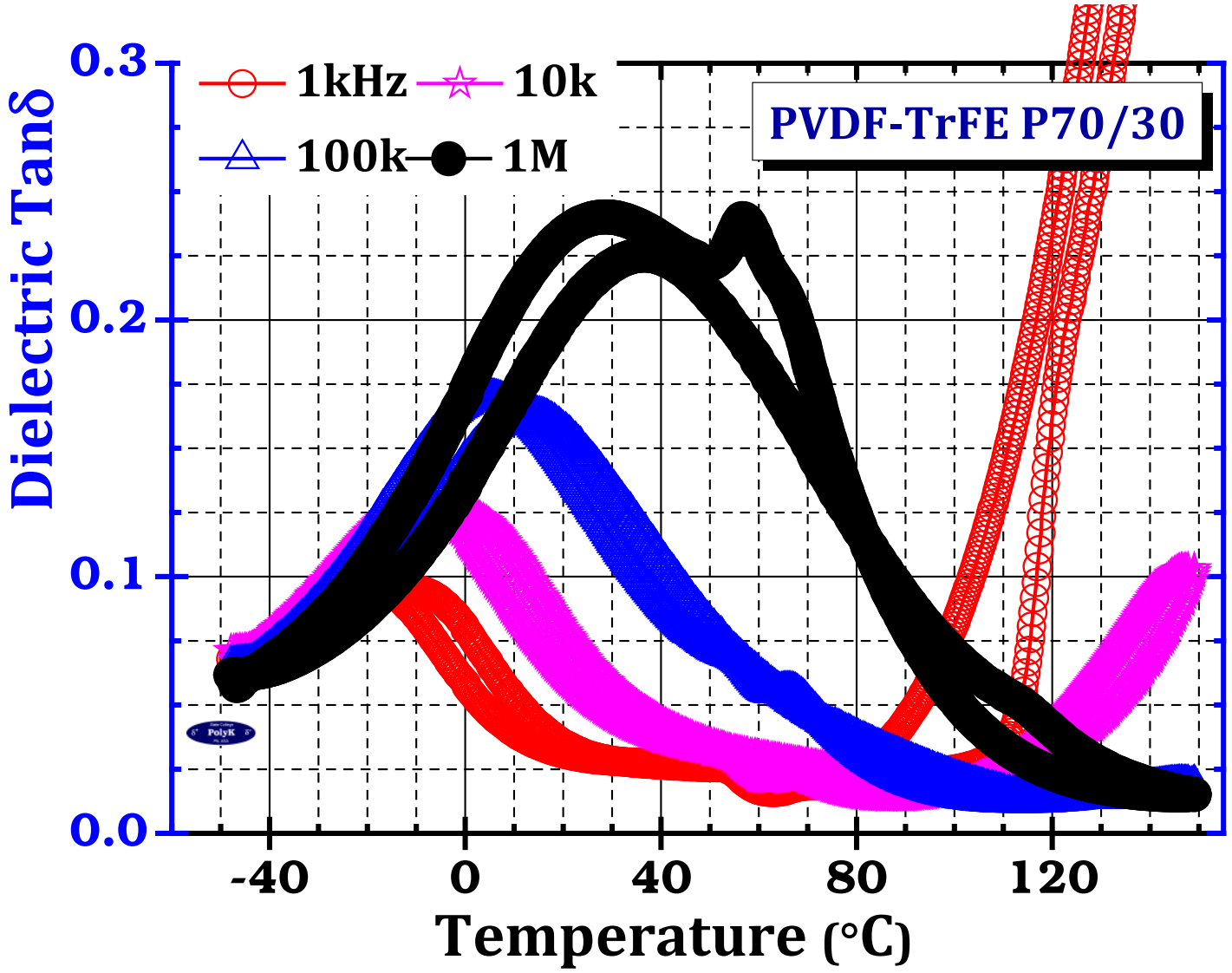
PVDF-TrFE 70/30 mol (2017, Powder)



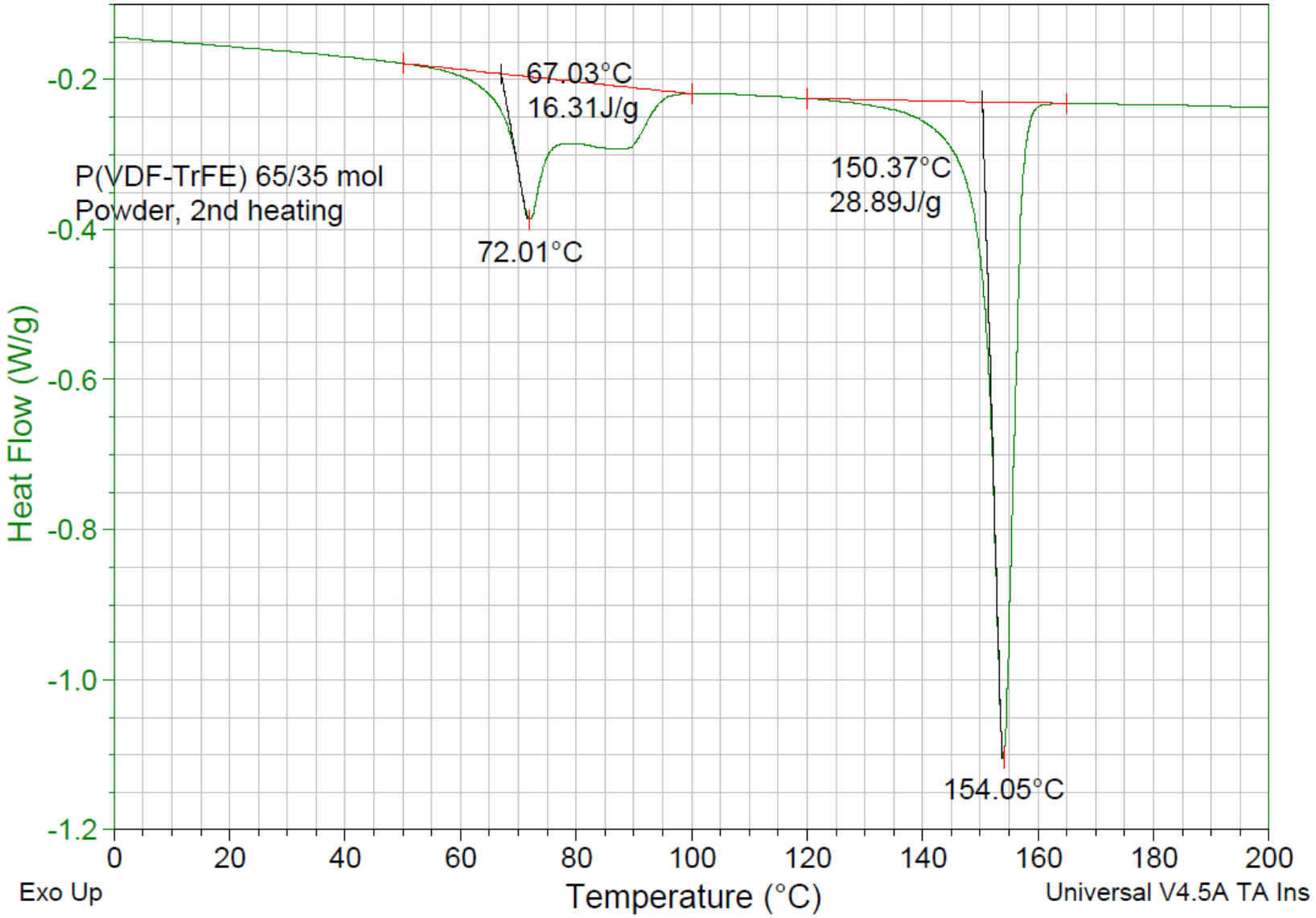
PVDF-TrFE 70/30 mol (2017, Powder)



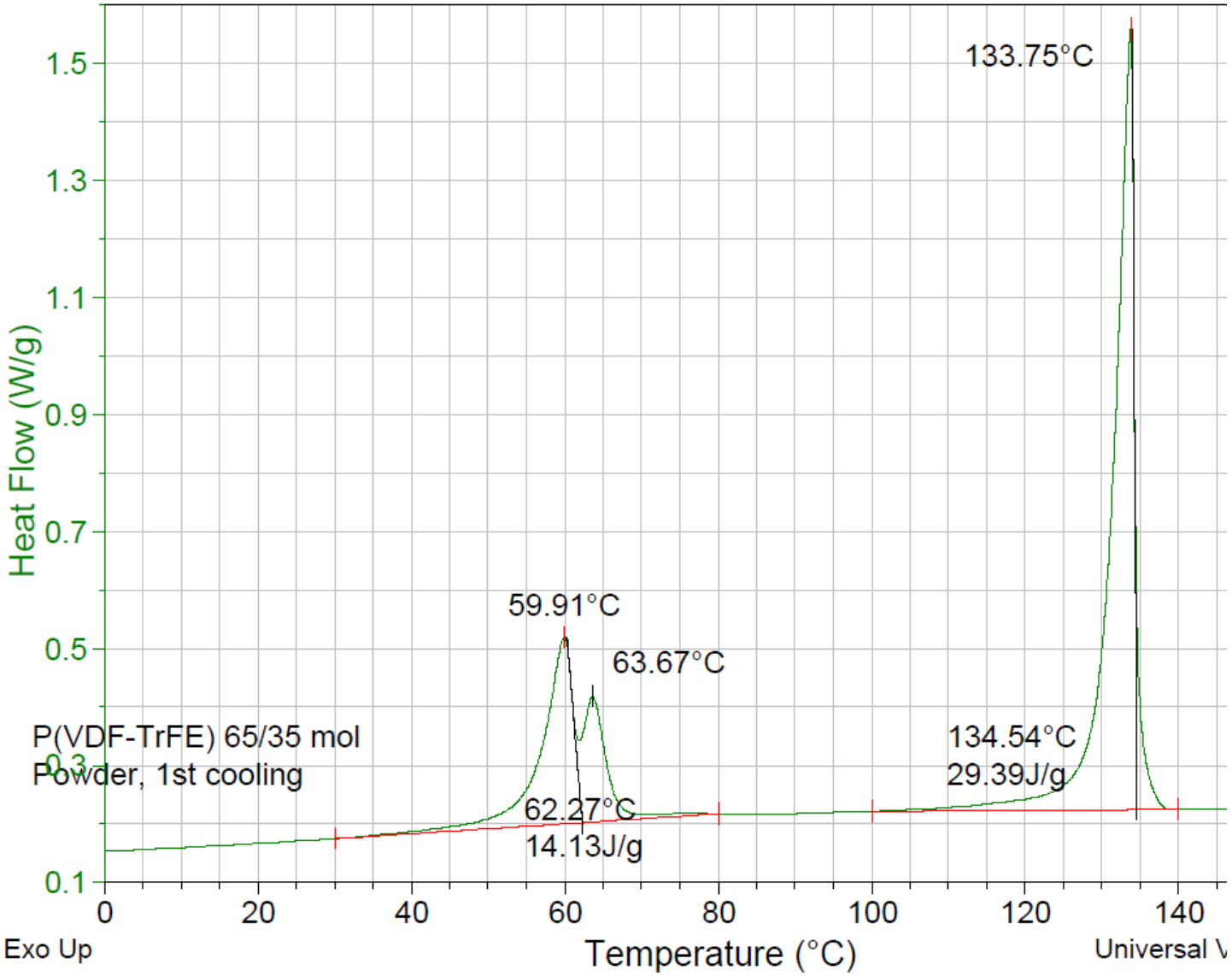
PVDF-TrFE 70/30 mol (2017, Powder)



