fringing electric field lines; second, the slit defines a sample chamber of fixed dimensions along which other sensors can be positioned; and third, it is the geometry of a slit die rheometer so that with knowledge of the pressure drop across the length of the slit and the volume flow rate, the viscosity of the material can be determined. The pressure transducer is positioned upstream from the dielectric sensor and yields the value of the pressure drop along the axial length of the slit **2**.

The optics sensor, shown in FIG. **5**, is situated upstream from the dielectric sensor in the stainless steel portion of the slit die. It consists of a bundle of seven 200 μm core optical fibers **33** that are placed into a sleeved half-inch sensor bolt **19** with a sapphire window **20** at its end. It operates in the reflection mode, i.e. one of the fibers **34**, shown in FIG. **6**, transmits light from the light source **21** (that has been confined to a narrow wavelength band by a filter **22**) through a focusing lens **23**, the sapphire window **20**, the flowing liquid, reflects off the far stainless steel surface, and reverses its path through the material, sapphire window **20** and lens **23**. The reflected light is collected by the other six fibers **35** and is transmitted to the photomultiplier (PMT) detector **24** as shown in FIG. **6**. The intensity of the light source **21** is monitored using a beamsplitter **25** that sends a source sampling beam to another photomultiplier (PMT) **26**. The ratio of the two light intensities is used to monitor the light transmission through the liquid. In this manner fluctuations in light source intensity are cancelled out. The light sensor can also be used for fluorescence monitoring where the single optical fiber transmits the excitation light to the flowing liquid, and fluorescence collected by the six fibers is transmitted to a monochromator **27**. For fluorescence detection, the monochromator substitutes for the PMT **24** in FIG. **6**.

A machined flat at the back end of the slit die is reserved for an ultrasonics sensor **28**. In this position, the ultrasonic sensor functions in a manner similar to the optical sensor, i.e. in the reflection mode. A transducer placed on the flat area transmits an ultrasonic wave through the stainless steel housing, through the material under investigation, reflecting off the far stainless steel wall, reversing its direction, taking a second pass through the material and returning through the stainless steel to the transducer that acts as both transmitter and detector. Using standard ultrasonics detection equipment, both the attenuation of the ultrasonic energy and the velocity of the wave in the examined material can be measured. Ultrasonics velocity is related to the bulk modulus of the material and the attenuation of ultrasonics energy is related to absorption and scattering of the ultrasonics wave.

As shown in FIG. **7**, additional instrumentation port sectors **29** can be added in-line with the slit die **1**, sandwiched between the extruder **14** with the adapter plate **13** and the slit die. These sectors can have standard half-inch instrumentation ports or have a custom port configuration for special sensors **36**, such as opposing optical windows, that are used for IR and UV spectroscopy. The instrument port sectors can be placed in service as the need for new data arises.

Example 1

To demonstrate the operation of the dielectric slit die, we show the results, in FIG. **8**, of single screw compounding of nylon 12 with 4% smectite clay. FIGS. **8***a* and **8***b* show real-time data for extrusion of nylon 12 (neat) and for nylon 12 compounded with 4% clay. Compounding was carried out at 195° C. Relative permittivity and conductivity are plotted versus time for fifteen different frequencies ranging from 500 Hz to 100 kHz. At t=400 s, the neat polymer entered the electrode region of the dielectric sensor and was extruded for approximately 1500 s, at which time resin pellets mixed with 4% mass fraction of clay were added to the feeder. Permittivity and conductivity began to increase as the mixture filled the slit region, and after significant transition time, the data reached a plateau value. The transition is associated with time it takes the clay/polymer mixture to completely fill the sensing region, particularly at the surface near the electrodes. At t=4200 s, the neat resin was again introduced and relative permittivity values returned to their original values.

The difference in relative permittivity at low frequency (500 Hz) and high frequency (105 Hz) is called the dielectric dispersion. We see that the dispersion for the clay/polymer nanocomposite is considerably larger than that for the neat polymer. This is because clay particles introduce ionic species into the resin mixture that contribute to conductivity and polarization over and above that which is present in the neat resin.

FIGS. **9***a* and **9***b* show pressure and optical signals as a function of time corresponding to the time scale of FIGS. **8***a* and **8***b*. Steady state conditions prevail after the transitions are complete. The optical transmission data are expressed as I/I_o where I is the intensity of light transmitted through the extruded resin in the slit and I_o is the intensity of the light source. The optical data show attenuation of the optical beam as it transmits through the neat and clay filled nylon. These data can be correlated with the volume fraction and microstructure of clay in nylon 12. Steady state pressure in conjunction with the volume flow rate can be use to calculate an apparent viscosity using equations for liquid flow through a slit die. In this case apparent viscosity values of 139 Pa·s and 164 Pa·s were obtained for the neat and clay filled nylon 12 at 195° C., respectively.

Example 2

Real-time fluorescence monitoring is illustrated in FIG. **10**. Here, polyethylene vinyl acetate copolymer, containing a low concentration of the fluorescent dye benzoxazolyl stilbene, was extruded through the slit and the fluorescence spectrum was detected using a monochromator as illustrated in FIG. **6**. The spectra can be used to determine machine residence time and resin temperature.

We claim:

1. An apparatus having a plurality of sensors that monitor material properties of a liquid medium, said apparatus comprising:

- a flow channel of predetermined shape and dimensions, said flow channel being a path for a flow of a liquid medium, whereby said liquid medium is contiguous with a surface of said flow channel;
- a metal housing of predetermined shape and dimensions surrounding said flow channel, said metal housing comprising an upper half and a lower half that are contiguous;
- a first plurality of sensor ports in said metal housing for providing a plurality of sensors access to said liquid medium;
- a first recess of predetermined shape and dimensions in said lower half for receiving a first ceramic block of predetermined shape and size thereby creating an exposed planar surface of said first ceramic block that is contiguous with said flow channel;