Custom Method for Automation of Microbolometer Design and Simulation

Mykhaylo Melnyk, Andriy Kernytskyy, Mykhailo Lobur
Department of Computer Aided Systems
Lviv Polytechnic National University
Lviv, Ukraine
melnykmr@gmail.com

Michal Szermer, Piotr Zajac, Cezary Maj, Wojciech Zabierowski
Department of Microelectronics and Computer Science
Lodz University of Technology
Lodz, Poland
michal.szermer@p.lodz.pl

***Abstract*—This paper presents an approach to facilitate the design of a microbolometer. It is based on three main steps: the construction of a simplified model in Matlab, automatic transfer of the generated model into ANSYS and the verification of the model using ANSYS FEM (Finite Element Method) simulation. The novel idea is the second step, realized using a special application, which reads the parameters from the simplified model and automatically creates a batch file for ANSYS with all appropriate material and geometry data as well as loads and simulation parameters.**

***Keywords*—heat loss, thermal imaging camera, MEMS, computer-aided design, microbolometer, FEM simulation, modelling**

I. INTRODUCTION

There has been a significant increase in the cost of energy for Ukrainian property owners. Therefore the identification of places through which most heat is lost is a vital task. Similar problems are present in other countries, for example in a typical British home, around one-third of the heat produced by a central heating system is rapidly lost through the roof, ceiling and walls. This means that for a poorly insulated property up to £1 out of every £3 spent on heating is being wasted [1].

In the EU and North America during construction the design software packages are used which calculate residential and other building heating and cooling [2], [3]. As for old buildings, there are many government programs to address these shortcomings [4]. Thermal imaging cameras are used as the technical tools that allow detecting heat losses [5]-[7]. Each pixel of a sensitive element of a thermal imaging camera is a microbolometer [8]. Thermal imaging cameras are also used in the army. Originally developed for military use [9], thermographic cameras have rapidly migrated into other fields as varied as building inspection, anti-terrorism, flame detectors, aerial archeology and medicine [10]-[12]. Therefore, research in this area is important and design needs to be further improved for better sensitivity and frame rate.

To model such devices today software packages using finite element method are used, namely ANSYS [13], [14], COMSOL [15], Coventor [16], etc. However, looking for optimal parameters of these microdevices takes a lot of time. Therefore it was decided to develop a program that would enable the use of simplified models on the initial stage. For the case study we used the model of microbolometer in Matlab with automatic conversion of selected geometry and material parameters of the simulation into ANSYS.

II. SIMULATION WITH SIMPLIFIED MODEL

Nowadays, there are many software packages that allow quickly and easily carry out mathematical calculations of varying difficulty, namely: Mathematica, Matlab, Mathcad, etc. [17], [18]. Matlab was selected because this system has many built-in functions and modules that enable effective implementation of the set objectives. With its intuitive graphical interface Matlab allows creating the developed software that is easy to use and does not require any special skills to operate with complex mathematical packages.

The user interface of the Matlab application is shown in Fig. 1. In this window, a user can set the properties for each material (i.e. thermal conductivity, heat capacity, electrical resistance, etc.) and all the sizes of the device elements (i.e. the total device height/width, the thickness of individual layers, the detailed size of anchors, etc.). The input simulation parameters can be also specified (i.e. bias current, current pulse time, radiation power, etc.). Based on these data, the program automatically calculates such device properties as thermal resistance, heat capacity, thermal time constant, electrical resistance, etc. However, the most important feature is that a user can immediately see on the graph the thermal response of the microbolometer. Thus, in a very easy and user-friendly way, a designer can modify the parameters and observe how they influence the temperature response. Therefore, it greatly facilitates the process of finding the desired device parameters. Moreover, in the top right corner the program shows the geometry of the device so the designer can quickly verify if the geometrical input data is correct.

The checkbox “Show isolation” allows displaying isolation in the area of visualization, or vice versa to remove isolation for visual verification of correct input of geometrical sizes of the active material. This checkbox also determines whether the designed program will generate code for the ANSYS system with settings just for the geometry of the active material, or all a complete set of parameters including boundary conditions and an automatic start of calculation. The example that includes isolation is presented in Fig. 2.

