Cu-C COMPOSITE DETONATION COATINGS

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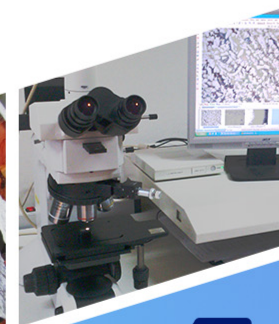


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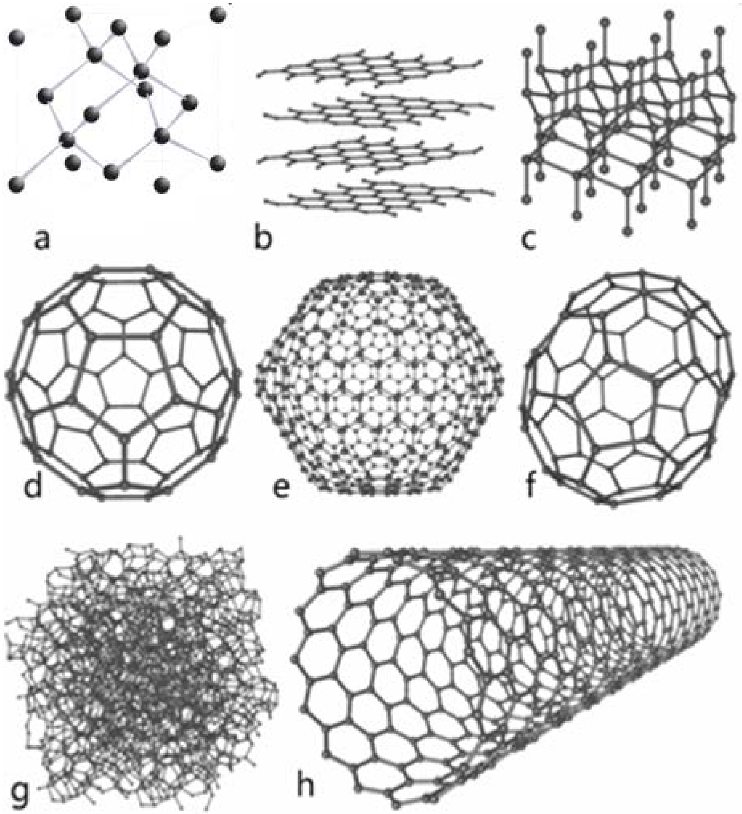
Carbon

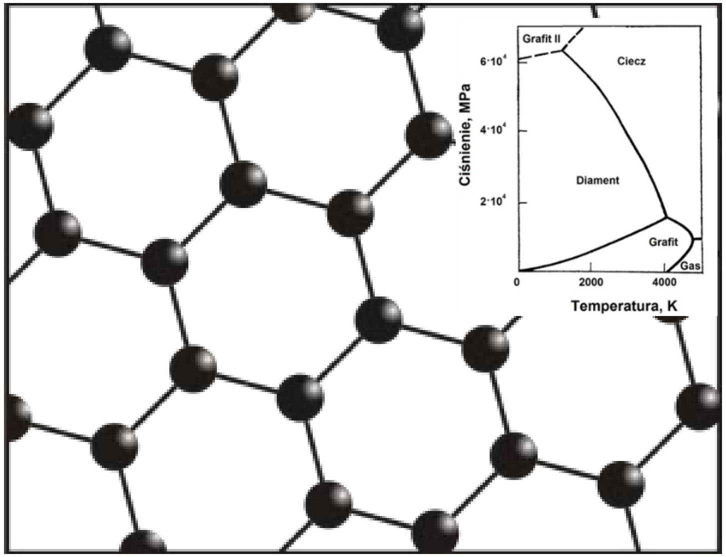


a) diamond, b) graphite, c) lonsdaleite,
d) fullerene C_{60}, e) fullerene C_{540},
f) fullerene C_{70}, g) amorphous carbon,
h) carbon nanotube

