Electronic Supplementary Information

Vanadium disulfide incorporated polymer nanocomposite for flexible piezoelectric energy generators and road safety sensors

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Supplementary file number	Details	Page number
S1	FESEM image of exfoliated VS_2 sheets and TEM image of VS_2.	3
S2	Size parameters of flexible electrodes and polymer nanocomposite film of small devices.	4
S3	Size parameters and flexibility of the film and electrode of big device.	5
S4	FESEM images of pure and nanocomposite polymer films.	6
S5	Percentage of β-phase calculated for polymer nanocomposite films.	7
S6	XRD analysis of polymer nanocomposite films	8
S7	Higher magnification FESEM image of P/VS_2(1) polymer nanocomposite.	9
S8	Zeta potential analysis of VS_2/DMF solution.	10
S9	PFM analysis of PVDF and P/VS_2(0.25).	11
S10	Programming code of FSR with block diagram of setup.	12
S11	Complete setup of optimisation of force at particular rpm of tapping machine.	13
S12	Error bar graph of output of small device	14
S13	Cycle stability of prototype	15
S14	Programming code for road safety system with lab scale setup of alert display operated by piezo-sensor.	16
S15	Programme coding and lab scale setup of smart door operated by piezo-sensor.	17
S16	Supplementary videos	18

Supplementary file number –S1

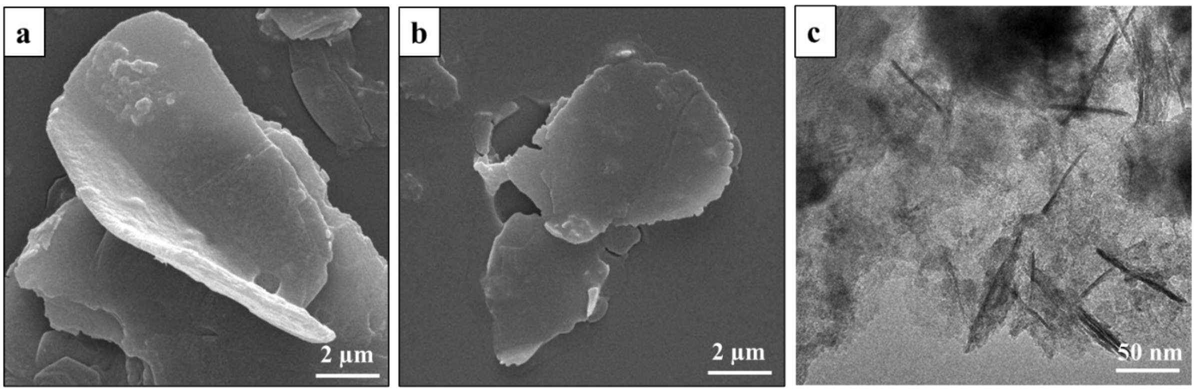

Figure S1. FESEM image of exfoliated layers of VS_2 (a) and (b) at different regions. (c) TEM image of layers structure of VS_2.

Supplementary file number –S2

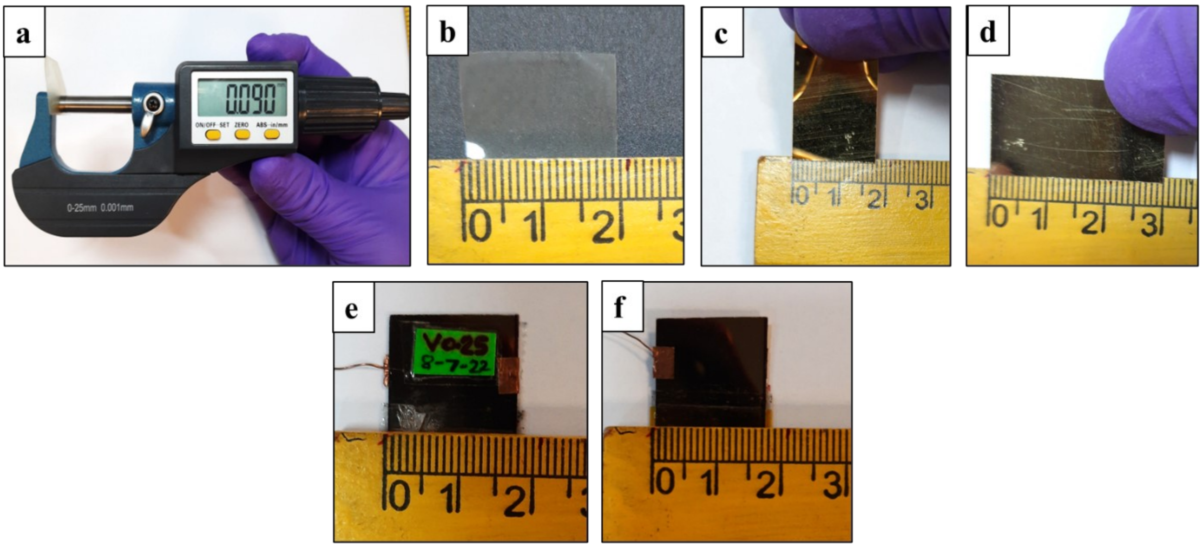

Figure S2. Parameters of flexible electrodes and polymer nanocomposite film of small devices. (a) and (b) thickness of 90 µm and size 2 cm × 2 cm. (c), (d), (e) and (f) length and breadth of the electrode (1.9 × 3 cm) and final device.