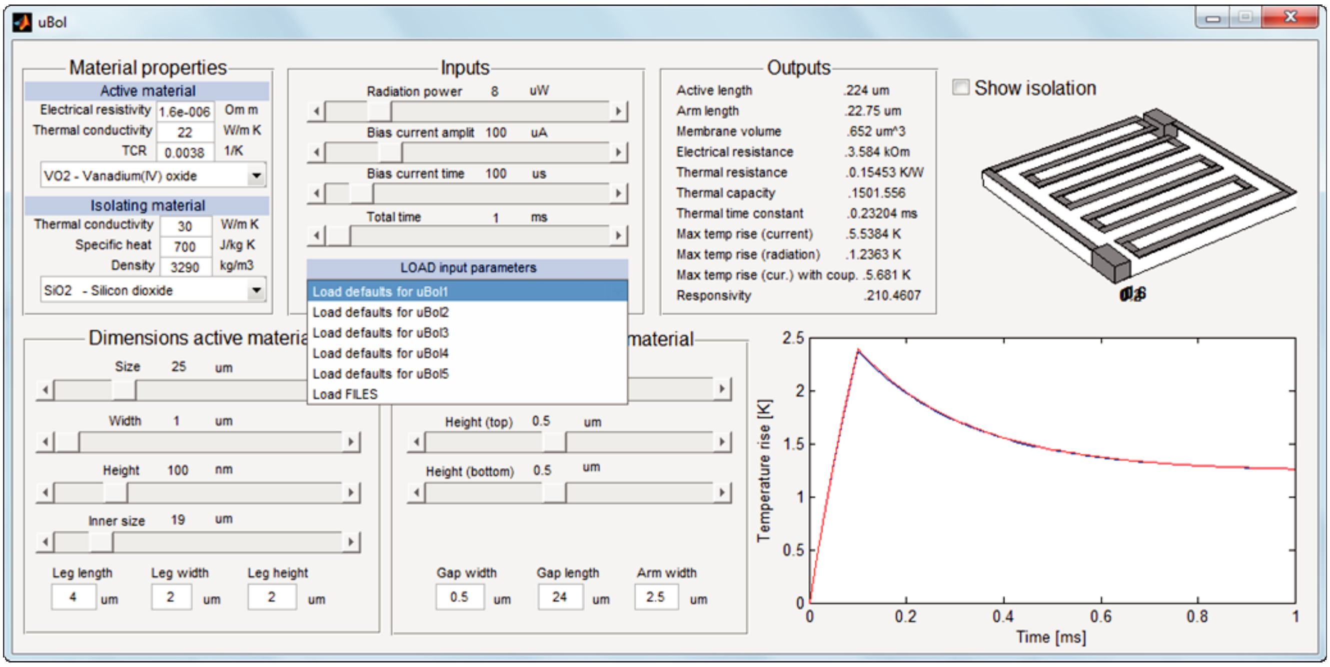


Fig. 1. User interface

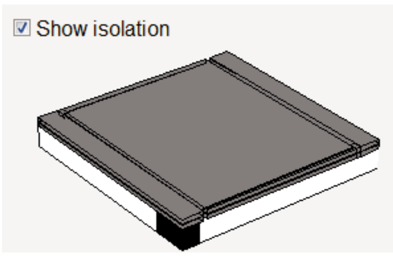
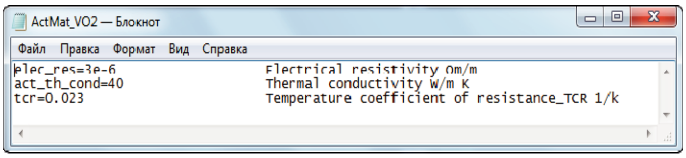


Fig. 2. Microbolometer with insulating material

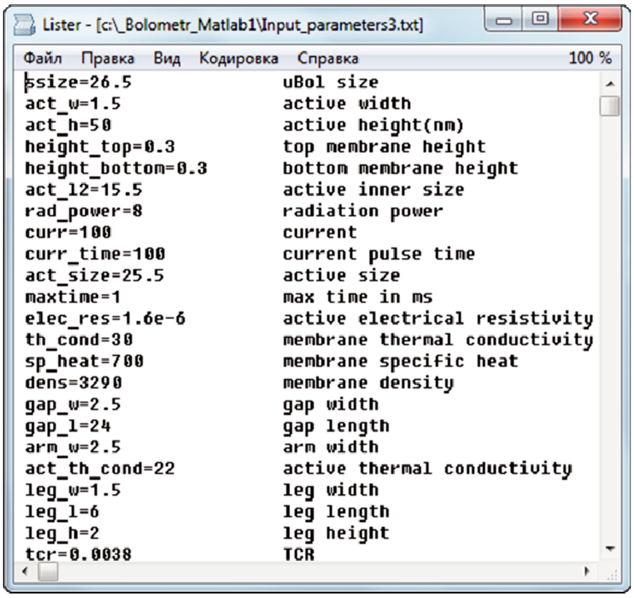


ActMat_VO2 — Блокнот

Файл Правка Формат Вид Справка

```
elec_res=3e-6                    Electrical resistivity Om/m
act_th_cond=40                   Thermal conductivity W/m K
tcr=0.023                        Temperature coefficient of resistance_TCR 1/k
```