Graphene

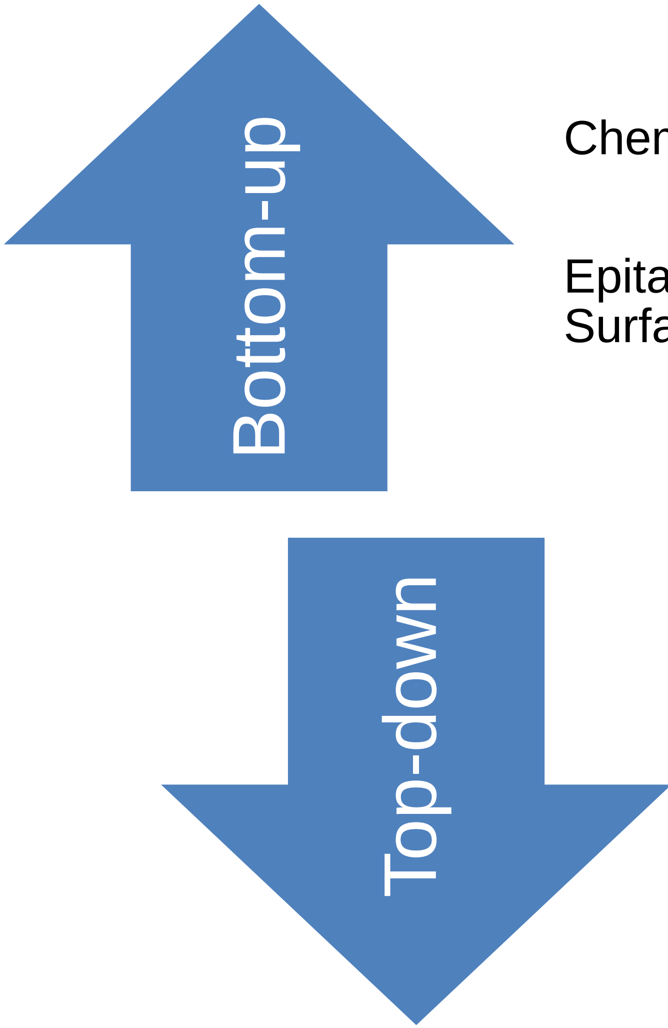
Properties of graphene

· high surface to volume ratio
· good conductivity of heat and electricity
· high mechanical strength and flexibility
· high optical transparency
· impermeable to gas
· bactericidal properties



Binding of hybridization sp^2 length of 0,142 nm

Produce of graphene



Chemical Vapor Deposition

Epitaxial Growth of Graphene on SiC Surface

Mechanical Exfoliation

Chemical Exfoliation

Institute of Precision Mechanics as the first and only one in Poland produces graphene on the powders.

Graphene 3D^{IMP} – composite material, where graphene covers powders of copper.

Copper powder covered with graphene

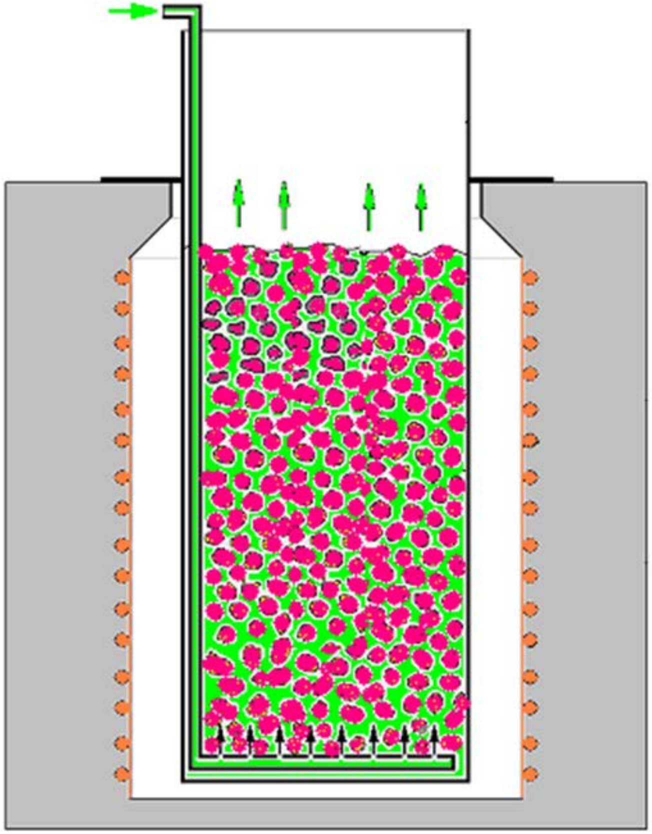
Produce of Graphene $3D^{IMP}$

Procedure for the production of Cu-C powders included the following steps:

1) *fluidization under gases containing hydrocarbons;*

2) high temperature decomposition of hydrocarbons which are carbon source;

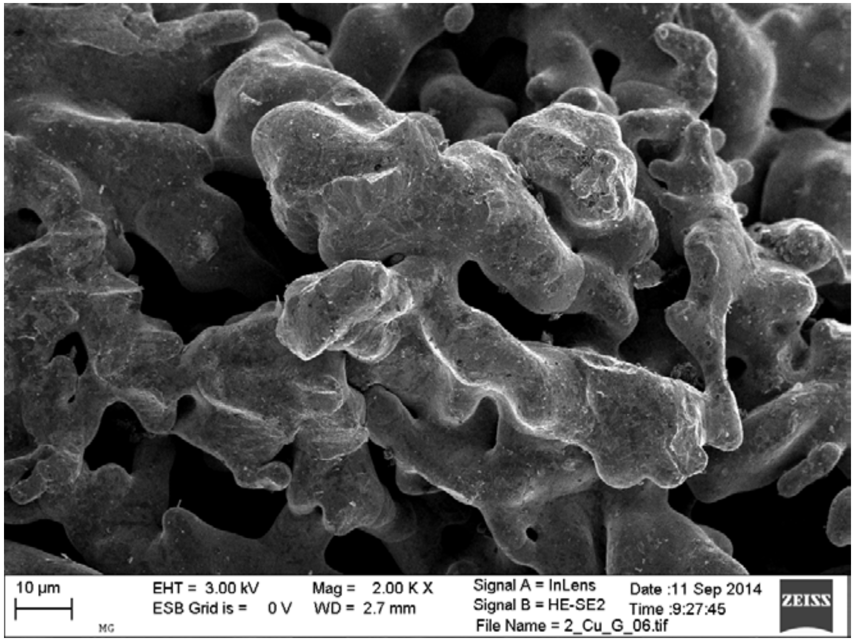
3) nucleation and growth of carbon structures on the surface of the copper (occurs through interaction of gases containing hydrocarbon, which surrounds the particles of powder)

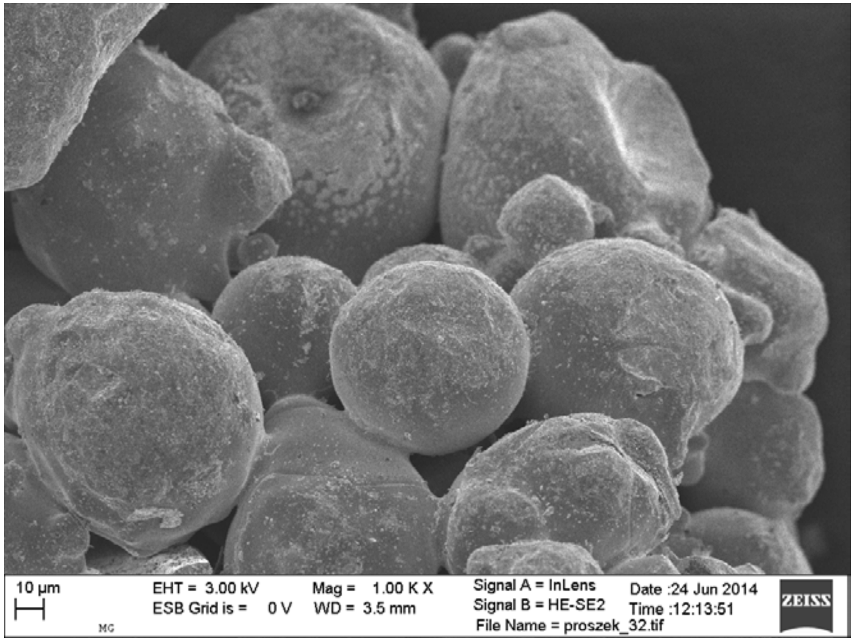


The scheme of the stand for fluidization processes

Graphene 3D^{IMP} – SEM

The Institute of Precision Mechanics uses mainly two copper powders to graphene production: dendritic and spherical.