Supplementary file number –S3

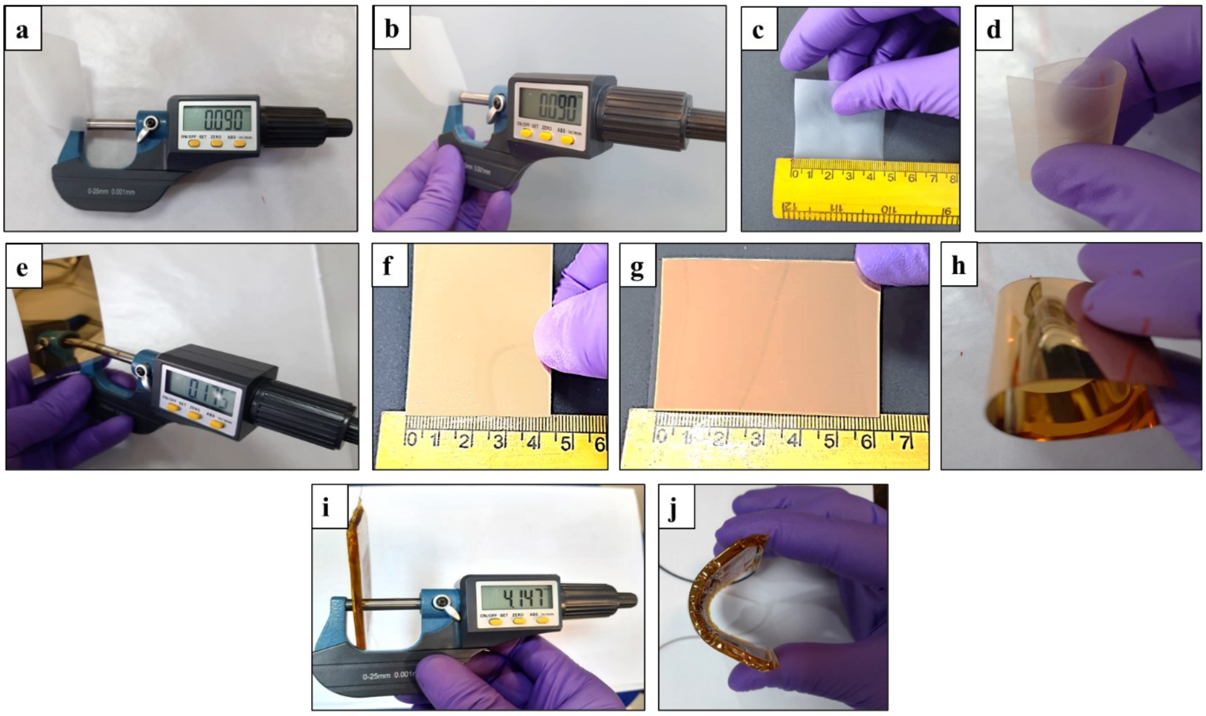

Figure S3. The size, thickness parameters and flexibility of the film and electrode of the big device. In addition, the thickness and bendability of the PDMS encapsulated prototype device. (a), (b), (c) and (d) parameters of polymer nanocomposite film. (e), (f), (g) and (h) parameters of the electrode. The thickness and bendability of the prototype in (i) and (j).

