# Theory of Heat Flux Sensor

## 1. Sensitivity

A heat flux sensor (HFS) with 'n' number of thermocouples with a Seebeck coefficient per thermocouple ($\alpha_T = |\alpha_p| + |\alpha_n|$), the output voltage $V_{out}$ for a temperature difference $\Delta T$ can be expressed as;

$$V_{out} = n\alpha_T \Delta T$$

The corresponding sensitivity of the heat flux sensor is:

$$S = \frac{V_{out}}{q}$$

The 'q' is the heat flux through the HFS. In transient state;

$$\vec{q} = -\kappa \frac{\partial T}{\partial x},$$

where x is the coordinate in the direction collinear to the heat flux vector $\vec{q}$. In this case, $\frac{\partial T}{\partial x} = \frac{\delta T_{HFS}}{\delta_{HFS}}$. The corresponding sensitivity of the heat flux sensor is;

$$S = \frac{n\alpha_T \delta}{\kappa}$$

Where $\delta$ is the thickness of the heat flux sensor.

## 2. The noise equivalent power (NEP)

The NEP can be expressed by the following equations:

$$NEP = \frac{Noise\ RMS}{Sensitivity} = \frac{V_n}{S}$$

The $V_n$ can be estimated as;

$$V_n = \sqrt{4k_B TR}$$

So,

$$NEP = \frac{\kappa\sqrt{4k_B TR}}{n\alpha_T \delta} \ \left[= \frac{W}{m^2\sqrt{Hz}}\right]$$

## 3. Detectivity (D)

The detectivity is expressed by;

$$D = \frac{1}{NEP}\sqrt{A}\ [= \frac{m^3\sqrt{Hz}}{W}]$$

Where 'A' is the area of the heat flux sensor

Hence,

$$D = \frac{n\alpha_T\delta}{\kappa}\sqrt{\frac{A}{4k_BTR}}$$