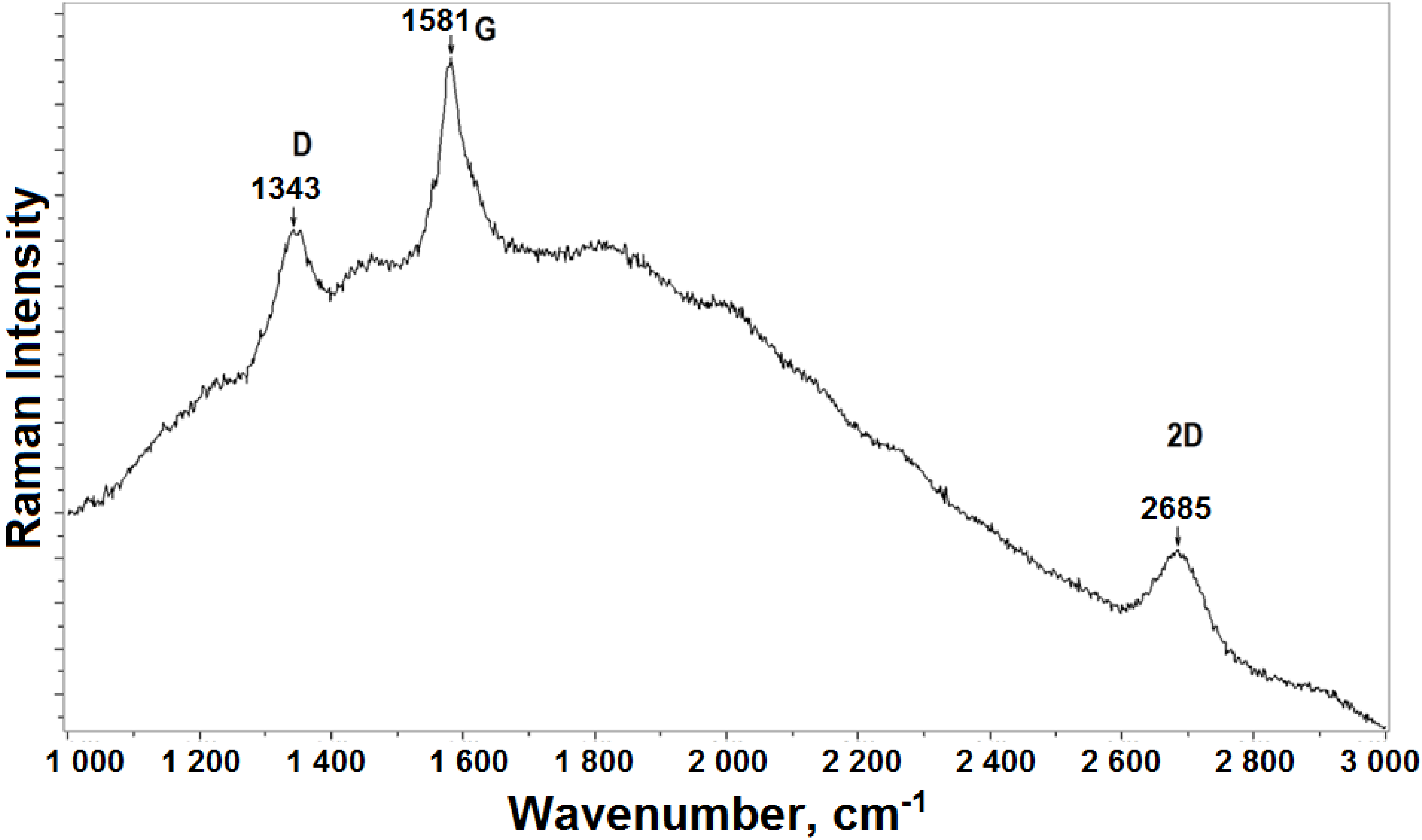




Dendritic copper powder particles after graphene processing

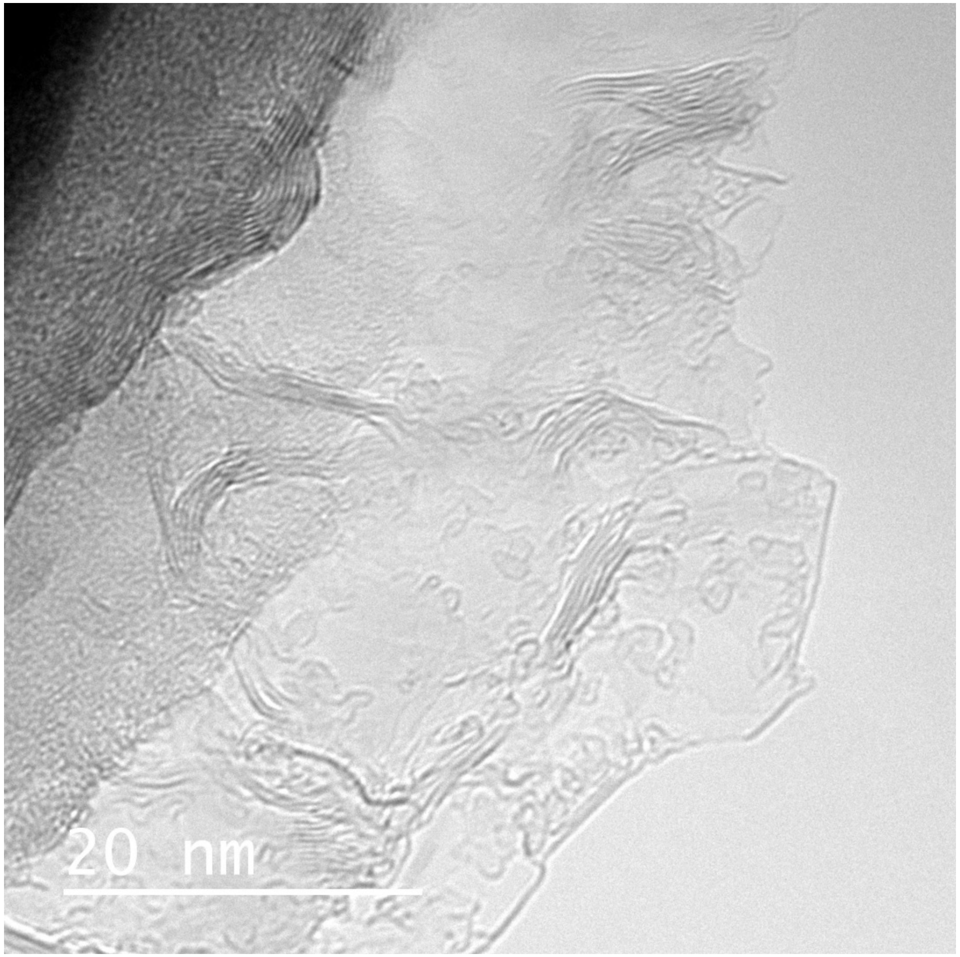
Spherical copper powder particles after graphene processing

