Supplementary Materials for

Optimal design of wearable micro thermoelectric generator working in a height-confined space

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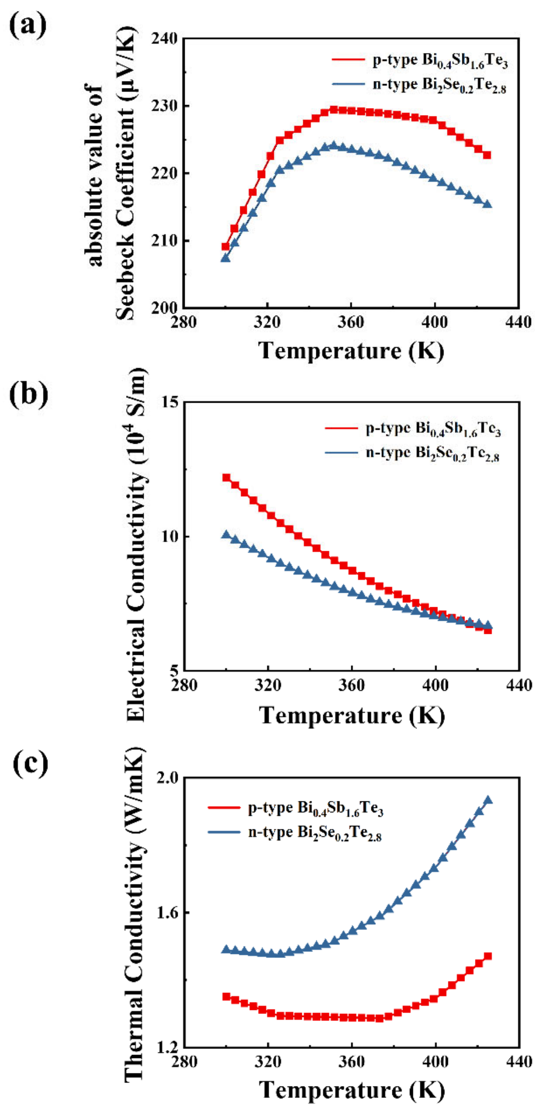

Figure S1. Temperature dependent properties of p-type $Bi_{0.4}Sb_{1.6}Te_3$ and n-type $Bi_2Se_{0.2}Te_{2.8}$ thermoelectric materials: (a) absolute value of Seebeck coefficient; (b) electrical conductivity; (c) thermal conductivity.