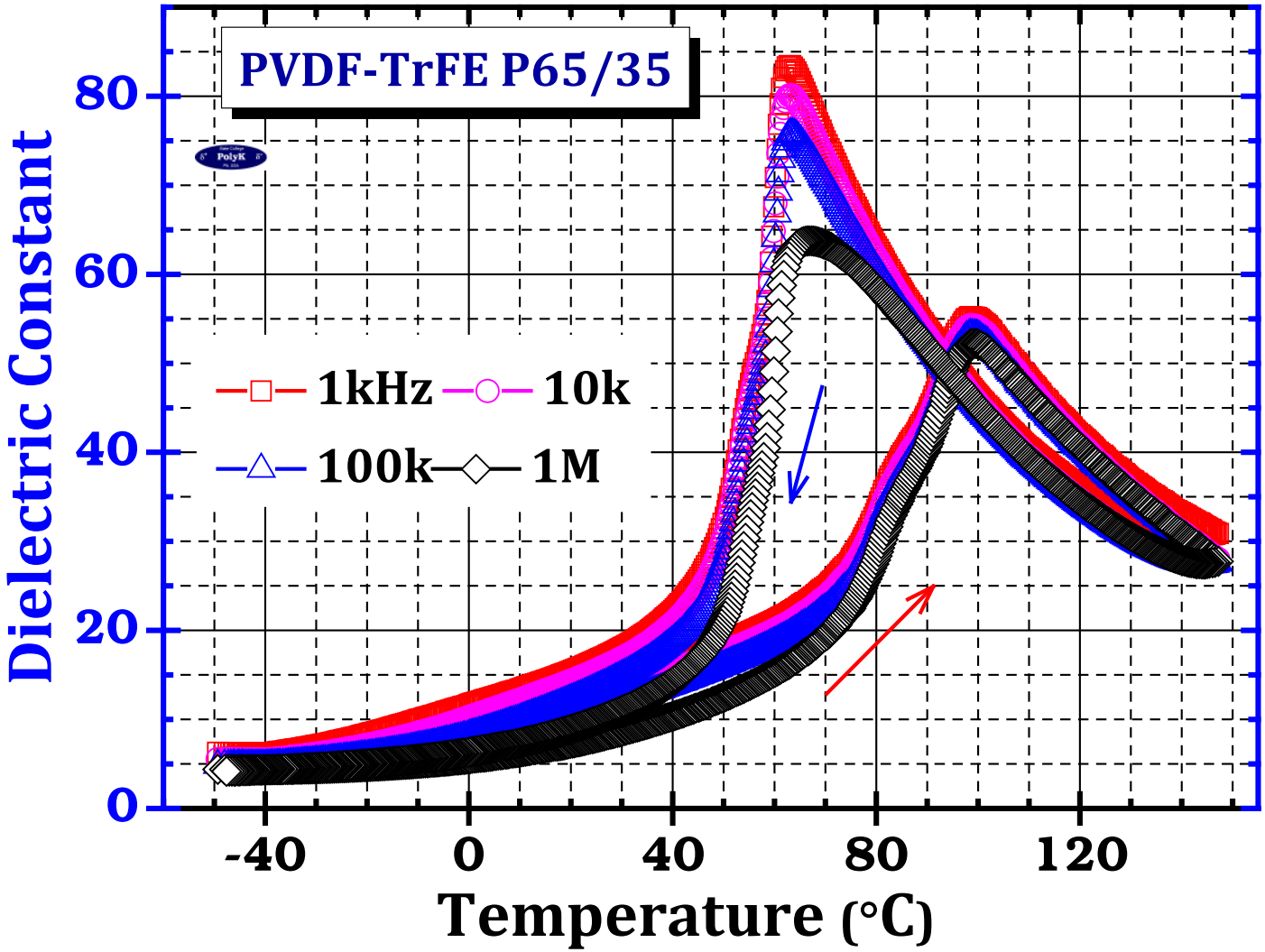
PVDF-TrFE 65/35 mol (2017, Powder)



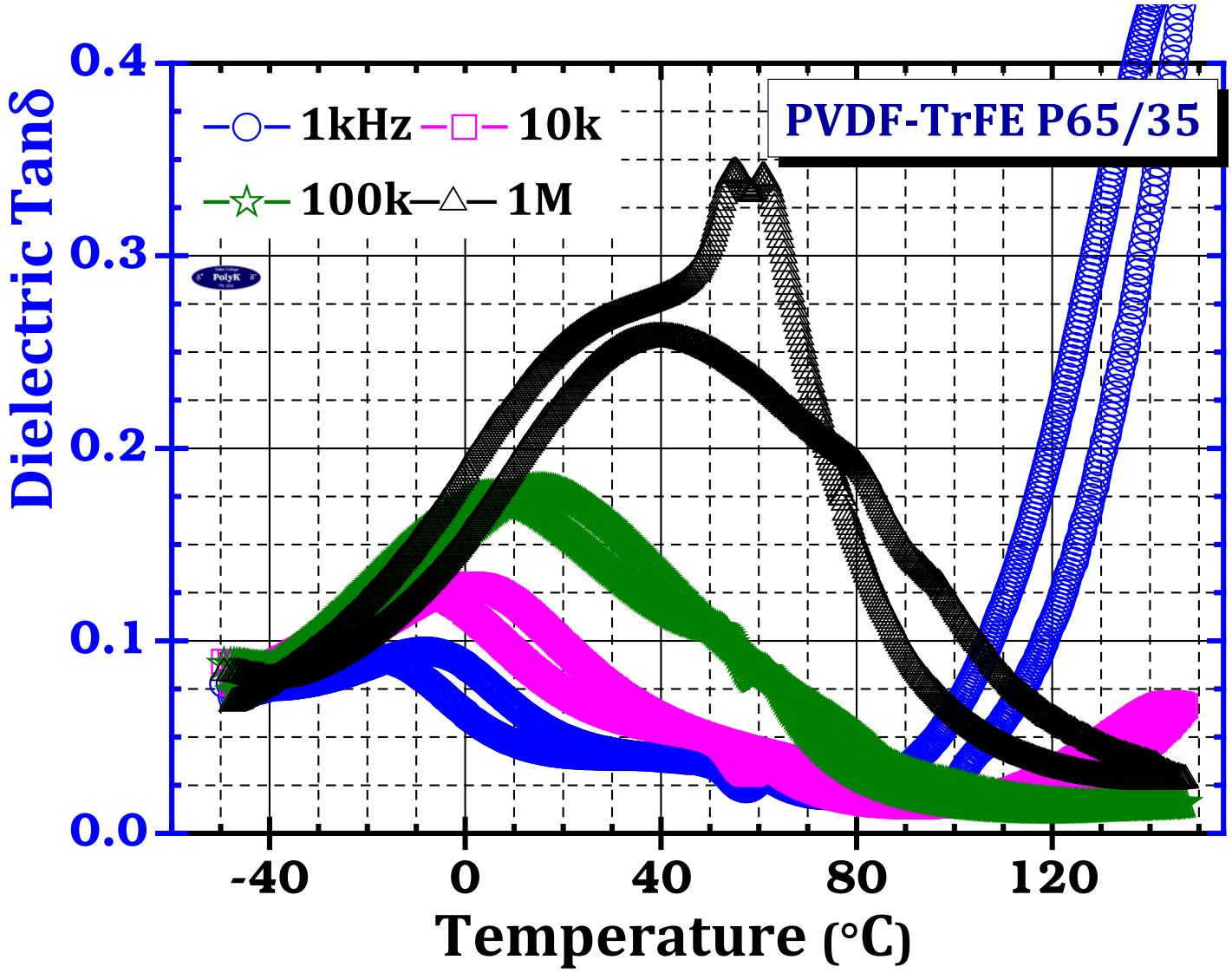
PVDF-TrFE 65/35 mol (2017, Powder)



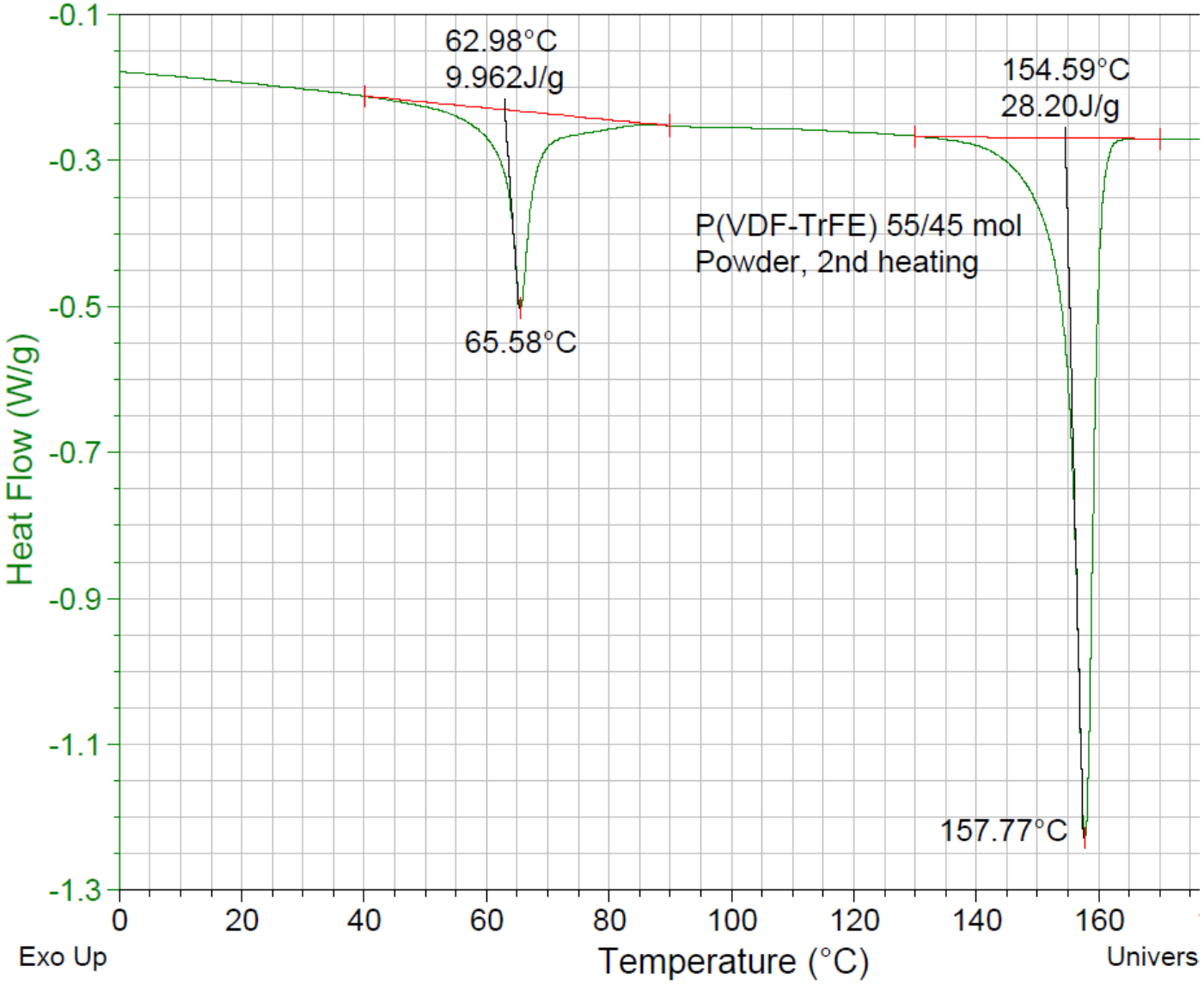
PVDF-TrFE 65/35 mol (2017, Powder)



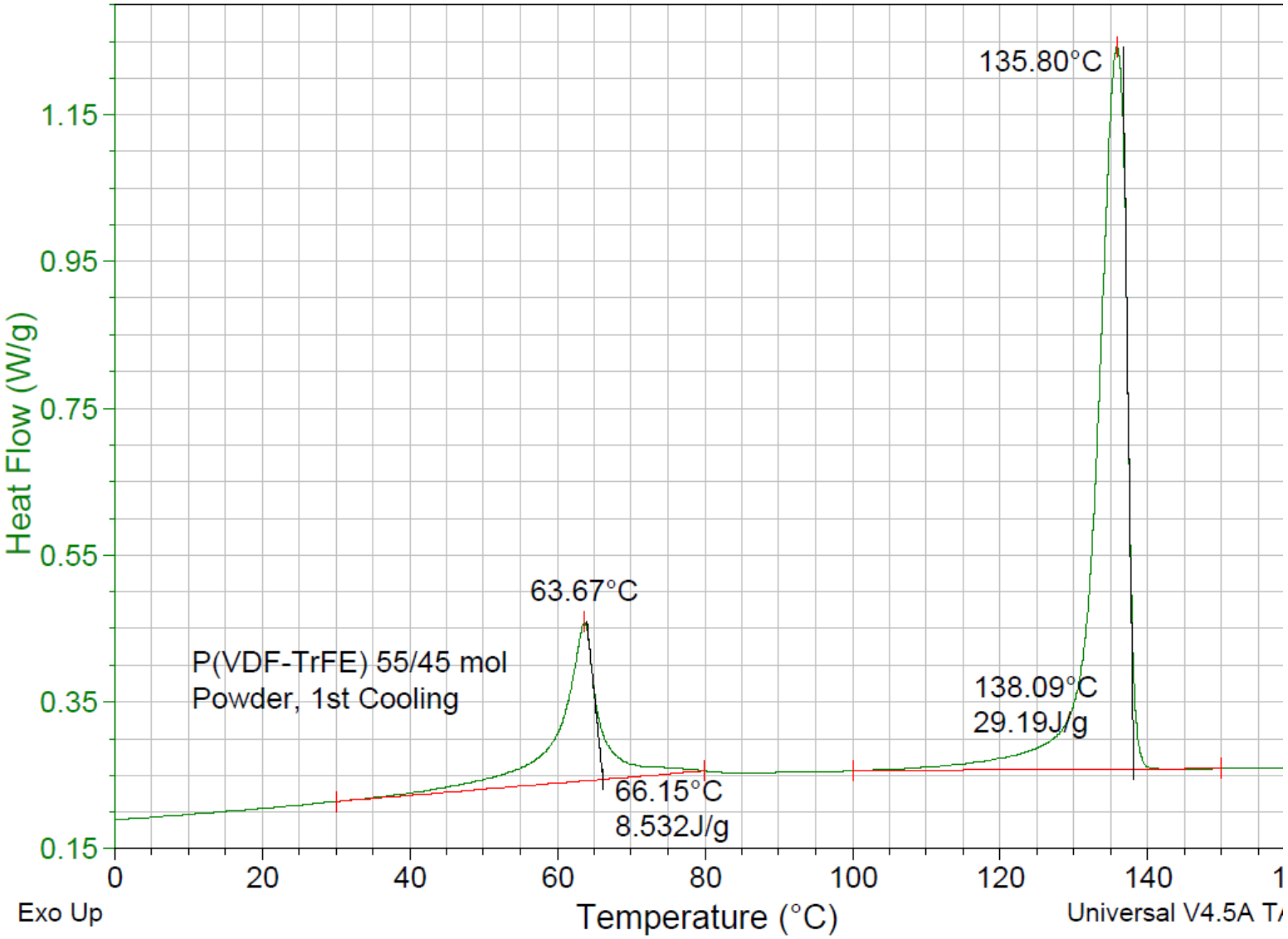
PVDF-TrFE 65/35 mol (2017, Powder)