Raman spectrum of Graphene 3D^{IMP}



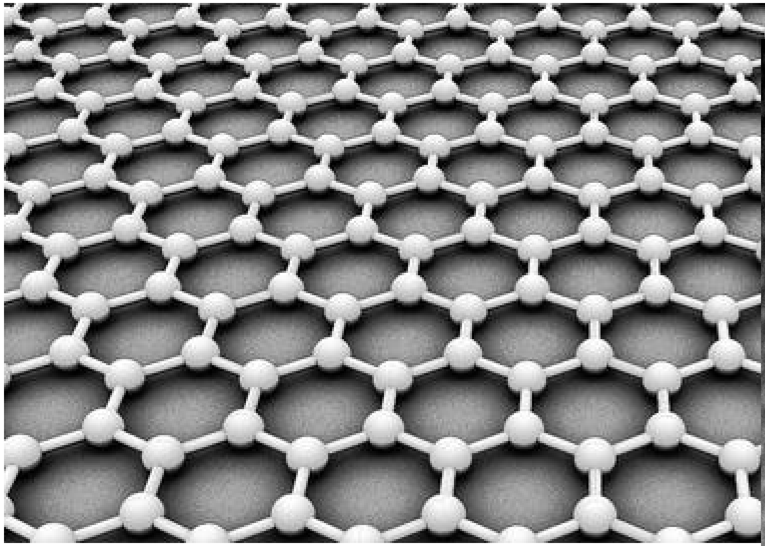
In the Raman spectra the peaks 2D and G characteristic for graphene spectra are clearly visible, which confirms its presence in the tested powders.