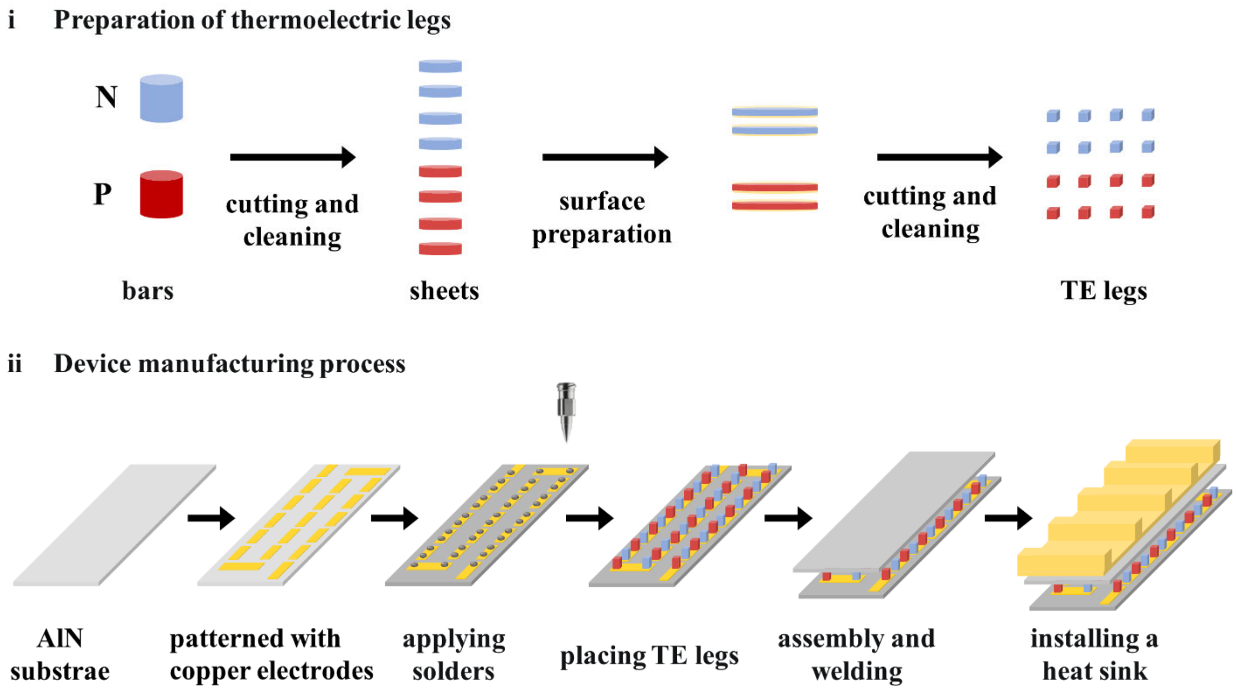

Figure S2. The manufacturing process flow chart of the micro device.