Supplementary file number –S4

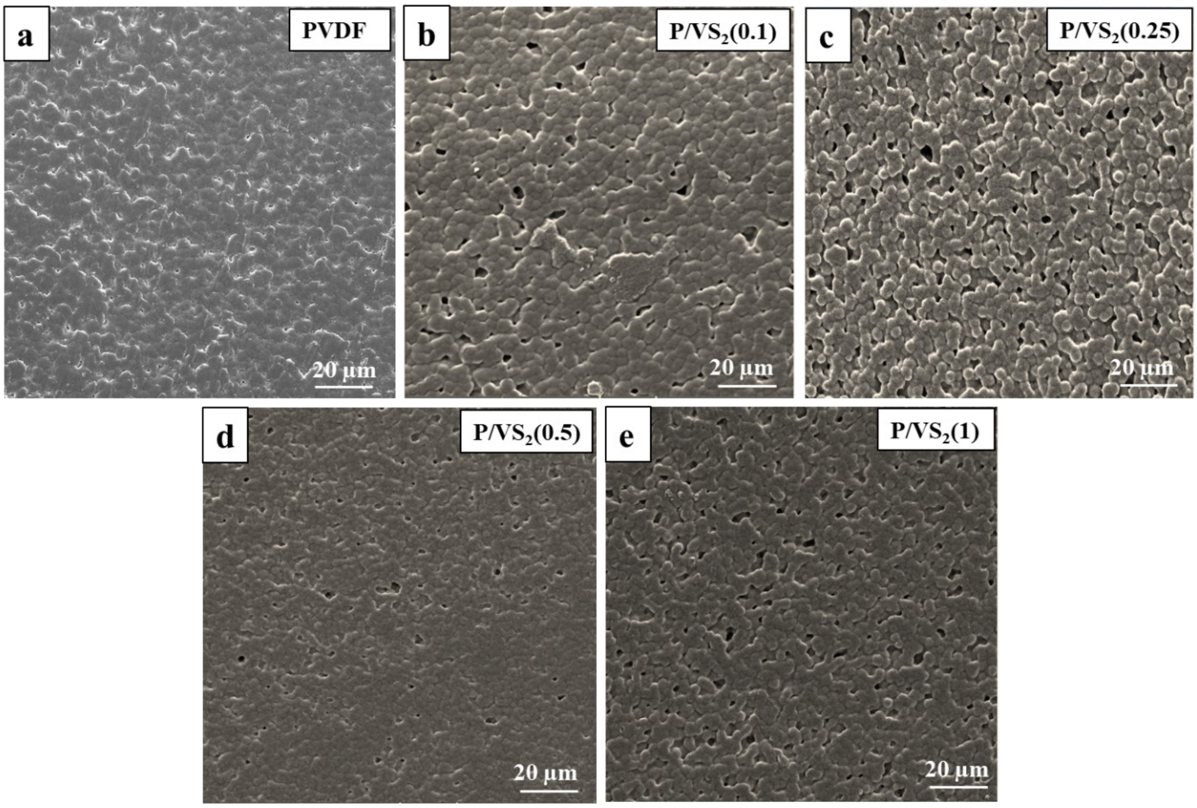

Figure S4. FESEM images of pure and nanocomposite polymer films.

Supplementary file number –S5

Table S5. Fraction of β-phase calculated for polymer nanocomposite films.

Sample Name	A_α (at 766 cm^{-1})	A_β (at 839 cm^{-1})	Percentage of β-phase = $[A_\beta/(1.26\times A_\alpha)+A_\beta]\times100$
PVDF	0.00038	0.0067	93.33%
P/VS_2(0.1)	0.00037	0.0074	94.07%
P/VS_2(0.25)	0.0004	0.0413	98.79%
P/VS_2(0.5)	0.0008	0.0324	96.98%
P/VS_2(1)	0.0004	0.0168	97%

The percentage of polar β-phase of the polymer films were calculated using the following equation by assuming the IR absorption follows Lambert-Beer law. Where A_α and A_β are the absorbance at 766 cm^{-1} and at 839 cm^{-1}, respectively

$$\text{Fraction of } \beta\text{-phase} = [A_\beta/(1.26\times A_\alpha)+A_\beta]\times100$$

Supplementary file number –S6

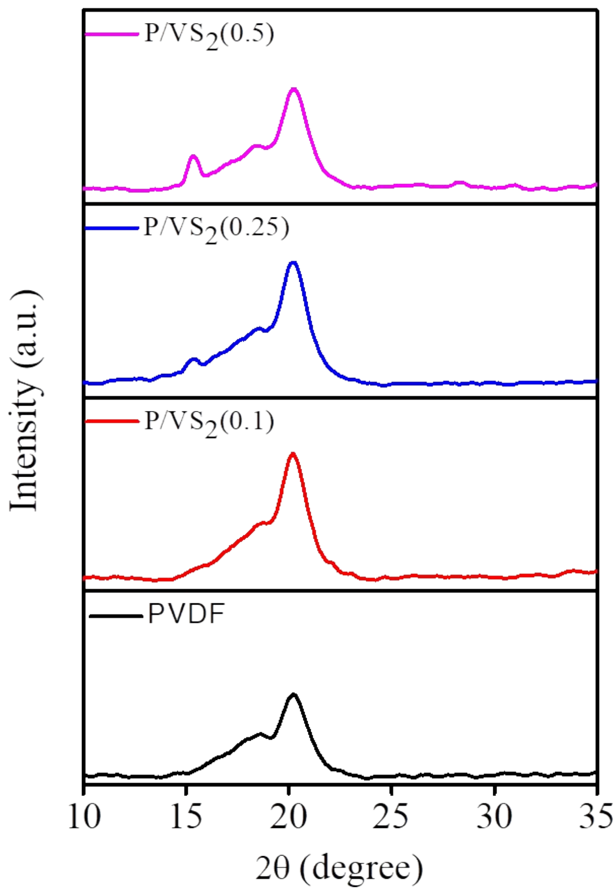

Figure S6. XRD analysis of polymer nanocomposite films.