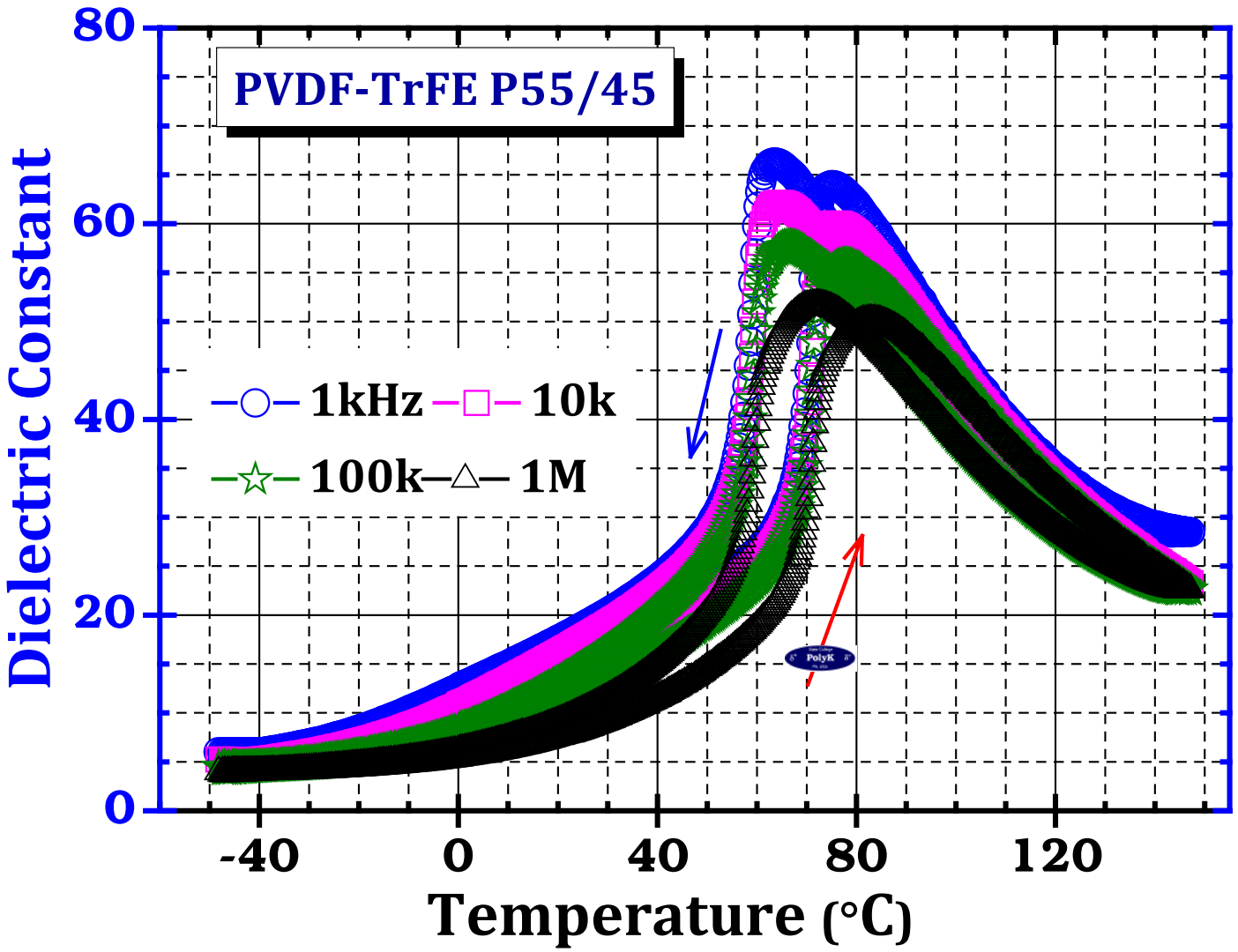
PVDF-TrFE 55/45 mol (2017, Powder)



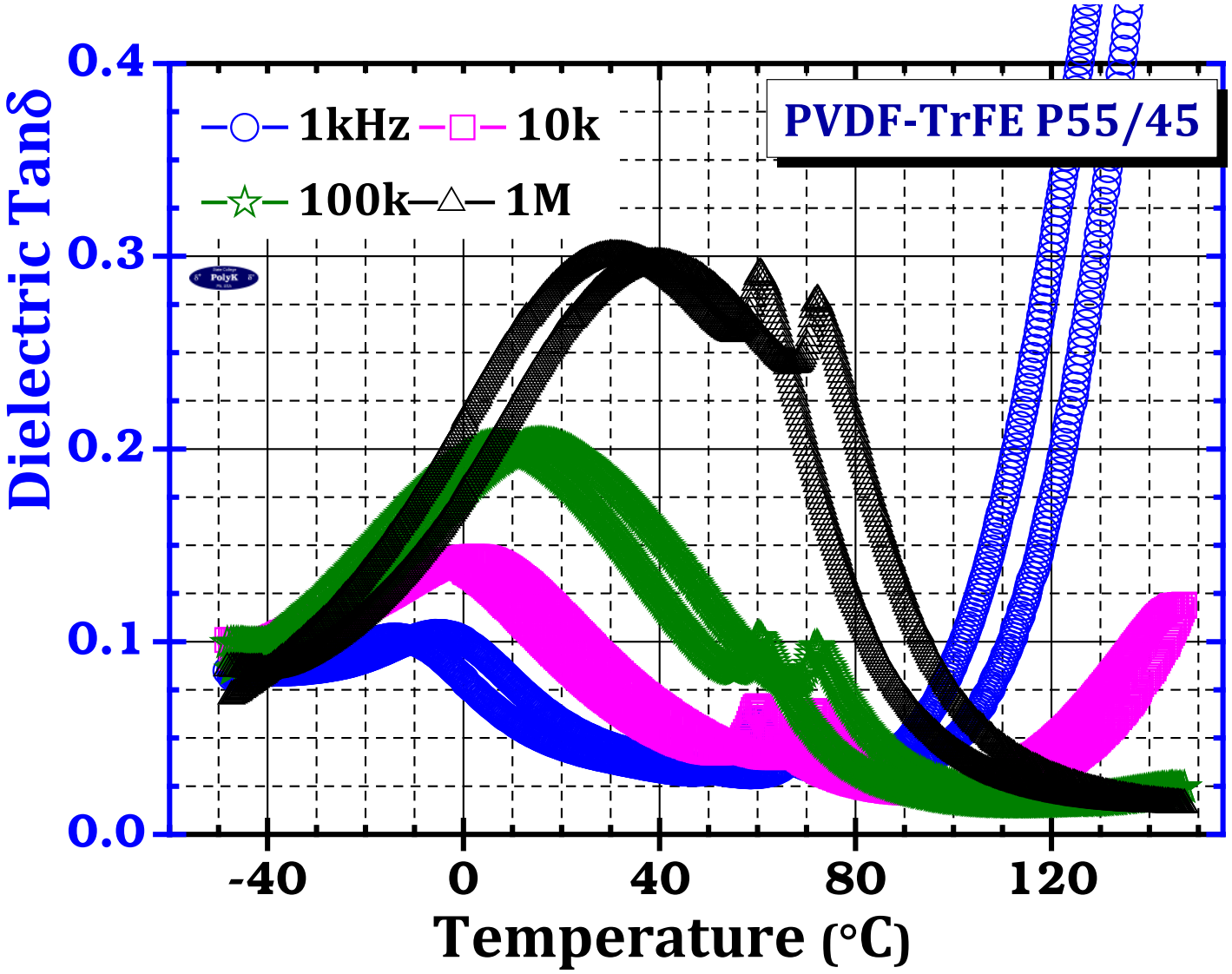
PVDF-TrFE 55/45 mol (2017, Powder)



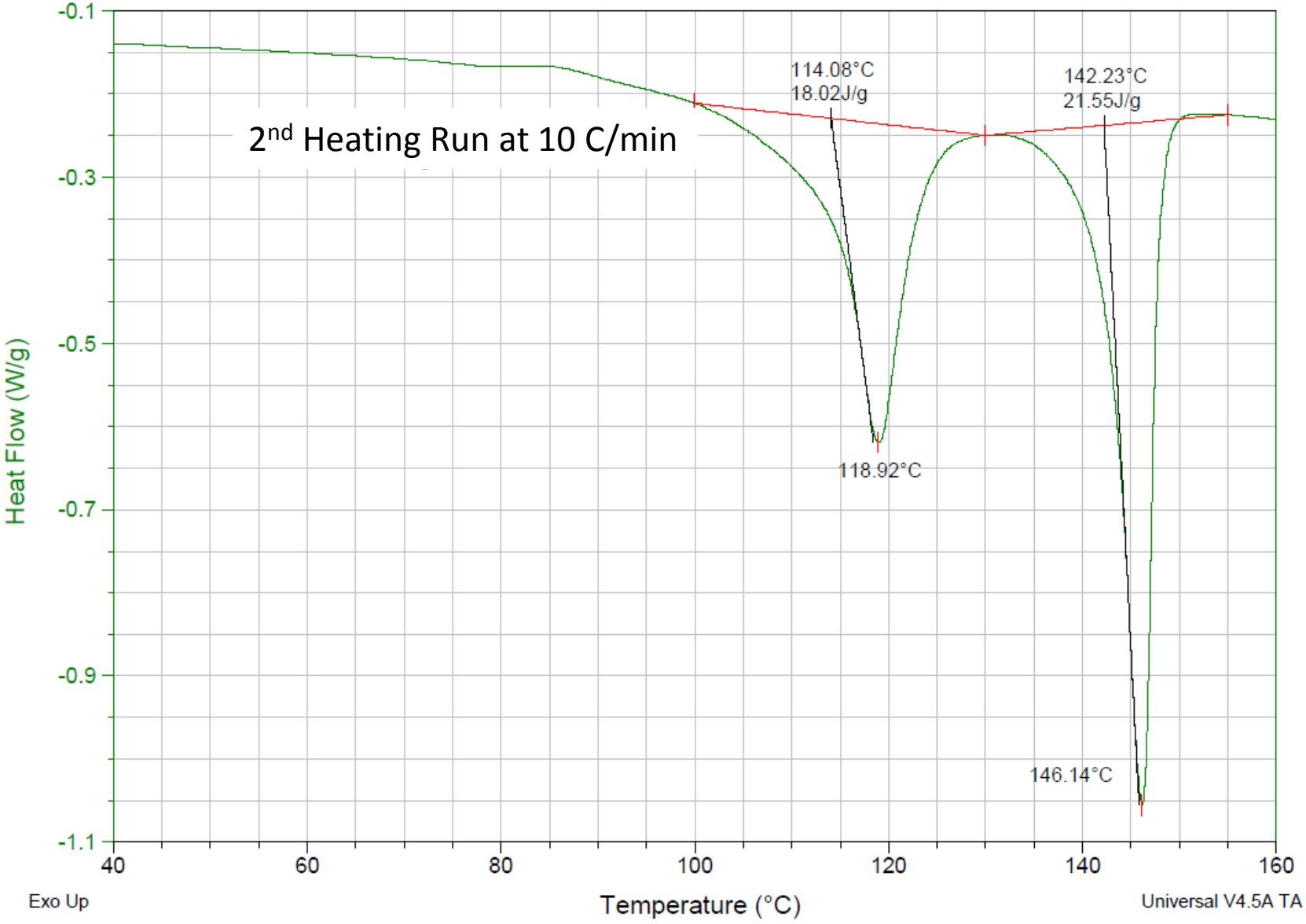
PVDF-TrFE 55/45 mol (2017, Powder)