Graphene – TEM

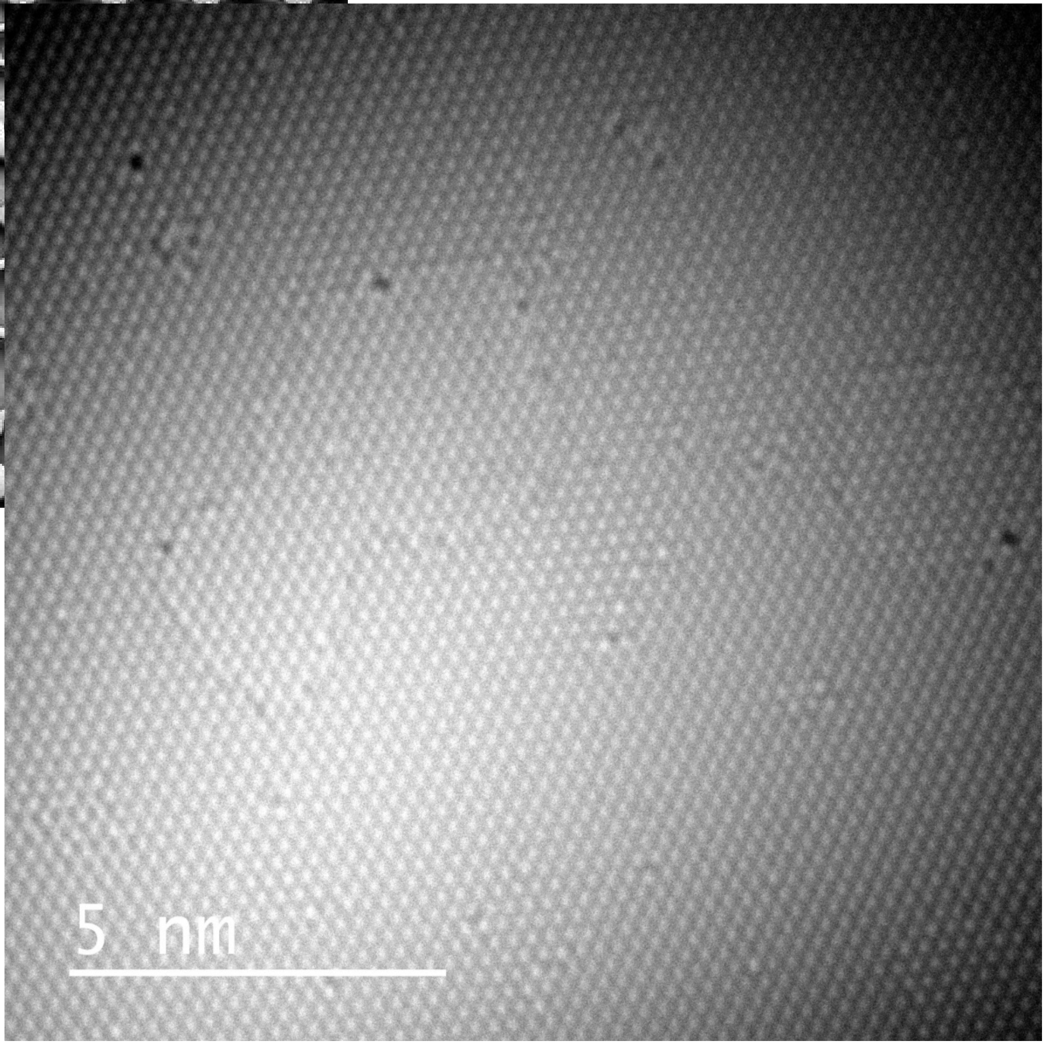


Graphene after copper etching

Graphene – TEM



Theoretical structure of graphene