Supplementary file number –S7

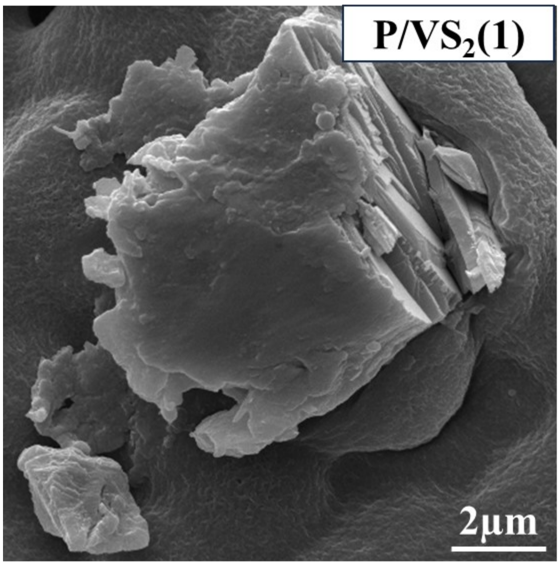

Figure S7. Higher magnification FESEM image of P/VS_2(1) polymer nanocomposite.

Supplementary file number –S8

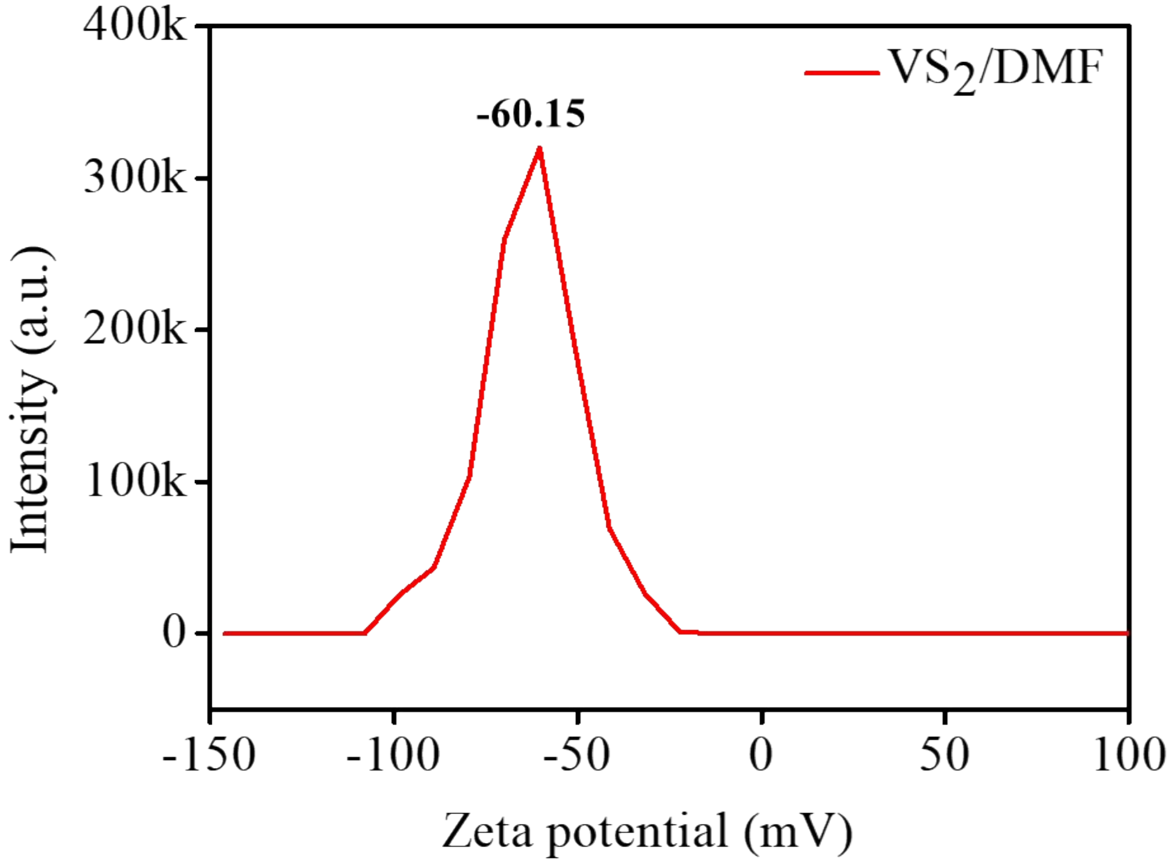

Figure S8. Zeta potential analysis of the VS_2/DMF solution. This peak at -60.15 represents the overall surface charge ofVS_2 layers, which may be the reason for the enhanced β phase of PVDF.