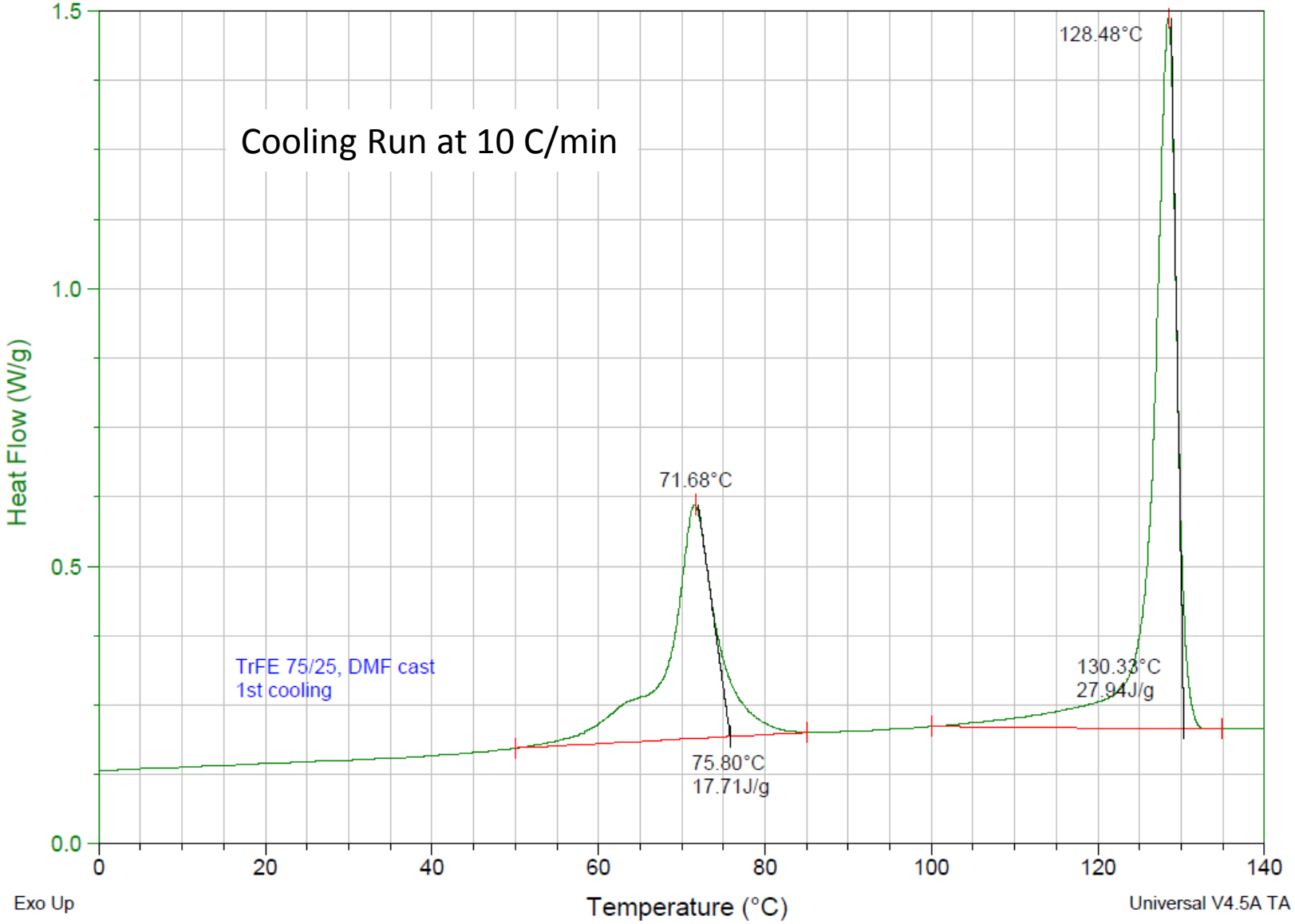
PVDF-TrFE 55/45 mol (2017, Powder)



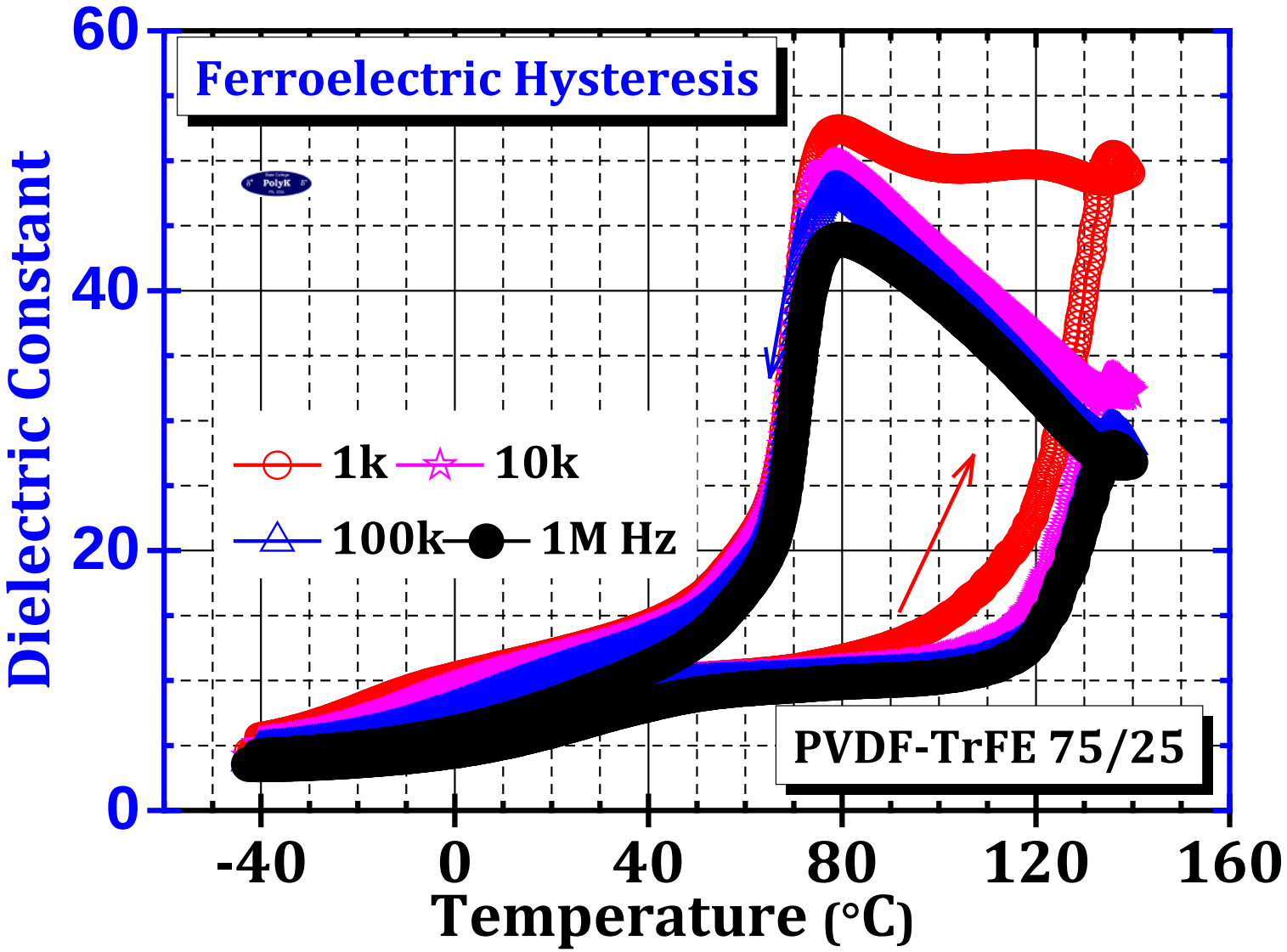
PVDF-TrFE 75/25 mol (old stock, Pellet)



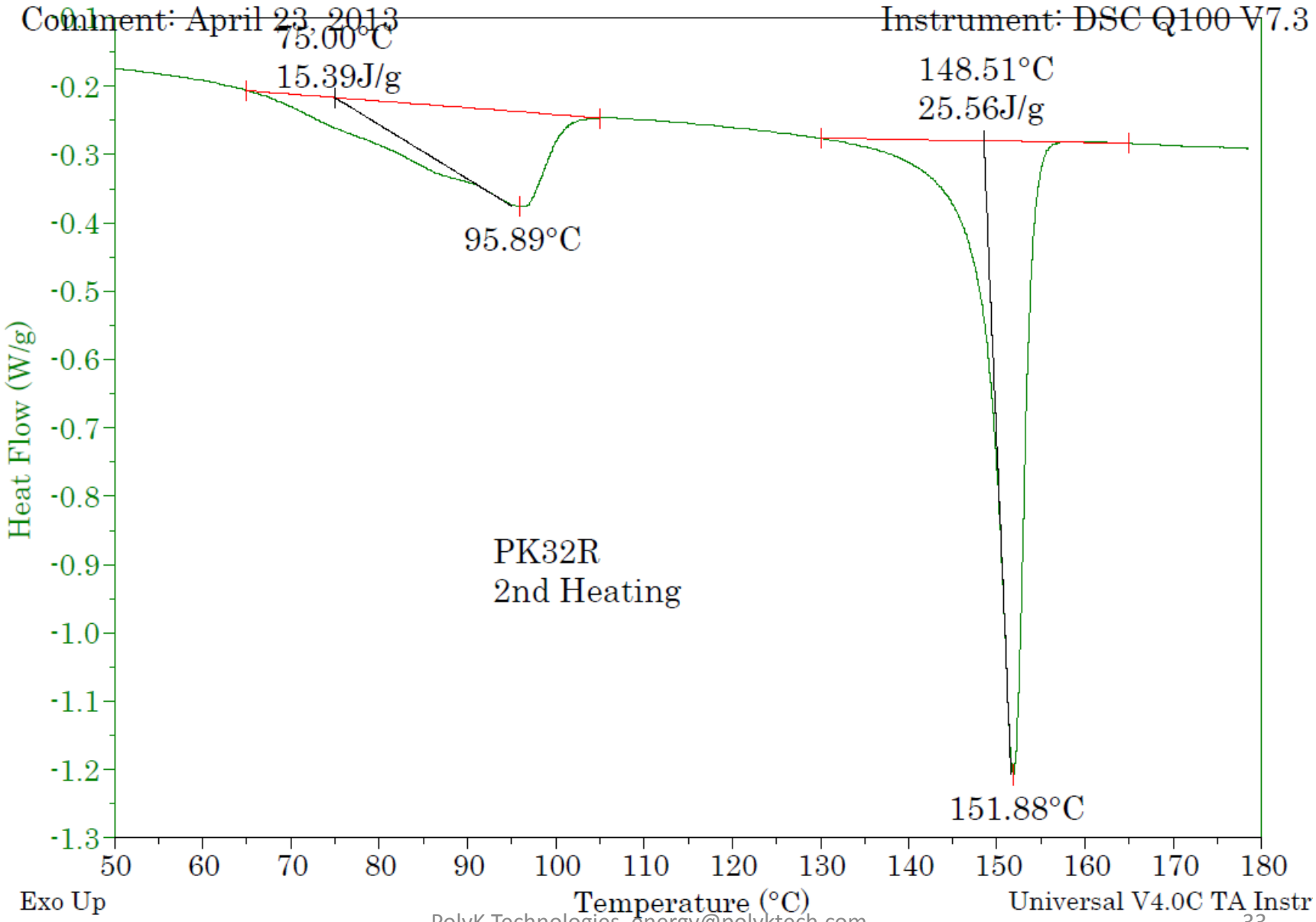
PVDF-TrFE 75/25 mol (old stock, Pellet)