Fig. 3. Configuration file for active material properties



Lister - [c:_Bolometr_Matlab1\Input_parameters3.txt]

Файл Правка Вид Кодировка Справка 100 %

```
size=26.5               uBol size
act_w=1.5               active width
act_h=50                active height(nm)
height_top=0.3          top membrane height
height_bottom=0.3       bottom membrane height
act_l2=15.5             active inner size
rad_power=8             radiation power
curr=100                current
curr_time=100           current pulse time
act_size=25.5           active size
maxtime=1               max time in ms
elec_res=1.6e-6         active electrical resistivity
th_cond=30              membrane thermal conductivity
sp_heat=700             membrane specific heat
dens=3290               membrane density
gap_w=2.5               gap width
gap_l=24                gap length
arm_w=2.5               arm width
act_th_cond=22          active thermal conductivity
leg_w=1.5               leg width
leg_l=6                 leg length
leg_h=2                 leg height
tcr=0.0038              TCR
```

Fig. 4. Configuration file for microbolometer parameters

A special module was developed that allows reading the data from pre-designed configuration files. The example of a configuration file for material properties of the active surface of a microbolometer is presented in Fig. 3, and the configuration file of the other available microbolometer parameters are presented in Fig. 4.

III. CONVERSION INTO ANSYS MODEL

In our case the microbolometer model can be divided into cuboid blocks, so for its visualization in Matlab we are using such blocks. Let us consider this using an anchor as an example. To construct the anchor we define eight vertices that form six sides. In Figs. 5 and 6 the numbers and coordinates of the anchor vertices are presented.

A comparison of commands for building anchors in Matlab and ANSYS is presented in Tab. 1.

TABLE I. INSTRUCTIONS TO BUILD AN ANCHOR

MATLAB	ANSYS
x=[0 2 2 0 0 2 2 0];	k,1,0,0
y=[0 0 4 4 0 0 4 4];	k,2,2,0
z=[-2-2-2-2 0 0 0 0];	k,3,2,4
F= [1 2 3 4; 5 6 7 8; 4 3 7 8; 1 4 8 5; 1 2 6 5; 2 3 7 6;];	k,4,0,4
V=[x y z];	a,4,3,2,1
patch('Vertices',V,'Faces', F);	vext,1,,,,,-2,

After analyzing the model in Matlab and command file for microbolometer simulation in ANSYS it was found that it is possible to record the coordinates at every step of constructing 3D models in Matlab and based on them to generate a batch file for ANSYS. A fragment of the program for automatic code generation for ANSYS is presented in Fig. 7.

The result of the program (presented in Fig. 7) is a batch file for ANSYS presented in Fig. 8. Such batch file can be used for importing into ANSYS the geometry presented in Fig. 9.