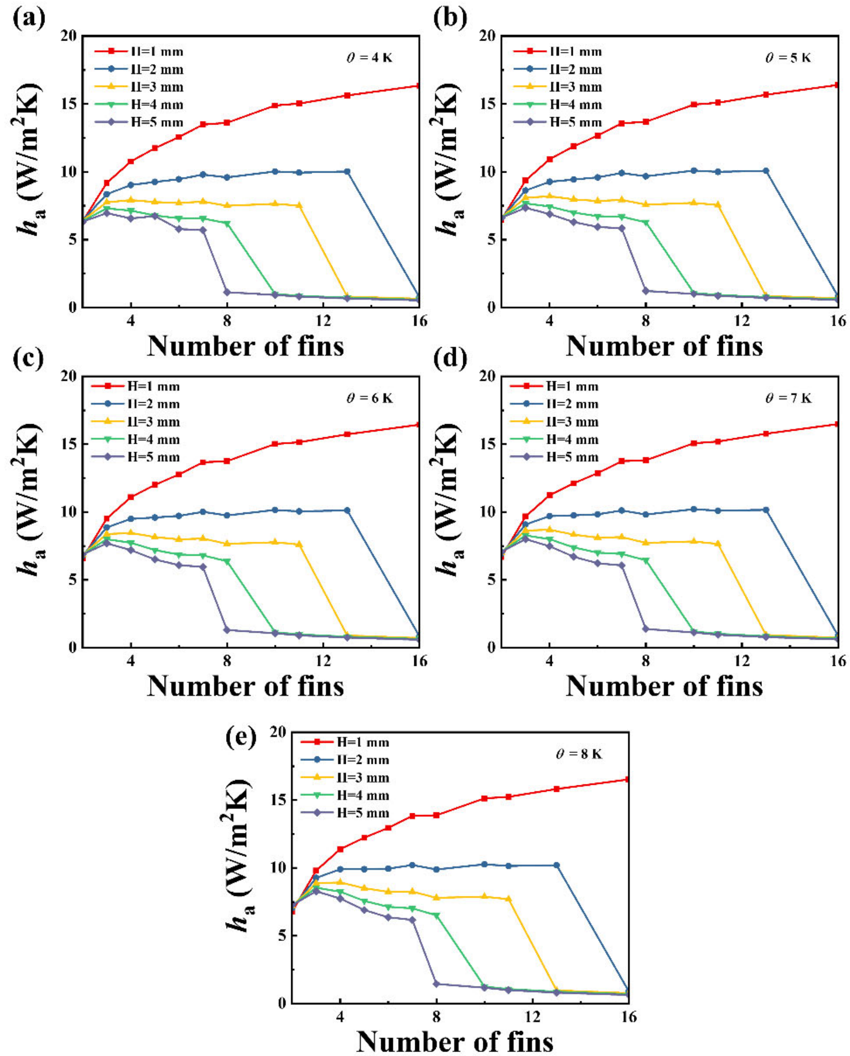

Figure S3. The relationship among the convective heat transfer coefficient per unit area (h_a), fin height (H) and number of fins under different temperature difference (θ) between fin base and the ambient: (a) $\theta = 4$ K, (b) $\theta = 5$ K, (c) $\theta = 6$ K, (d) $\theta = 7$ K, and (e) $\theta = 8$ K.

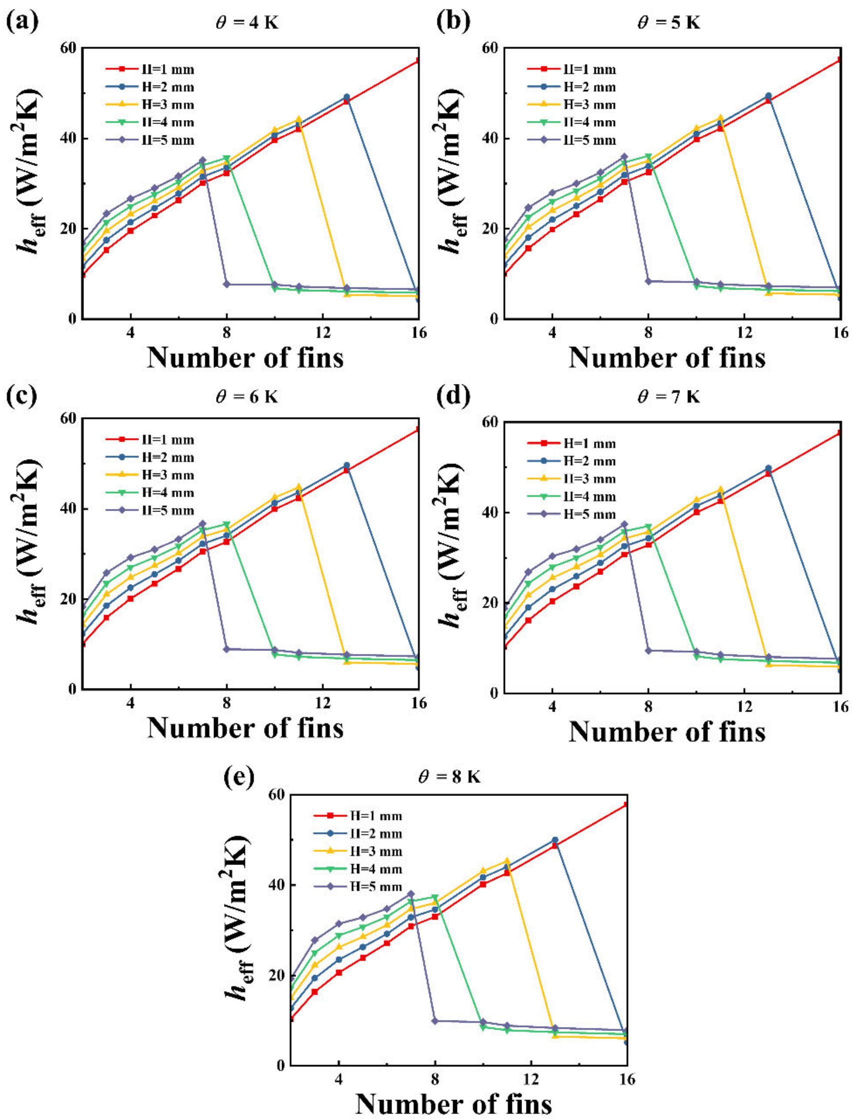

Figure S4. The relationship among the equivalent convective heat transfer coefficient (h_{eff}), fin height (H) and number of fins under different temperature difference (θ) between fin base and the ambient: (a) $\theta = 4$ K, (b) $\theta = 5$ K, (c) $\theta = 6$ K, (d) $\theta = 7$ K, and (e) $\theta = 8$ K.