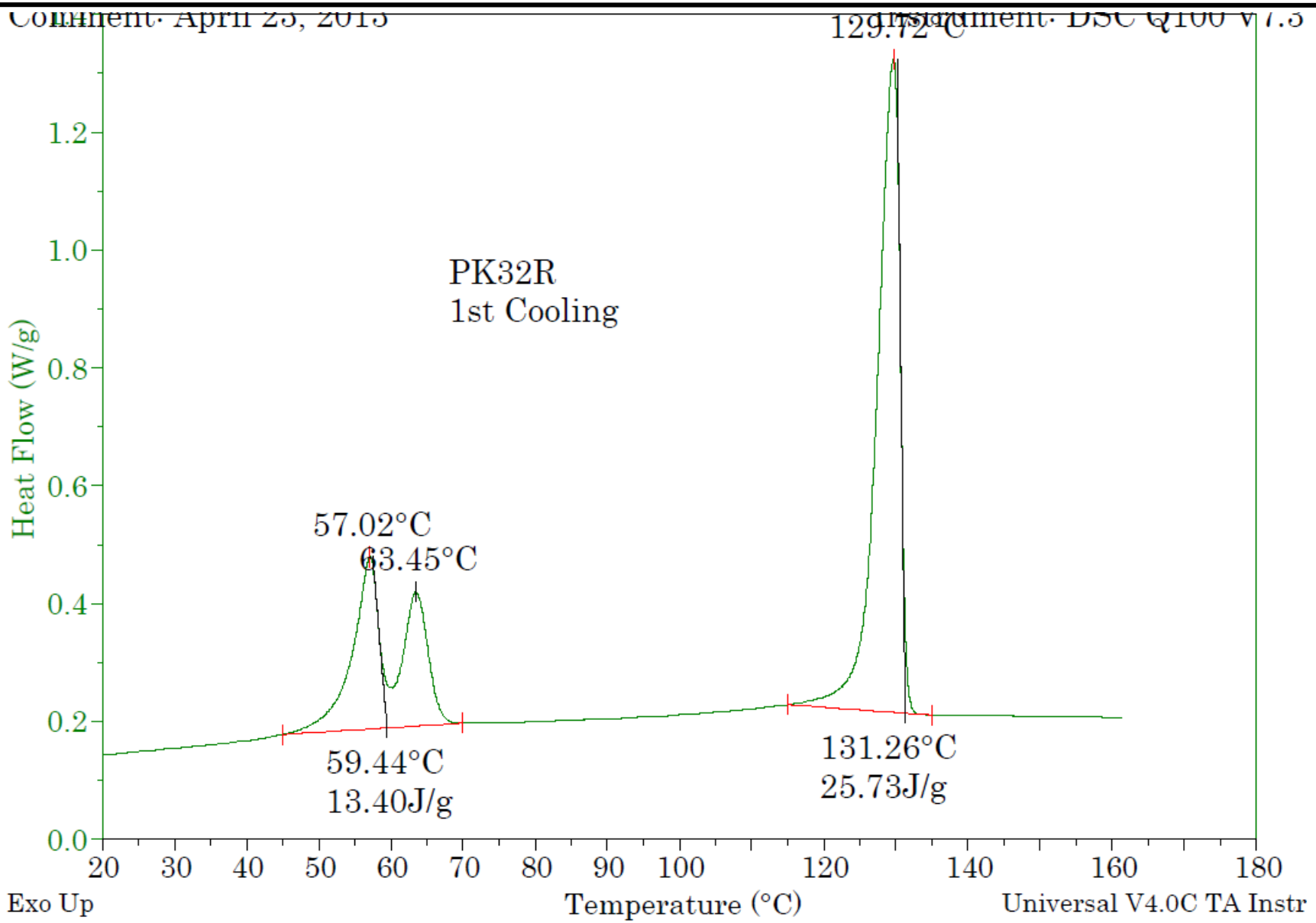
PVDF-TrFE 75/25 mol (old stock, Pellet)



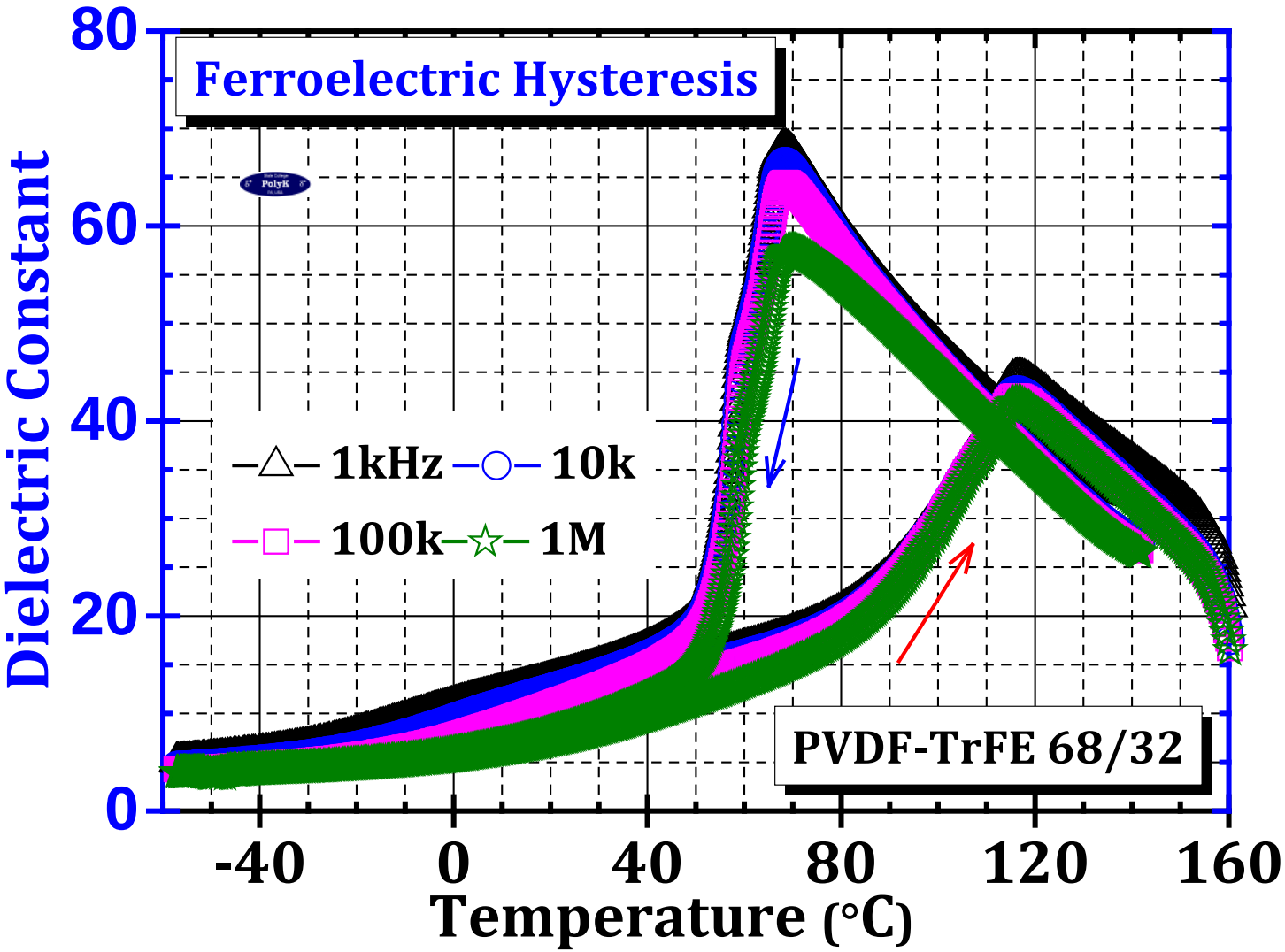
PVDF-TrFE 68/32 mol



PVDF-TrFE 68/32 mol



PVDF-TrFE 68/32 mol



Specialized in high voltage dielectric and ferroelectric polymers, free-standing ultrathin film, low cost test instrument, and manufacturing machines.

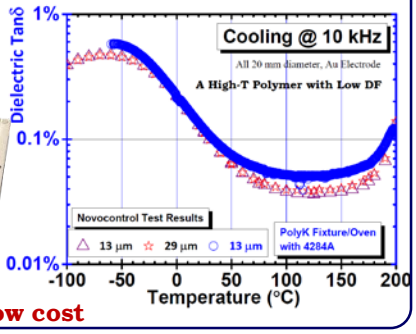
1. Over 20 different PVDF, P(VDF-HFP), P(VDF-CTFE), P(TFE-HFP-VDF) polymers from different global suppliers.
   - Solvent cast, extruded, or oriented film
2. High temperature P(TFE-VDF) copolymers with melting temperature >250 C and dielectric constant > 8.
3. Ferroelectric P(VDF-TrFE) copolymer, high dielectric constant P(VDF-TrFE-CTFE) and P(VDF-TrFE-CFE) terpolymer resin and film
4. Low-cost test instrument designed for soft polymers: dielectric vs temperature and frequency, polarization loop, dielectric breakdown strength, leakage current, TSDC, pyroelectric, capacitor charge-discharge
5. Film production and orientation machine: low cost roll-to-roll with quality comparable to machines made in Japan and Germany

PolyK *Specialized in high voltage polymer dielectric, ferroelectric, and smart materials and their applications (capacitors, sensors, actuators, energy harvesting)*

δ⁺ PolyK δ⁻

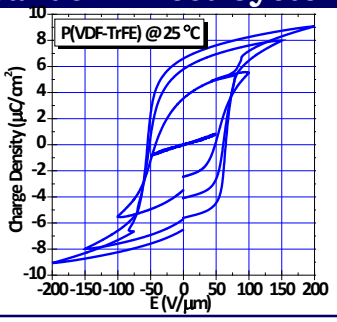
Low-Cost Turnkey Dielectric Test System

Capacitance (dielectric constant) and **loss tanδ** vs. frequency and temperature: Integrate Agilent 4284A (E4980A) Precision LCR meter with Sun chamber (w/ liquid nitrogen cooling) with LabView Control Program. Multiple specimens. Up to 250 °C, DF accuracy<0.1%. **Cost <$25K**



Modular design: Can expand to TSDC with Low cost

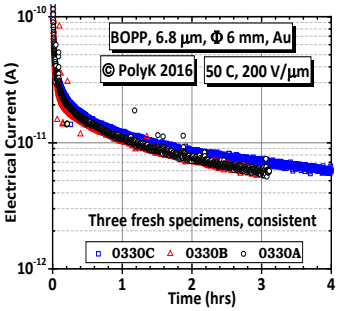
Polarization Loop & Dielectric Breakdown Test System

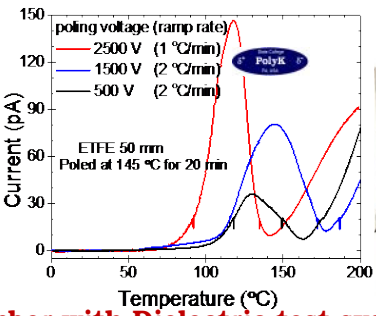


Including a used Trek amplifier for <$9,999. Sample test fixture for soft polymer films. Software can directly provide charged and discharged energy density, and perform lifetime test with a summary file of energy density vs. test cycles.

High Voltage Leakage Current, TSDC, & Pyroelectric

- Test voltage >10 kv
- Temperature: -150 °C to 300 °C
- High sensitivity, leakage current accuracy < 1 pA
- Integration of multi-mode measurements: TSDC, pyroelectric & leakage current
- Spring-loaded electrode to maintain a necessary minimum force to avoid damage to thin or soft specimen

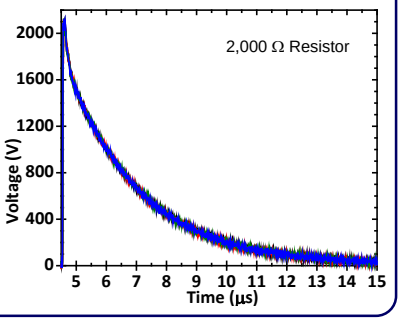




Modular design: share chamber with Dielectric test system

Capacitor Charge-Discharge Test System

- Directly measure the discharge speed and energy of capacitive samples at speed of 100 ns
- Voltage >15 kV
- Capacitance: 10 pF to >1 mF
- Computer control, capable of life-time cycle test



Current Customers

PENNSTATE

Georgia Tech

Università di Cagliari

UNIVERSITY OF WOLLONGONG AUSTRALIA

จุฬาลงกรณ์มหาวิทยาลัย Chulalongkorn University

NANJING UNIVERSITY OF TECHNOLOGY

SIAT

State College, PA, USA; admin@polyktech.com Cell Phone: +1(518)605-6897

Piezoelectric, Ferroelectric, Pyroelectric & Electroactive Polymer Kit: P(VDF-TrFE)

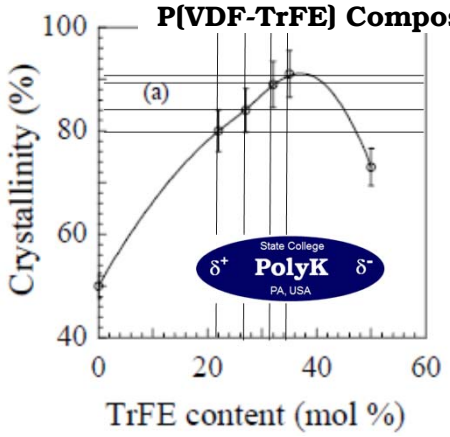
For R&D in high energy density capacitor, piezoelectric, pyroelectric, electrocaloric ECE, & electroactive polymer EAP. Include **20 grams** of each of **Seven** typical polymer resins based on P(VDF-TrFE).