Supplementary file number –S9

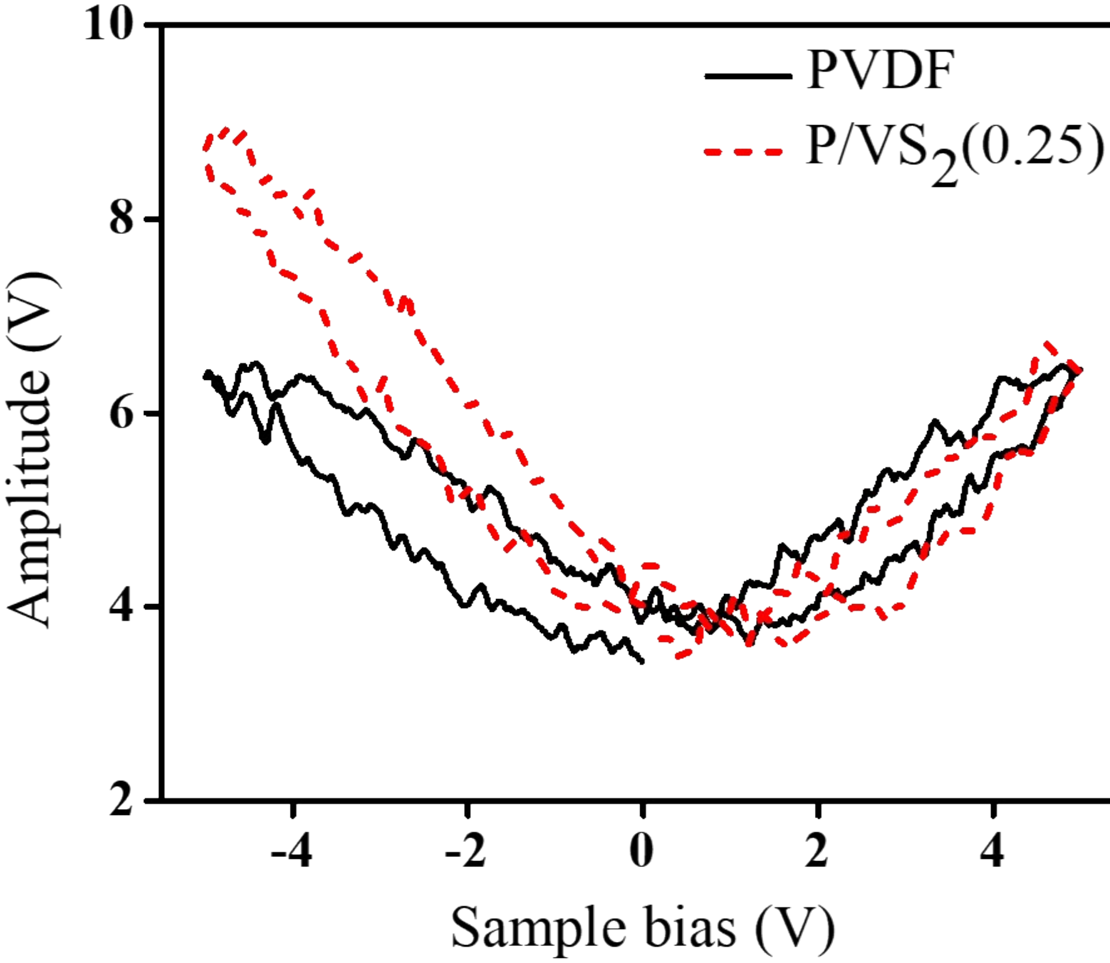

Figure S9. Ferroelectric butterfly loop taken by using PFM analysis of PVDF and P/VS_2(0.25).

Supplementary file number –S10

Force Sensitive Resistance (FSR)

```
#include "LiquidCrystal.h"
LiquidCrystal lcd(8,7,6,5,4,3);

int Force_VAL = 0;

void setup()
{
  pinMode(A0, INPUT);
  Serial.begin(9600);
  lcd.begin(16,2);

  lcd.setCursor(0,0);
  lcd.print("Force Sensor VALUE");

  pinMode(11, OUTPUT);


}

void loop()
{
  Force_VAL = analogRead(A0);
  Serial.println(Force_VAL);

  lcd.setCursor(0,1);
  lcd.print(Force_VAL);

 if (Force_VAL > 100)
 {
    digitalWrite(11, HIGH);
  }
else
 {
    digitalWrite(11, LOW);
  }

  delay(10); // Delay a little bit to
improve simulation performance
}
```

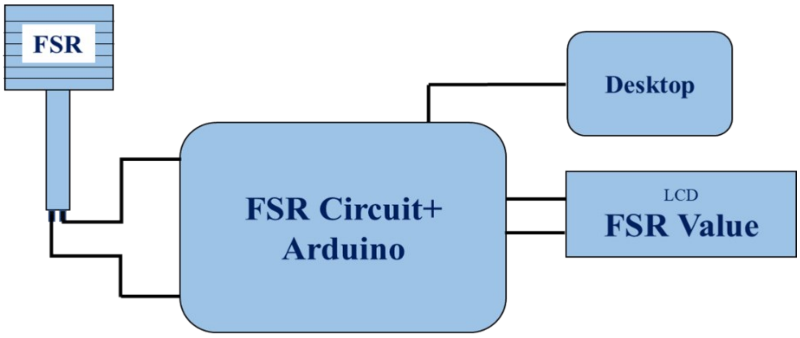

Figure S10. Programming code of FSR on left side and block diagram of full setup of FSR and circuit on right side.