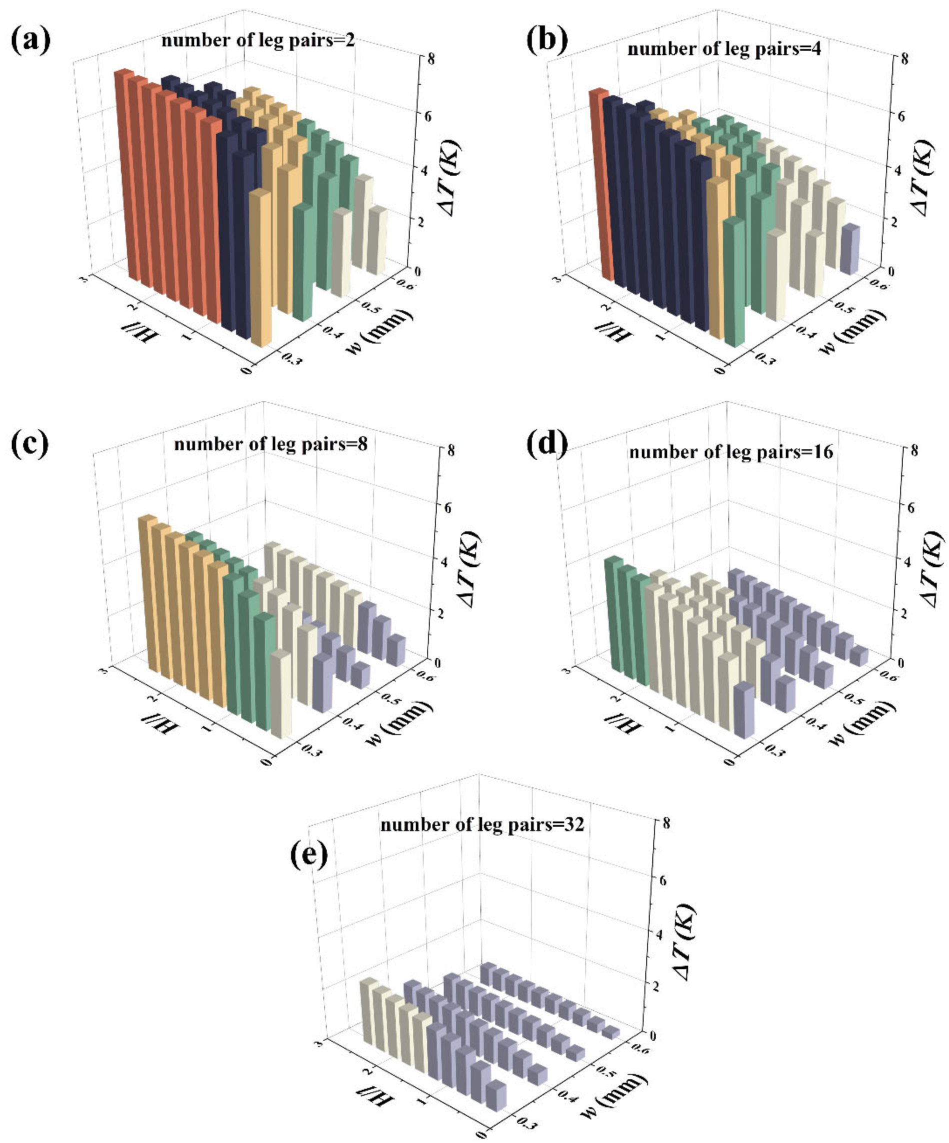

Figure S5. The relationship among the temperature difference between the two ends of the device (ΔT), the ratio of leg height to fin height (l/H), leg width (w) with different number of leg pairs: (a) 2, (b) 4, (c) 8, (d) 16, and (e) 32.