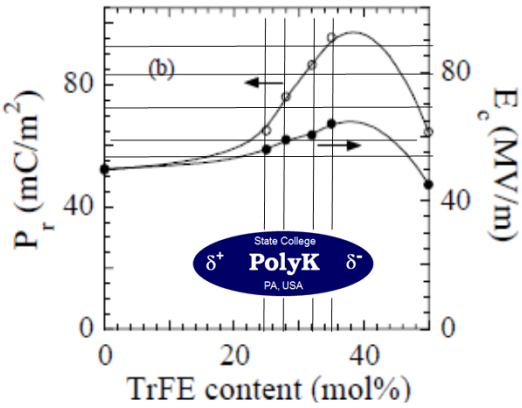
1. P(VDF-TrFE) 80/20 (mol), Curie: 135 °C
2. P(VDF-TrFE) 75/25 (mol), Curie: 112-121 °C
3. P(VDF-TrFE) 70/30 (mol), Curie: 104 °C
4. P(VDF-TrFE) 65/35 (mol), Curie: 72 °C
5. P(VDF-TrFE) 55/45 (mol), Curie: 66 °C
6. P(VDF-TrFE-CFE) Terpolymer 63/30/7 (mol), T_m: 130 °C. Ferrorelaxor polymer with high dielectric constant ~60 at 25 °C.
7. P(VDF-TrFE-CTFE) Terpolymer 65/31/4 (mol), T_m: 130 °C. Ferrorelaxor polymer with high K~60 at 50 °C and 1 kHz.

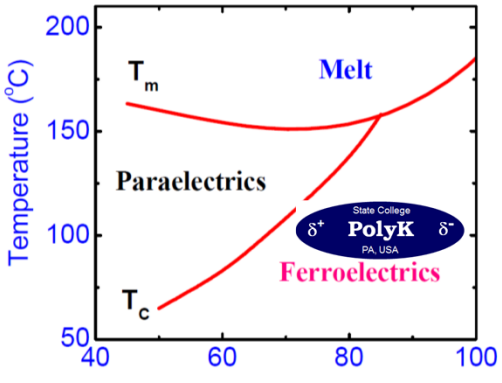
Other compositions available upon request

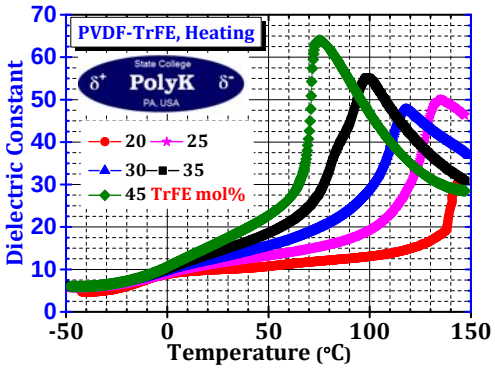
Poly(vinylidene fluoride-co-trifluoroethylene) copolymers & terpolymers (CFE, CTFE)

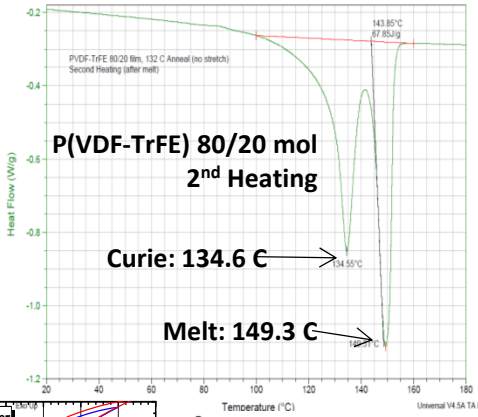
P(VDF-TrFE) Composition Effect (from QM. Zhang, 2001)

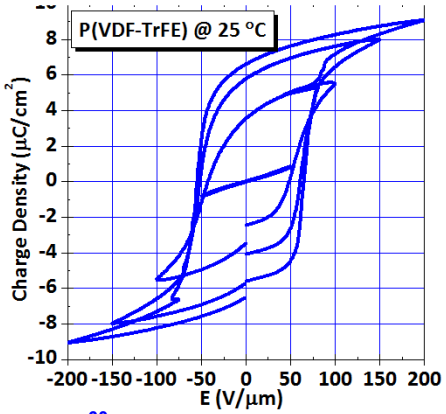


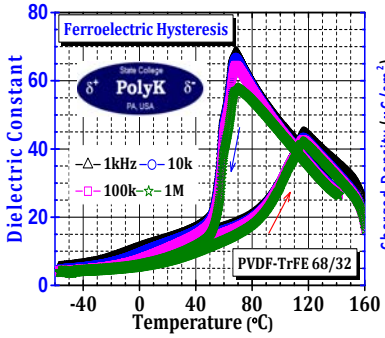


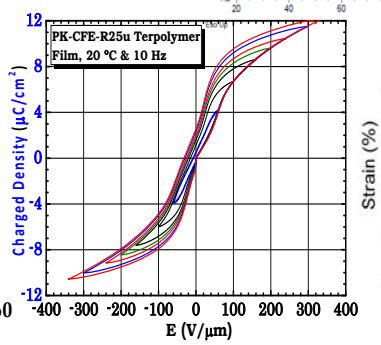


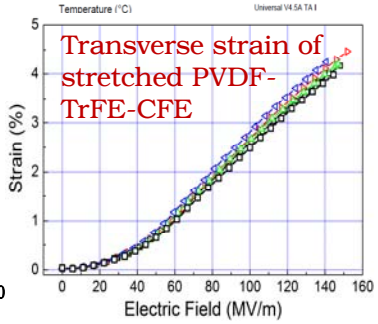


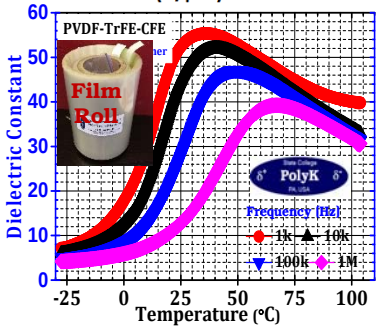












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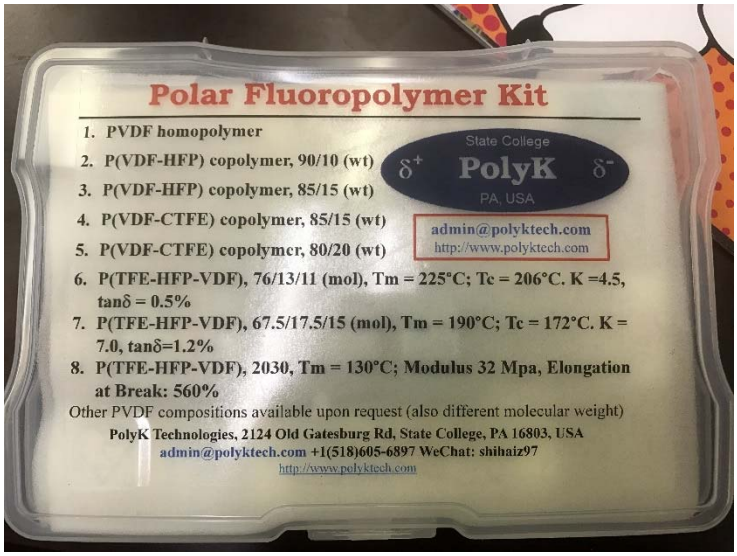
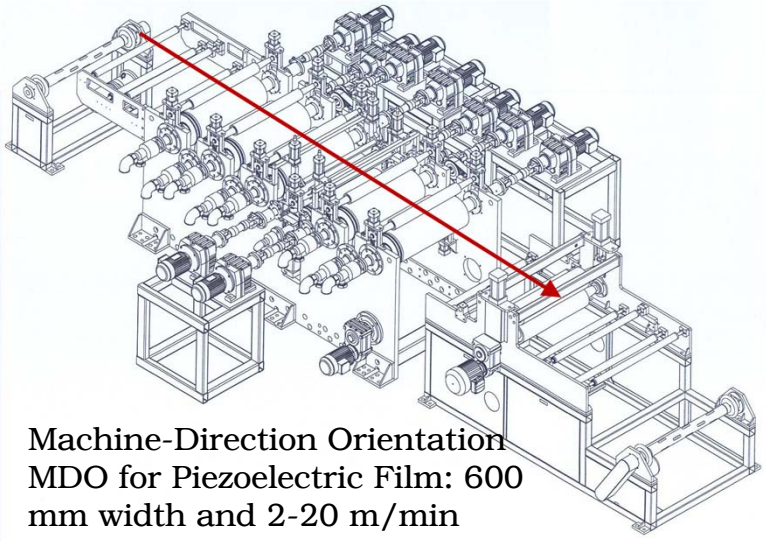
Dielectric Polymer Kit: PVDF-Based Polar Fluoropolymers

Polymer kit for R&D in capacitor, piezoelectric, pyroelectric, electrocaloric ECE, & electroactive polymer EAP. Include **20 grams** of each of **Eight** typical polymer resins based on PVDF.

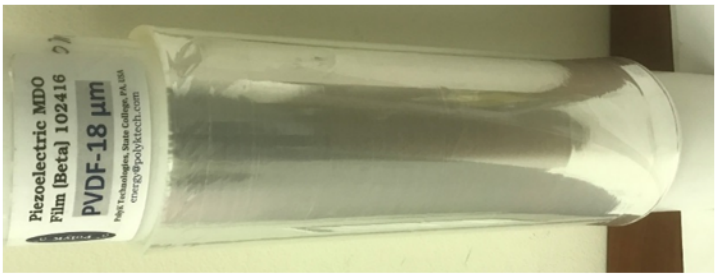


Polyvinylidene fluoride [PVDF] & Copolymers

- Other PVDF compositions also available
- PVDF homopolymers with different molecular weight: ultra-low MW for electrospinning and ultra-high MW for battery binders
- PVDF-based polymers from Solvay (SOLEF), Arkema (Kynar), 3M (Dyneon), Kureha, China
- TFE-VDF based copolymers with high melting temperature and high dielectric constant
- Small quantity of 20 g to large quantity of 5 kg: commercial products with high quality
- Film based on PVDF: solvent cast, extruded, uniaxial orientation, biaxial orientation, poling, metallized
- Film thickness: 2 um to >100 um
- PVDF piezoelectric film and actuator film (beta phase film)

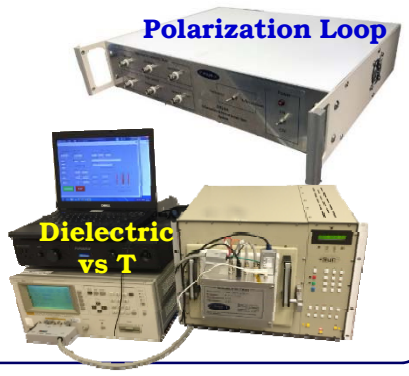


Machine-Direction Orientation MDO for Piezoelectric Film: 600 mm width and 2-20 m/min



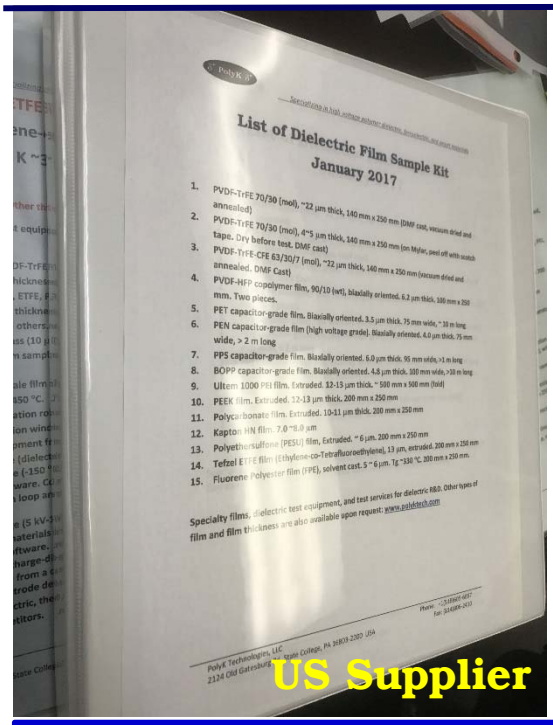
Dielectric, Piezoelectric R&D

- Polymers: fluoropolymers of VDF with over 20 compositions & molecular weight
- Films: solvent cast, extrusion, poled, electrode, 1-100 um
- Low-Cost Test Equipment: polarization loop, dielectric constant vs temperature & frequency, leakage current
- Device: piezoelectric sensors, capacitors, actuators, etc



Ultrathin Free-Standing Dielectric & Capacitor Film Sample Kit

PolyK: Bridge Academic Research with Industry Standard & Manufacturing

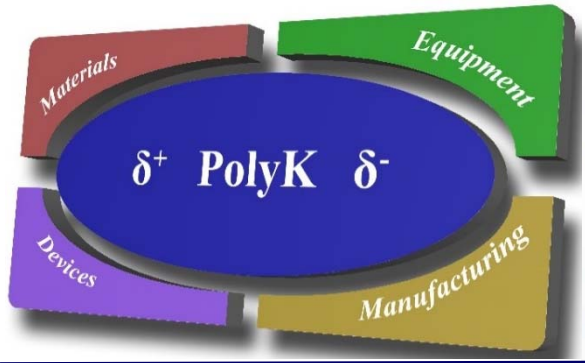


- High energy density film capacitors with high operation temperature are critical to many emerging applications such as hybrid electric vehicles, wind turbine generators, grid-tie photovoltaics, oil & gas down-hole drilling, and pulsed power systems.
- This sample kit will help scientists that are developing new dielectric material to understand current state-of-the-art industry products in capacitor films and establish a true and unbiased baseline to evaluate new dielectric materials.
- Most films are free-standing and produced by melt extrusion + biaxial orientation with minimal pinholes
- Also available: different thickness from 0.9 um to >100 um; large rolls of films, etc.