Supplementary file number –S11

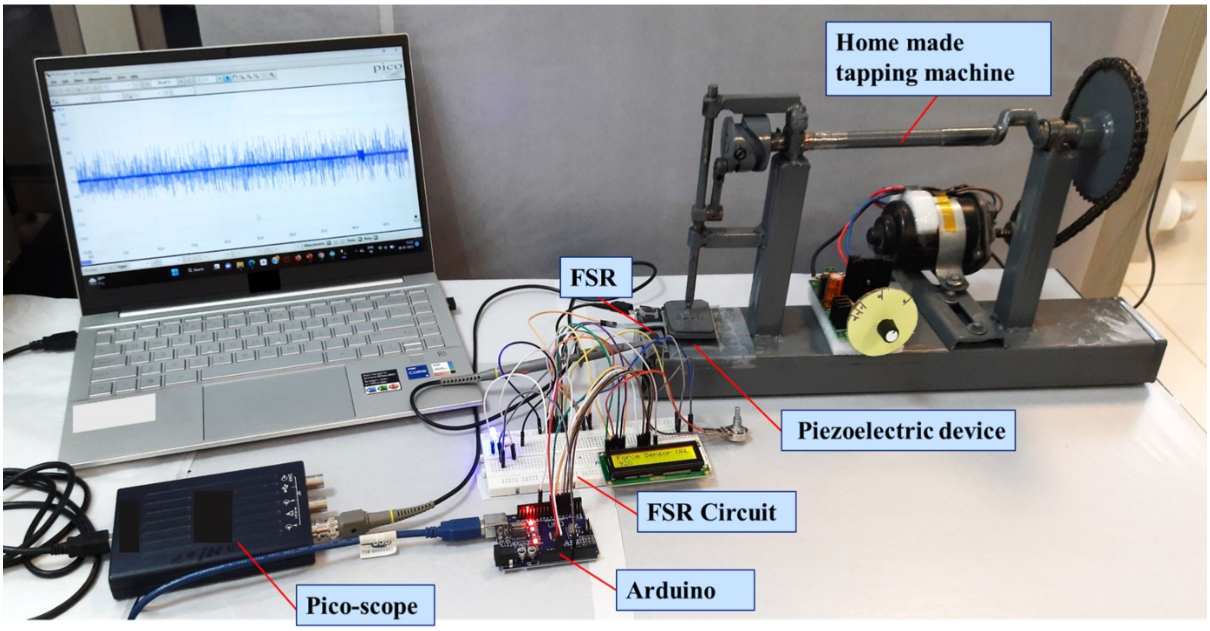

Figure S11. Complete setup of optimisation of force at particular rpm of tapping machine and taking output voltage of the device.