Method

To enhance the accuracy of convective heat transfer coefficient calculations in fin structures, we propose a closed-loop calculation program in this study. Initially, an assumed value for the convective heat transfer coefficient of the fin surface, denoted as h_{fin}, is inputted into the program. Subsequently, the fin efficiency is computed using this assumed value, and a new value of the fin surface convective heat transfer coefficient is derived. The new value is then used to validate the reasonability of the initial assumption. If the difference between the solved convective heat transfer coefficient and the initial assumed value for the fin is less than the prescribed calculation accuracy (set to 10^{-5} in our study), the convective heat transfer coefficient is considered the true value. In the event that the difference exceeds the calculation accuracy, the calculated value becomes the new assumed value for the next iteration until the accuracy requirement is satisfied. By iteratively updating the assumed values, our closed-loop calculation program can provide accurate and reliable results for convective heat transfer coefficient calculations in fin structures. The proposed method can have broad applications in the design and optimization of finned heat sinks, heat exchangers, and other similar heat transfer systems.

Program code

```
clear
clc
tic

W=0.016;
L=0.004;
B=0.0005;
H=0.001:0.001:0.005;
s=0.0005:0.0002:0.007;
t=0.0005;
k=398;
rho=8930;
Tbase=34;
Tm=25;
g=9.8;

% Part 1 - Air parameters under different temperature calculated by fitting

T1=(Tbase+Tm)/2;
if T1<-190
        rhoair=4.6;
        Cp=1085;
        kairbase=0.008;
        vbase=0.000001;
        Prbase=0.82;
        betabase=0.0139;
elseif -190<=T1<=-50
        kairbase=0.02431953809+7.518224311E-5*T1-5.763988567E-8*T1^2+1.940778858E-
11*T1^3;
        vbase=1.259475411E-5+9.442592043E-8*T1+8.659465938E-11*T1^2-1.131848448E-
14*T1^3;
        Prbase=0.7748565913+0.002684876119*T1+4.555821026E-5*T1^2+3.042822449E-
7*T1^3+7.625823457E-10*T1^4;
        betabase=9.689932248E-4-1.071676635E-4*T1-9.819884521E-7*T1^2-3.98587543E-
9*T1^3;
elseif -50<T1<100
        kairbase=0.02436042515+7.65402427E-5*T1-4.427109391E-8*T1^2+4.840868215E-
11*T1^3;
        vbase=1.331591261E-5+8.764705688E-8*T1+1.129519999E-10*T1^2-6.096246859E-
14*T1^3;
        Prbase=0.7108349532-1.549219913E-4*T1+5.457110087E-7*T1^2-5.4115776E-
10*T1^3;
        betabase=0.00367381015-1.368428997E-5*T1+5.168098484E-8*T1^2-1.415765736E-
10*T1^3;
```

```
elseif 100<T1<=400
        kairbase=0.02442641558+7.518614412E-5*T1-3.413036936E-8*T1^2+1.878191914E-
11*T1^3;
        vbase=1.324027252E-5+8.922356539E-8*T1+1.008844371E-10*T1^2-2.464624954E-
14*T1^3;
        Prbase=0.7110306957-1.591492564E-4*T1+5.605131E-7*T1^2-4.561145485E-
10*T1^3;