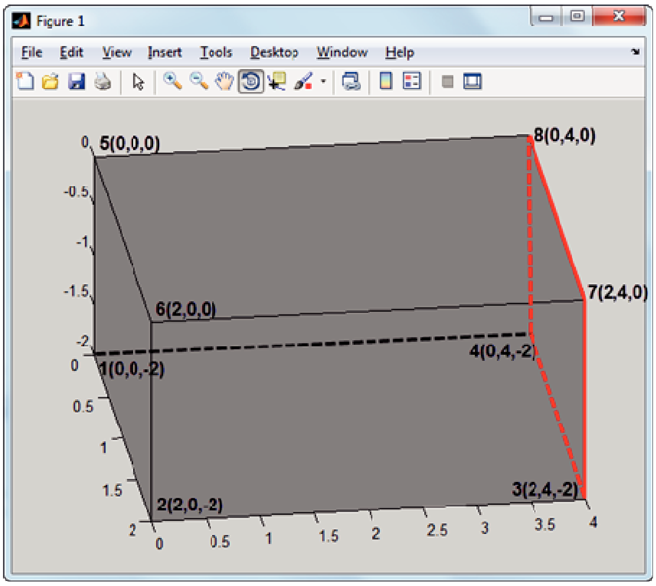


Fig. 5. Anchor visualization in Matlab

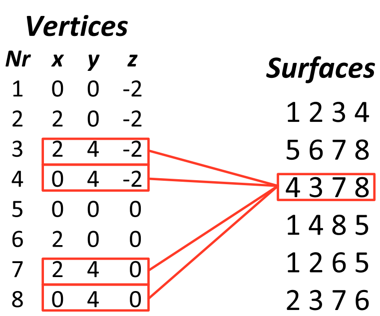


Fig. 6. Vertices and surfaces mapping for anchor visualization in Matlab

```
% Conversion to ANSYS start
 [r c]=size(a_x)
 fid = fopen('uBOL.txt','wt');
 fprintf(fid,'%s\n','FINISH');
 fprintf(fid,'%s\n','/CLEAR,START');
 fprintf(fid,'%s\n','/PREP7');
 j=3;  % 3 because we miss two anchors for aadd ANSYS
 aadd='aadd';
 for i=1:r
  a_xy=strcat('k,',num2str(i),',',num2str(a_x(i,1)),',',num2str(a_y(i,1)));
  fprintf(fid,'%s\n',a_xy);
  if rem(i,4)==0
   a_xy=strcat('a,',num2str(i),',',num2str(i-1),',',num2str(i-2),',',num2str(i-3));
   fprintf(fid,'%s\n',a_xy);
  end
  if i>8
   aadd=strcat(aadd,',',num2str(j));
   j=j+1;
  end
 end
 fprintf(fid,'%s\n',aadd);
 fprintf(fid,'%s\n',strcat('vext,1,,,,,',num2str(-leg_h),','));
 fprintf(fid,'%s\n',strcat('vext,2,,,,,',num2str(-leg_h),','));
 fprintf(fid,'%s\n',strcat('vext,22,,,,,',num2str(-h),','));
fprintf(fid,'%s\n','VGLUE,1,2,3 ! Define area');
```

Fig. 7. A fragment of the program code for converting geometry of microbolometer into code into ANSYS batch file

```
/CLEAR,START
/PREP7
k,1,0,0
k,2,2,0
k,3,2,4
k,4,0,4
a,4,3,2,1
k,5,23,21
…
k,83,22,22
k,84,3,22
a,84,83,82,81
aadd,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,
29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,
54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78
vext,1,,,,,-3,
vext,2,,,,,-3,
vext,22,,,,,-0.1,
VGLUE,1,2,3 ! Define area
```

Fig. 8. The batch file for ANSYS

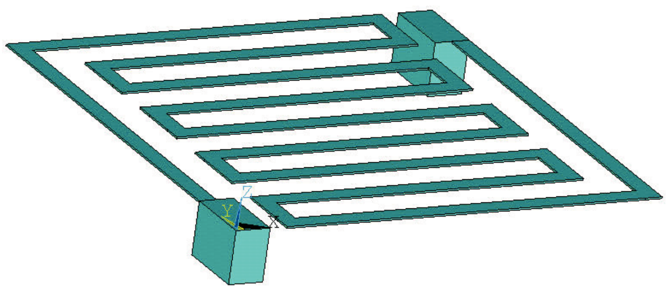


Fig. 9. Microbolometer geometry imported into ANSYS

To automatically generate not only the geometry of the active material and anchors but also isolation, boundary conditions, simulations loads and other parameters of the design, "Show isolation" checkbox should be ticked in the main window. This shows isolation on the screen and simultaneously generates a batch file for ANSYS, which will include modeling parameters, loads, etc. The output of automatically generated batch file is presented in Fig. 10: in this particular case it is a temperature distribution in a microbolometer caused by incident radiation.

IV. CONCLUSIONS

The paper presents a Matlab-based software for researching the properties of microbolometers which visualize microbolometer geometry. It allows preliminary fast simulation of a microbolometer. The designed model can be then completely automatically converted into ANSYS model using a custom-made application. Thus, the model which was initially developed by using fast but less accurate simulation can be quickly verified in ANSYS using a very accurate FEM simulation. Such an approach should significantly reduce the time spent on the selection of optimal parameters.

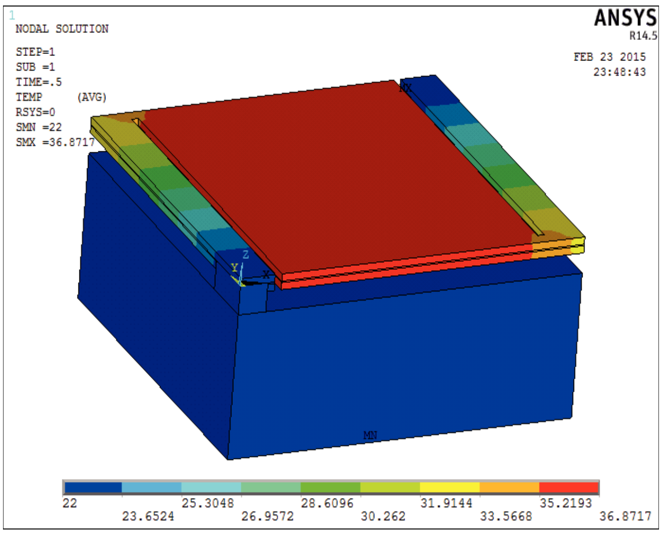


Fig. 10. The result of the steady-state thermal simulation of microbolometer

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