Supplementary file number –S12

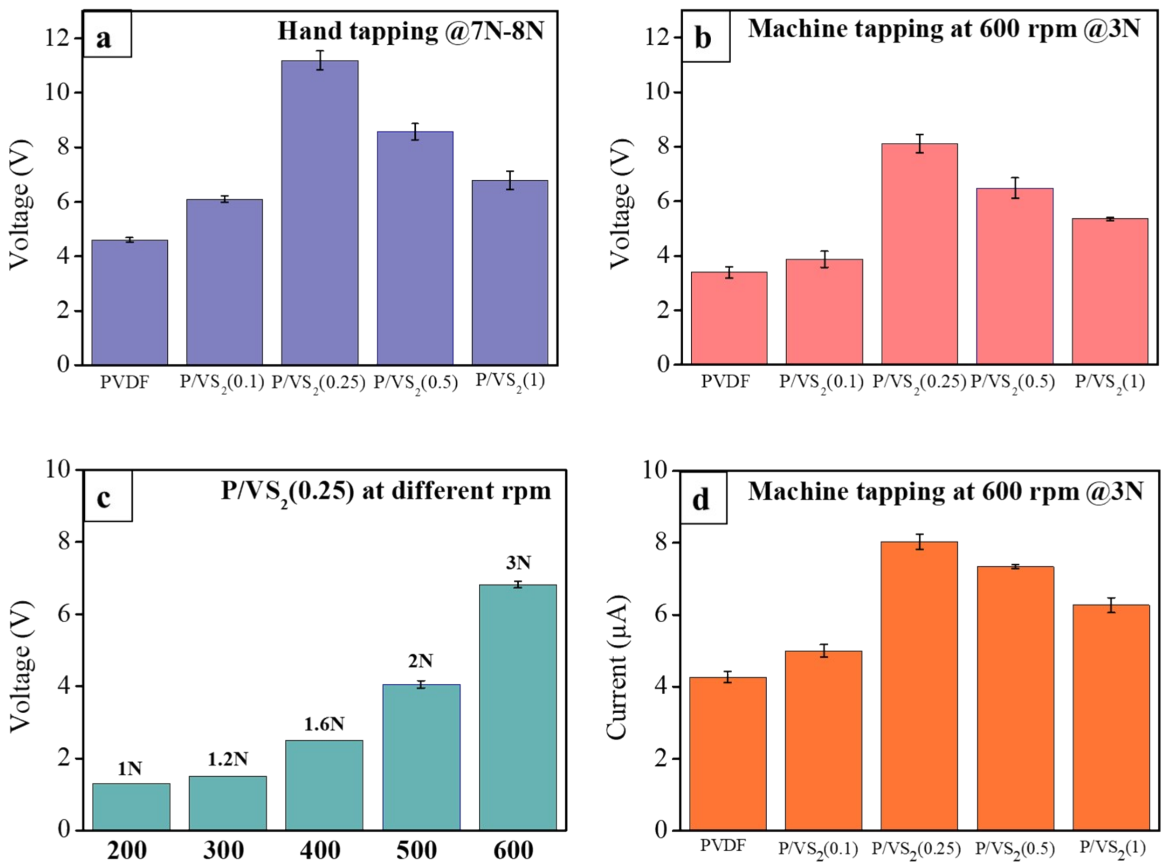

Figure S12. Error bar graph of the output of small devices. (a) and (b) voltage output of Pure PVDF and different concentrated small device by hand tapping and machine tapping at 600 rpm @3N force. (c) P/VS_2(0.25) voltage output by machine tapping at different rpm. (d) current output of different device by machine tapping at 600 rpm.

Supplementary file number –S13

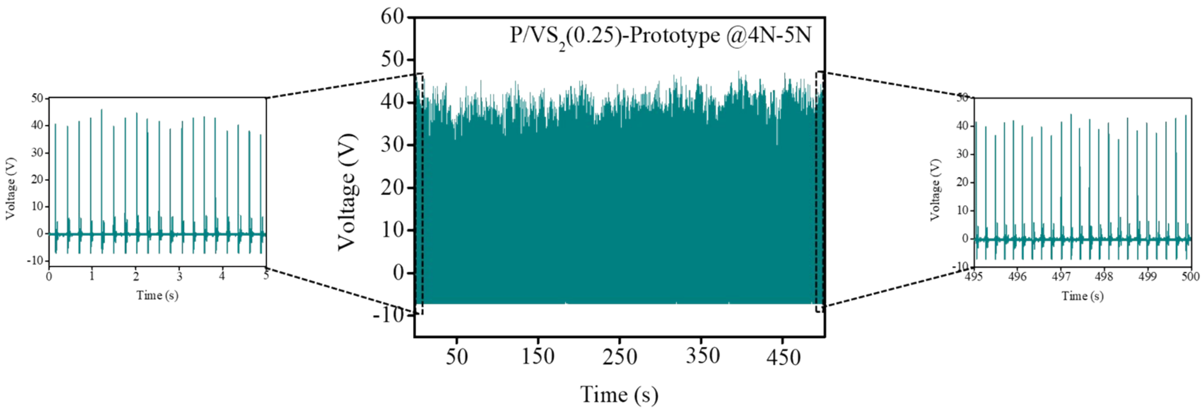

Figure S13. Cycle stability of prototype with hand tapping by giving 4N-5N force continuously for up to 500 seconds.

Supplementary file number –S14

```
#include "LiquidCrystal.h"

LiquidCrystal lcd(8, 9, 4, 5, 6,
7);

float input_voltage = 0.0;
float temp=0.0;


void setup()
{
   Serial.begin(9600);     //  ope
ns serial port, sets data rate to
9600 bps
   lcd.begin(16, 2);       ////
set up the LCD's number of columns
and rows:
   lcd.print("CeNS ");
}
void loop()
{

//Conversion formula for voltage

   int analog_value =
analogRead(A0);
   input_voltage = (analog_value *
5.0) / 1023.0;


   if (input_voltage <4.0 )
   {
     Serial.print("v= ");
    Serial.println(input_voltage);
    lcd.setCursor(1, 1);
    lcd.print("No Vehicle");

    delay(5000);
   }
    else if(input_voltage >4.1 &
input_voltage <5.0)
   {
     Serial.print("v= ");
    Serial.println(input_voltage);
    lcd.setCursor(0, 1);
    lcd.print("Alert Vehicle");

    delay(1000);
   }


}
```