        betabase=0.003527650338-1.020010748E-5*T1+1.861552011E-8*T1^2-1.473895167E-
11*T1^3;
end
betafin=betabase;
kairfin=kairbase;
vfin=vbase;
Prfin=Prbase;
thetabase=Tbase-Tm;
e=0;
for i=1:length(H)
        for j=1:length(s)
                for p=1:length(t)
e=e+1
n(e)=floor(W/(t(p)+s(j)));


% Part 2 - Calculate the heat dissipated by the base plate of the heat sink

if s(j)/H(i)<=0.28
        Grbase(e)=g*betabase*thetabase*H(i)^3/vbase^2;
        Rabase(e)=Grbase(e)*Prbase;
        if 10^4<=Grbase(e)<=4.6*10^5
                Nubase(e)=0.212*Rabase(e)^0.25;
        elseif Grbase(e)>4.6*10^5
                Nubase(e)=0.061*Rabase(e)^(1/3);
        elseif Grbase(e)<2430
                Nubase(e)=1;
        end
        hbase(e)=Nubase(e)*kairbase/H(i);
elseif s(j)/H(i)>0.28
        Grbase(e)=g*betabase*thetabase*((s(j)*L)/2/(s(j)+L))^3/vbase^2;
        Rabase(e)=Grbase(e)*Prbase;
        if Rabase(e)<2*10^4
                Nubase(e)=1;
        elseif 10^5<=Rabase(e)<=2*10^7
                Nubase(e)=0.54*Rabase(e)^(1/4);
        elseif 2*10^7<Rabase(e)<=3*10^10
                Nubase(e)=0.14*Rabase(e)^(1/3);
        end
```

```
        hbase(e)=Nubase(e)*kairbase/((s(j)*L)/2/(s(j)+L));
end
Qbase(e)=hbase(e)*(n(e)-1)*s(j)*L*thetabase;

% Part 3 - Calculate the heat dissipated by the middle fins of the heat sink

hfinA(e)=0.1;
for q=1:1000
        Ac(e)=L*t(p);
        P(e)=2*(L+t(p));
        mA(e)=sqrt(hfinA(e)*P(e)/(k*Ac(e)));
        H1(i)=H(i)+t(p)/2;
        eta(e)=tanh(mA(e)*H1(i))/(mA(e)*H1(i));
        Rafin(e)=g*betafin*thetabase*Prfin*s(j)^4/(L*vfin^2);
        Nufin(e)=(576/(eta(e)*Rafin(e))^2+2.873/(eta(e)*Rafin(e))^0.5)^(-0.5);
        hfinB(e)=Nufin(e)*kairfin/s(j);
        hfinBB(q)=hfinB(e);
        if abs(hfinB(e)-hfinA(e))<10^-5
                hfin(e)=hfinA(e);
                break
        else
                hfinA(e)=hfinB(e);
                continue
        end
        hfinAA(q)=hfinA(e);
end
Qfin(e)=hfin(e)*2*H(i)*L*thetabase;

% Part 4 - Calculate the heat dissipated by the end fins of the heat sink

GrfinB(e)=g*betabase*thetabase*H(i)^3/vbase^2;
RafinB(e)=GrfinB(e)*Prfin;
if 1.43*10^4<=GrfinB(e)<=3*10^9
        NufinB(e)=0.59*RafinB(e)^0.25;
elseif 3*10^9<GrfinB(e)<=2*10^10
        NufinB(e)=0.0292*RafinB(e)^0.39;
elseif GrfinB(e)>2*10^10
        NufinB(e)=0.11*RafinB(e)^(1/3);
end
hfinB(e)=NufinB(e)*kairfin/H(i);
QfinB(e)=hfinB(e)*2*H(i)*L*thetabase;

% Sum the heat disspated by the heat sink

Q(e)=(n(e)-1)*Qfin(e)+QfinB(e)+Qbase(e);
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```
% Calculate different kinds of heat transfer coefficient
% Area Heat transfer coefficient

Area(e)=(n(e)-1)*s(j)*L+n(e)*2*H(i)*(t(p)+L)+L*t(p)*n(e);
AA(e)=W*L;
ha(e)=Q(e)/Area(e)/thetabase;
heff(e)=Q(e)/thetabase/AA(e);
T(e,:)=[H(i),s(j),t(p),n(e),Area(e),AA(e),ha(e),heff(e)];
        end
    end
end
disp(T)
toc
```