List of Dielectric & Capacitor Film Sample Kit

1. PVDF-TrFE 70/30 (mol), ~22 μm thick, 140 mm x 250 mm (DMF cast, vacuum dried and annealed)
2. PVDF-TrFE 70/30 (mol), 4~5 μm thick, 140 mm x 250 mm (on Mylar, peel off with scotch tape. Dry before test. DMF cast)
3. PVDF-TrFE-CFE 63/30/7 (mol), ~22 μm thick, 140 mm x 250 mm (vacuum dried and annealed)
4. PVDF-HFP copolymer film, 90/10 (wt), biaxially oriented. 6.2 μm thick. 100 mm x 250 mm. Two pieces.
5. PET capacitor-grade film. Biaxially oriented. 3.5 μm thick. 75 mm wide, ~ 10 m long
6. PEN capacitor-grade film (high voltage grade). Biaxially oriented. 4.0 μm thick. 75 mm wide, > 2 m long
7. PPS capacitor-grade film. Biaxially oriented. 6.0 μm thick. 95 mm wide, >1 m long
8. BOPP capacitor-grade film. Biaxially oriented. 4.8 μm thick. 100 mm wide, >10 m long
9. Ultem 1000 PEI film. Extruded. 12-13 μm thick. ~ 500 mm x 500 mm (fold)
10. PEEK film. Extruded. 12-13 μm thick. 200 mm x 250 mm
11. Polycarbonate film. Extruded. 10-11 μm thick. 200 mm x 250 mm
12. Kapton HN film. 7.0 ~8.0 μm
13. Polyethersulfone (PESU) film, Extruded. ~ 6 μm. 200 mm x 250 mm
14. Tefzel ETFE film (Ethylene-co-Tetrafluoroethylene), 13 μm, extruded. 200 x 250 mm
15. Fluorene Polyester film (FPE), solvent cast. 5 ~ 6 μm. Tg ~330 °C. 200 mm x 250 mm.

δ⁺ PolyK δ⁻



- Thickness (free-standing): 0.9 um to > 100 um
- Biaxially oriented, extruded without orientation, solvent cast, etc.
- Films from different suppliers

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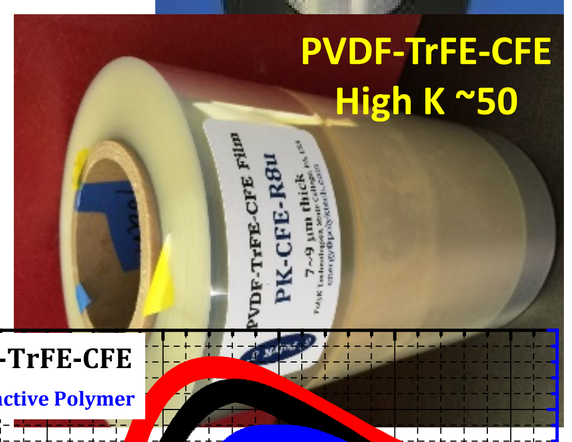
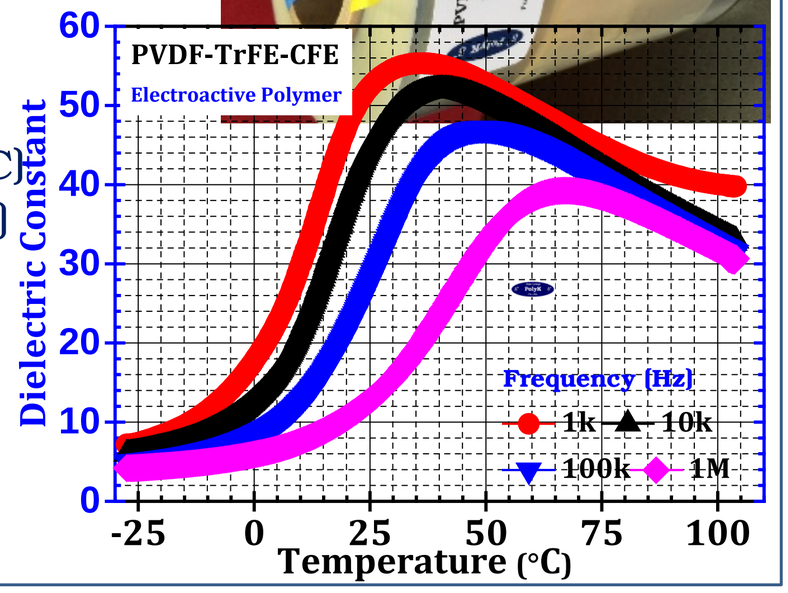
Specialized in high voltage polymer dielectric, ferroelectric, and smart materials and their applications (capacitors, sensors, and actuators)

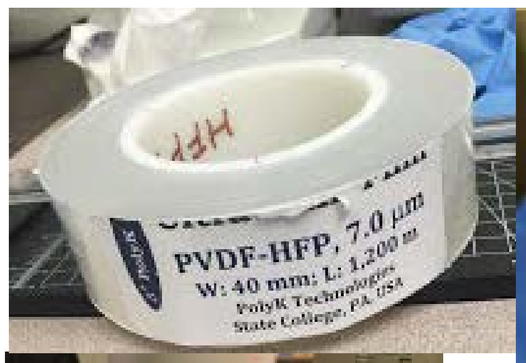
Ultrathin Free-Standing Dielectric & Ferroelectric Films: 1 µm – 100 µm

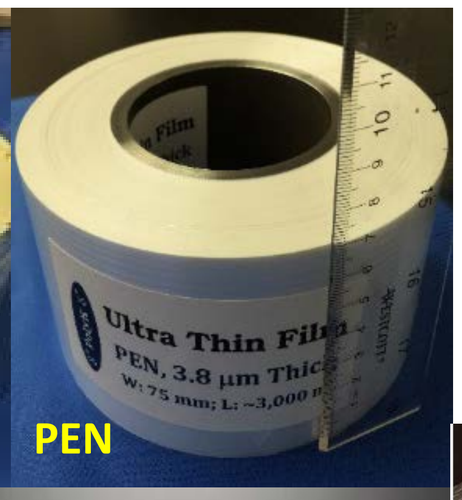
PolyK has a unique collection of ultrathin dielectric films and resins for R&D in capacitors, batteries, printed electronics, wearable electronics, OLED, photovoltaics, acoustics, electro-wetting, speakers, actuators, sensors, etc. Examples include:

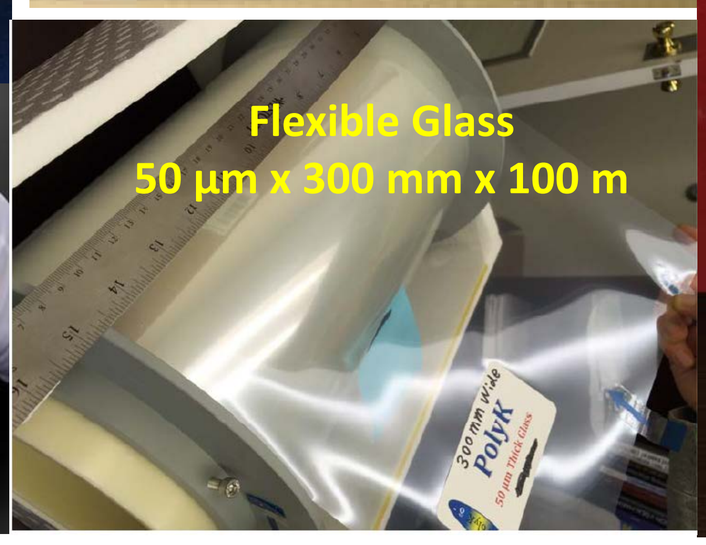
1. Biaxially oriented polypropylene (BOPP): 2.0 um, 2.4 um, 3.0 um, 3.5 um, 3.8 um, 4.8 um, 5.8 um, 6.8 um, 7.8 um, 9.8 um, 15 um.
2. Biaxially oriented polyethylene terephthalate PET): 1.4 um, 2.0 um, 3.5 um, 4 um, 6 um
3. Biaxially-oriented polyethylene-naphthalate (PEN): 2.4 um, 3.8 um, 5 um, 6 um
4. Biaxially-oriented polyphenylene sulfide (PPS): 4.5 um, 6 um, 9 um
5. Biaxially-oriented Poly(vinylidene fluoride-co-hexafluoropropylene) (PVDF-HFP) and PVDF: 2.0 um, 3.0 um, 4.0 um, 4.8 um, 6.2 um, 8.0 um, 10 um
6. Ferroelectric poly(vinylidene fluoride-co-trifluoroethylene (PVDF-TrFE or PVDF-VF3): 5 um, 21 um, and other thickness (also with polymer resin)
7. Electroactive polymers: P(VDF-TrFE-CFE) and P(VDF-TrFE-CTFE) with K > 40
8. Extruded PVDF and PVDF-HFP film (no orientation): from < 25 um to > 100 um
9. Extruded PP film without orientation: any thickness above 15 um
10. Polycarbonate films (<10 um)
11. Polyetheretherketone (PEEK) film: 9 um and 12 um
12. Polyetherimide (Ultem 1000) film: 6 um, 12 um
13. High temperature polyetherimide polymers and films (Tg from 225 C to 265 C)
14. Polyethersulfone (PESU) and polyphenyl sulfone (PPSU): film (6 um to 25 um)
15. Fluorene polyester (FPE) film: 6 um (and polymer powders, Tg 330 deg C)
16. Soluble polyimide Matrimide 5218: Tg ~ 325 C (NO imidization required)
17. Flexible glass: 10 um, 25 um, and 50 um, dielectric constant of 5.5
18. Polymer resins of the above films and capability to produce other films.
19. Machine-direction oriented polymer film with our own MDO machine.
20. Most commercial fluoropolymer resins (Solvay, Arkema, Daikin, 3M, Kureha)