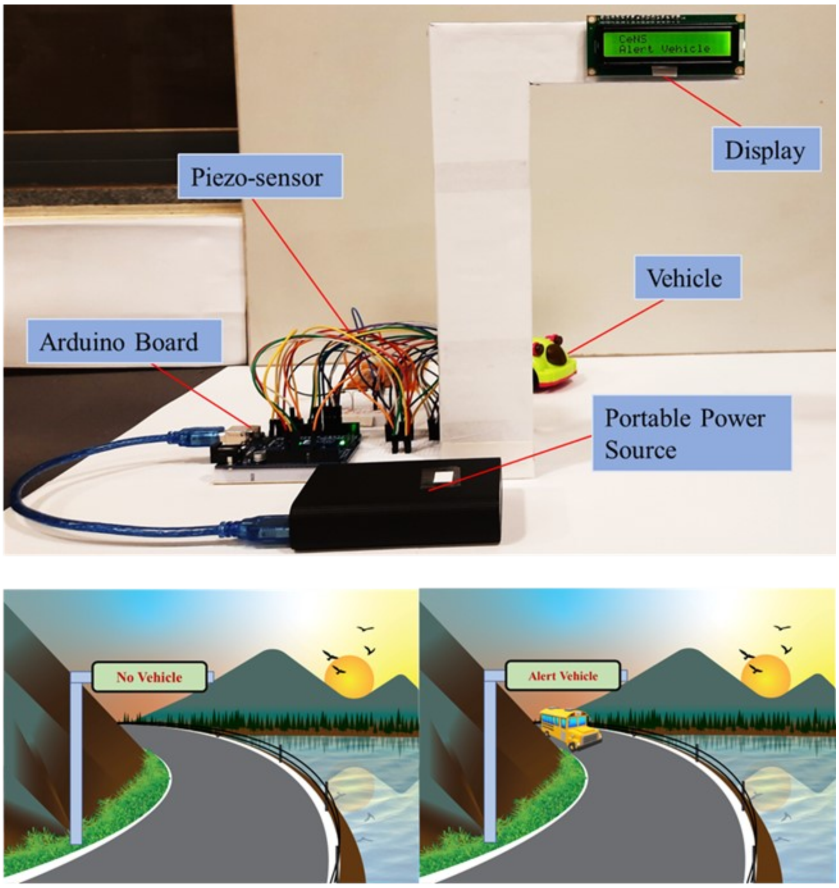

Figure S14. Programming code for road safety system with lab scale setup of alert display operated by piezo-sensor. Schematic of the real-time application of piezo sensor at the dangerous turning points of mountains to avoid accidents.

Supplementary file number –S15

```
#include "LiquidCrystal.h"
LiquidCrystal lcd(8, 9, 4, 5, 6, 7);
float input_voltage = 0.0;
void setup()
{
   Serial.begin(9600);      //  opens
serial port, sets data rate to 9600 bps
   lcd.begin(16, 2);        //// set up
the LCD's number of columns and rows:
   lcd.print(" CeNS ");
   pinMode (10,OUTPUT); // put your setup
code here, to run once:
   pinMode(11,OUTPUT);
  }
void loop()
{
//Conversion formula for voltage

   int analog_value = analogRead(A0);
   input_voltage = (analog_value * 5.0) /
1023.0;

       if (input_voltage >4.5  &
input_voltage <5.0 )
   {
     Serial.print("v= ");
     Serial.println(input_voltage);
     lcd.setCursor(1, 1);
     lcd.print("Welcome      ");
     digitalWrite (10,HIGH);// clockwise
rotation
     digitalWrite (11,LOW);
     delay(5000);
     digitalWrite (11,HIGH);// anti-
clockwise rotation
     digitalWrite (10,LOW);
     delay(1000);

   }
      else
   {
     Serial.print("v= ");
    Serial.println(input_voltage);
    lcd.setCursor(1, 1);
    lcd.print("Access Denied");// When
the input force is very less
    }
}
```

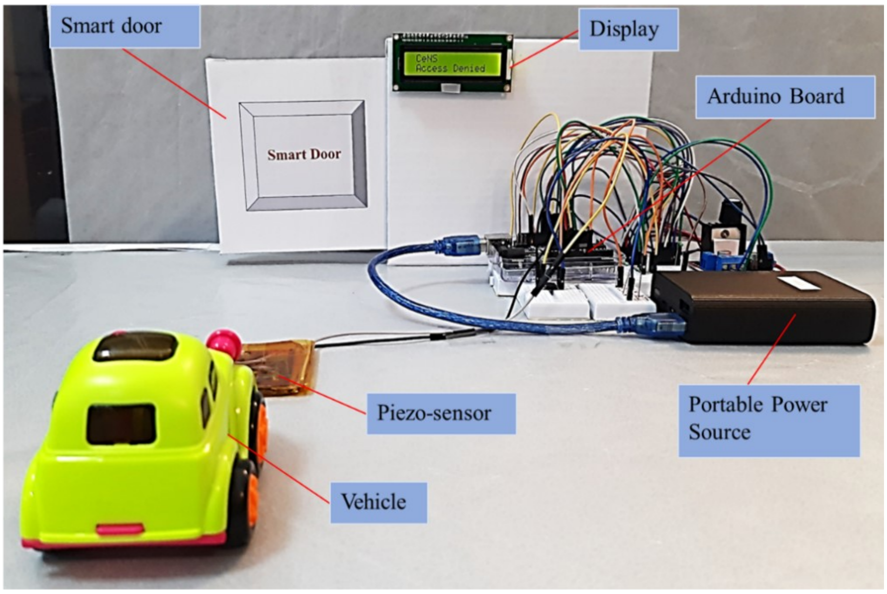

Figure S15. Programme coding and lab scale setup of smart door operated by piezo-sensor with well labelled.

Supplementary file number –S16

S.16 Supplementary Movies

ESI Movie 1. LEDs glowing
ESI Movie 2. LCD powered by the prototype
ESI Movie 3. Capacitor charging by prototype
ESI Movie 4. Heel tapping
ESI Movie 5. Toe-tapping
ESI Movie 6. Road safety sensor demonstration
ESI Movie 7. Smart door controlled by prototype as pressure sensor demonstration