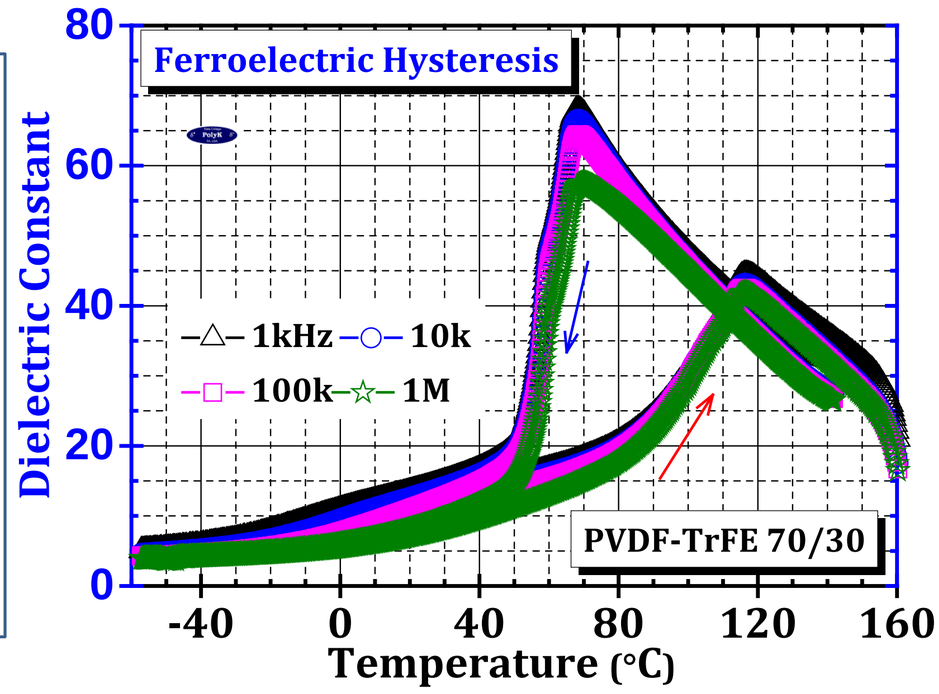
Test Capability

Polymer/Film

- TA Q2000 Modulated DSC
- TA Q800 DMA with LN2
- Nicolet FTIR with polarizer
- Thermal Conductivity
- MTI Folding Test
- Environment Chamber (-50 to 200 C, with RH control)

Special

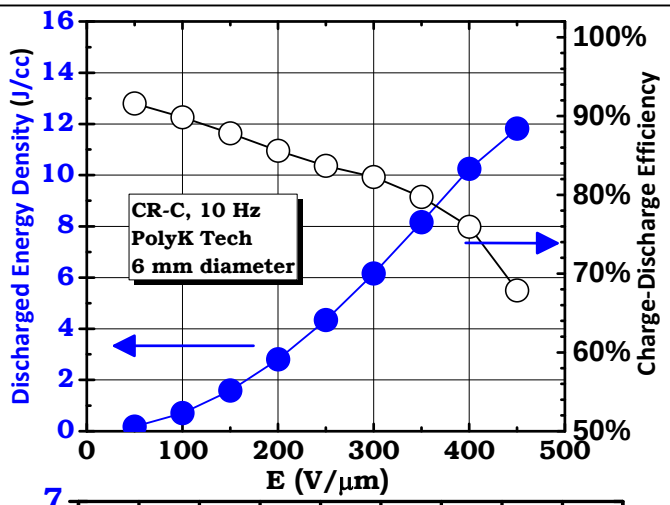
- Electrode Deposition: sputtering (Au, Ag, Pt), evaporation (Al, Au)
- High voltage dielectric and polarization test vs T and F
- Piezoelectric: charge d33 & d31
- Energy harvesting 100 lb shaker
- Laser, diamond wire saw cutting

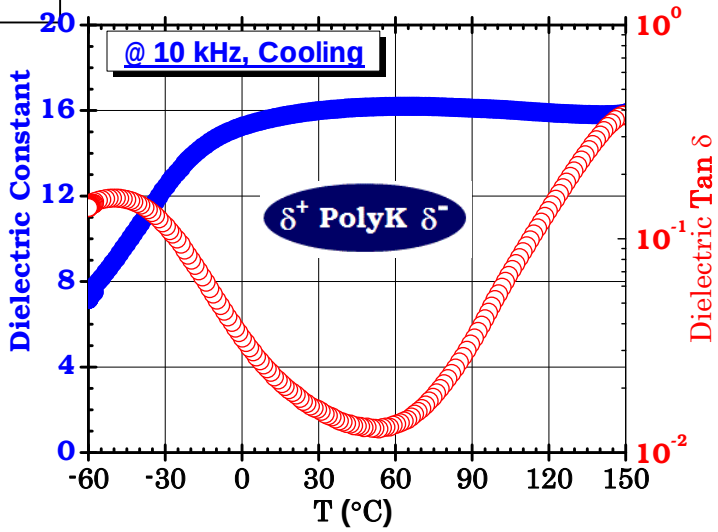


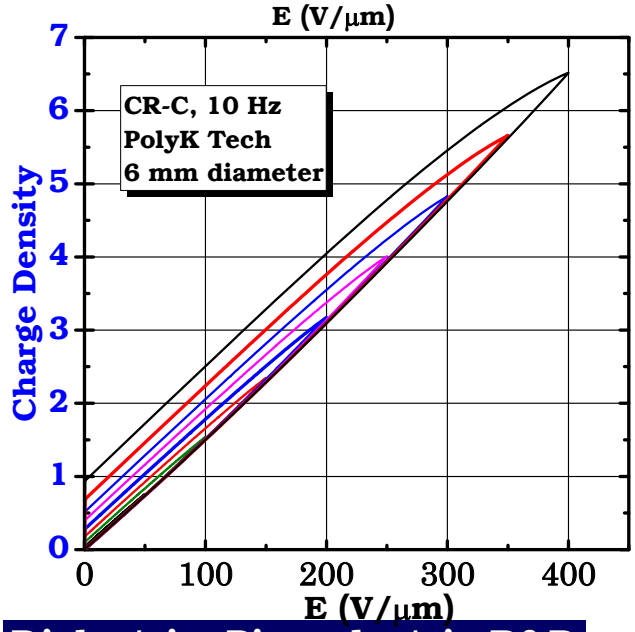
PolyK, energy@polyktech.com Cell Phone: (518)605-6897

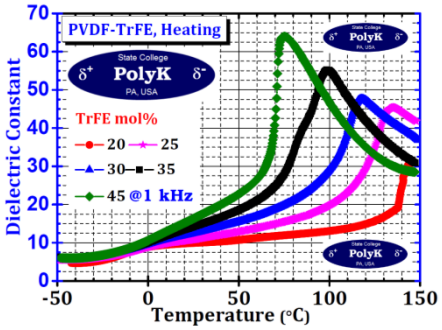
High Dielectric Constant Cyanoethylated Cellulose CR-C

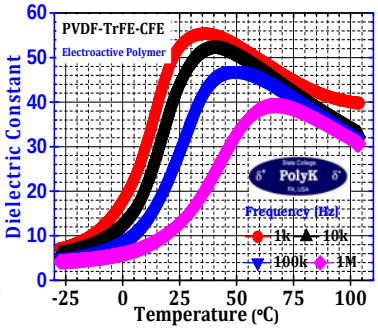
1. Thermoplastic with high K of 16
2. Unlike PVDF, CR-C is linear dielectric and it does not have polarization saturation, therefore offer higher energy density for capacitor energy storage.
3. Soluble in DMF, MEK, Acetone, and easy to prepare thin film and nanocomposites in lab scale.
4. CR-C has the best mechanical and high voltage performance than other compositions.





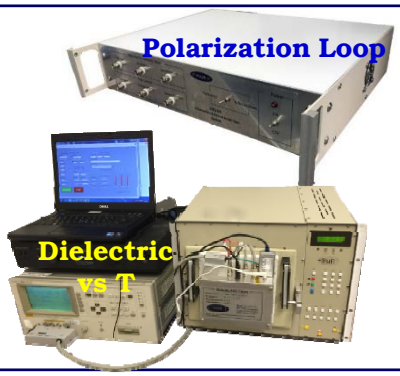






Dielectric, Piezoelectric R&D

- Polymers: fluoropolymers of PVDF with over 20 compositions & molecular weight
- Films: solvent cast, extrusion, poled, electrode, 1-100 um
- Low-Cost Test Equipment: polarization loop, dielectric constant vs temperature & frequency, leakage current
- Device: piezoelectric sensors, capacitors, actuators, etc



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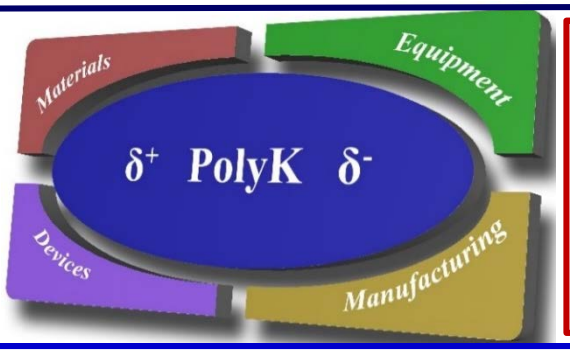
Refurbished Test Equipment for R&D in High Voltage Dielectric & Ferroelectric



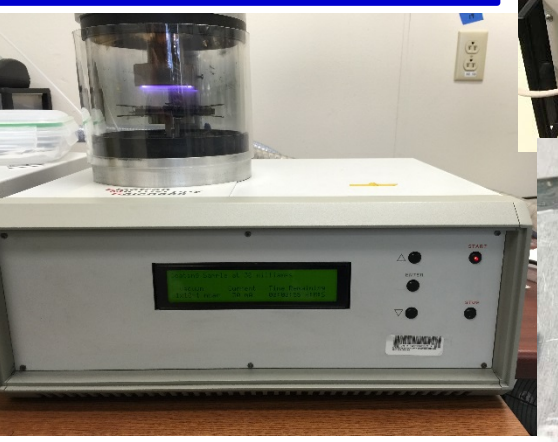
- Refurbished equipment: all carefully cleaned, performance calibrated, manual included, all cables and connection and power cord included.
- Price is usually 20% -40% of new equipment.
- Three-month warranty

Trek High Voltage Power Supply, Amplifier, and Controller

- The best high voltage amplifier for studying ferroelectric and dielectric materials & devices
- Available models: 610C/610B, 10/10-2, 609A, 609C & 609D, 20/20, 30/20, etc
- Voltages: ±4 kV, 10 kV, 20 kV, 30 kV
- More than 60 units in stock, ready to ship

Emitech Sputtering Machine

- Best table-top sputtering machine made in UK, cold plasma design that will NOT burn thin polymer film
- Including manual and all connection tubing, vacuum pump, and targets



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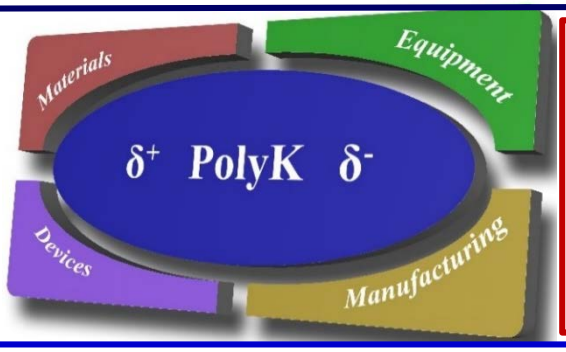
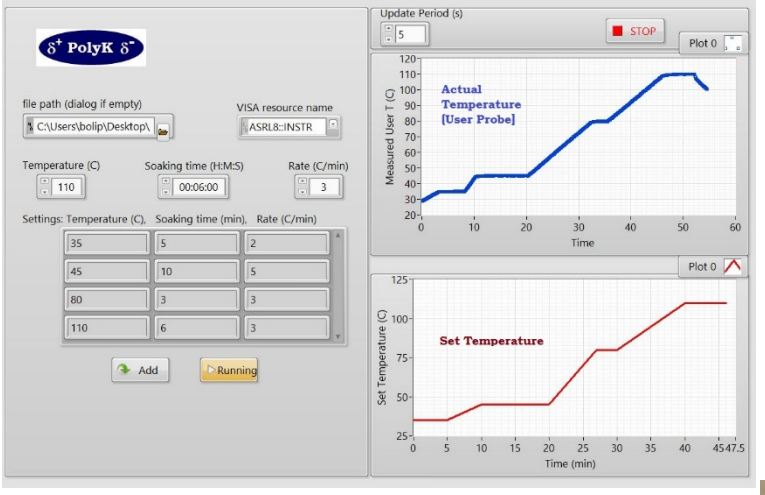
Refurbished Test Equipment for R&D in High Voltage Dielectric & Ferroelectric



- Refurbished equipment: all carefully cleaned, performance calibrated, manual included, all cables and connection and power cord included.
- Price is usually 20% -40% of new equipment.
- Three-month warranty

Temperature Chamber

- Liquid nitrogen cooling capability
- -185 ° C to 315 ° C
- Software to automatically control the chamber temperature with computer
- Made in the US with lifetime >30 years without failure



Precision LCR Meters & Impedance Analyzers

- The legend HP/Agilent 4284A
  - ✓ 20 Hz – 1 MHz
- Software to automatically control the LCR meter with computer
- Low-cost impedance analyzer (10 Hz -30 MHz) made in Taiwan
- Compatible with Sun or Delta Design chamber for dielectric test vs T & F

1. Piezoelectric d33 meter
2. High voltage poling station
3. Electrometer for pA test (TSDC)

Specialized in high voltage polymer dielectric, ferroelectric, and smart materials and their applications (capacitors, sensors, and actuators)

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