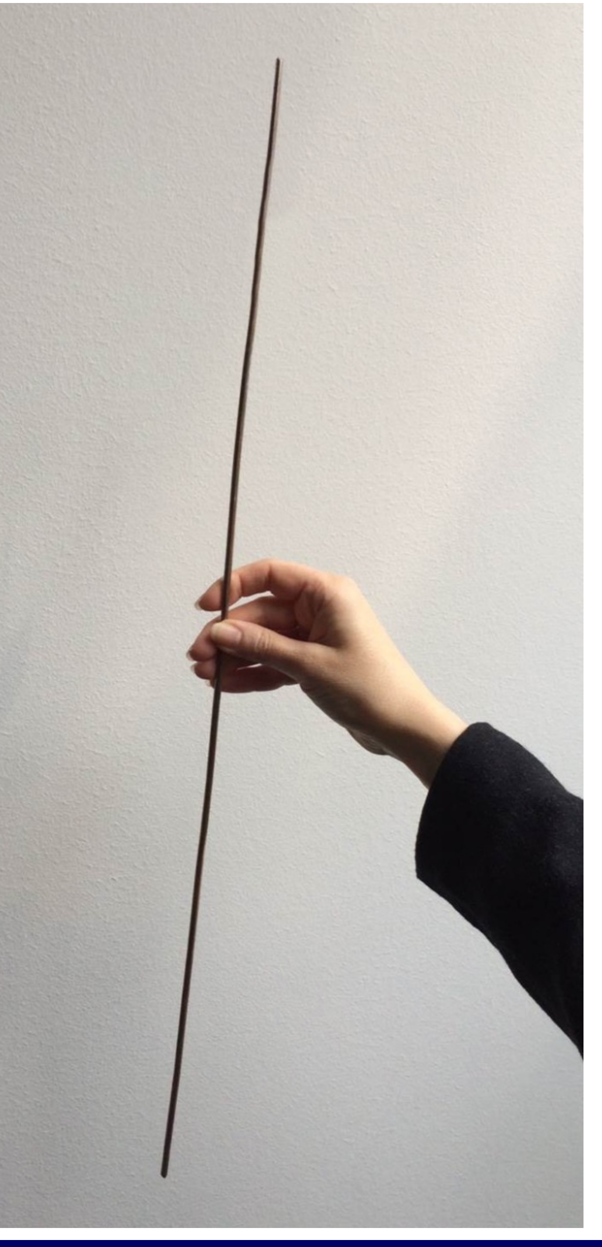


Graphene after copper etching

Consolidation of Graphene 3D^{IMP}

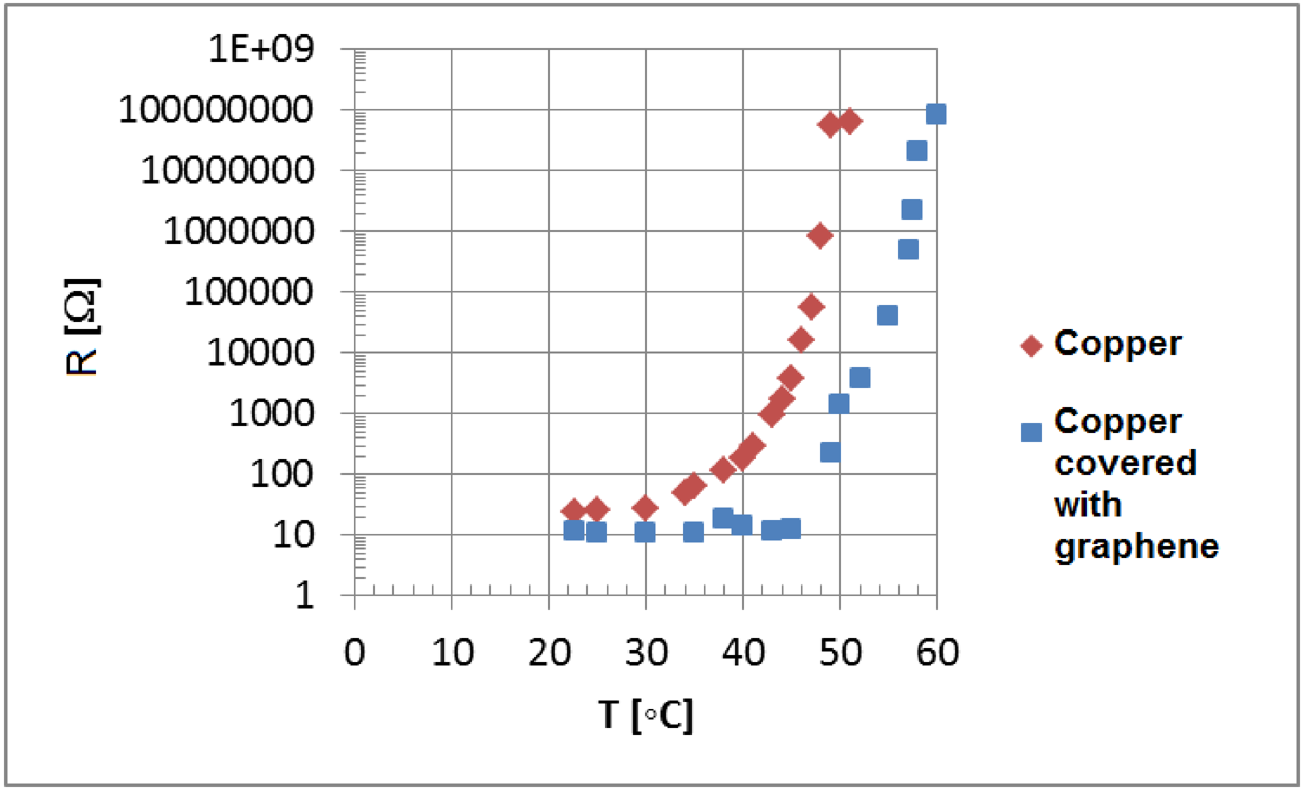
Methods of consolidation:

- cold isostatic pressing
- spark plasma sintering
- extrusion
- KOBO



Resistance of fuses

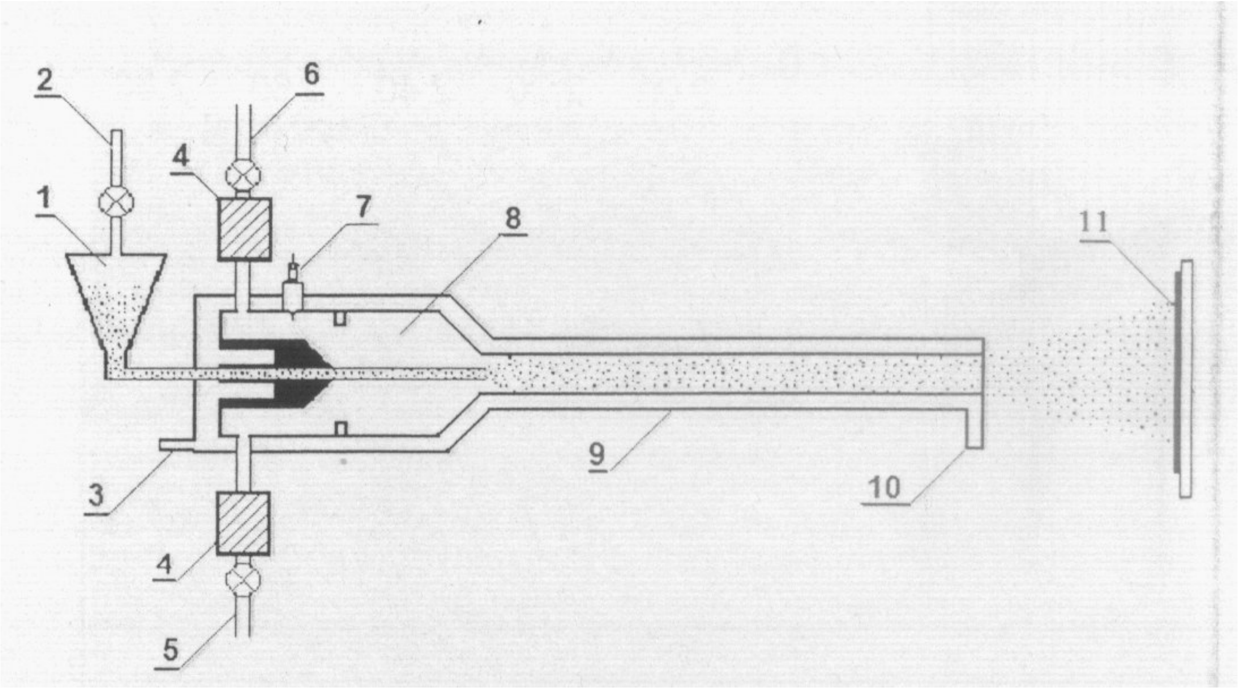
Fuses



Resistance of fuses

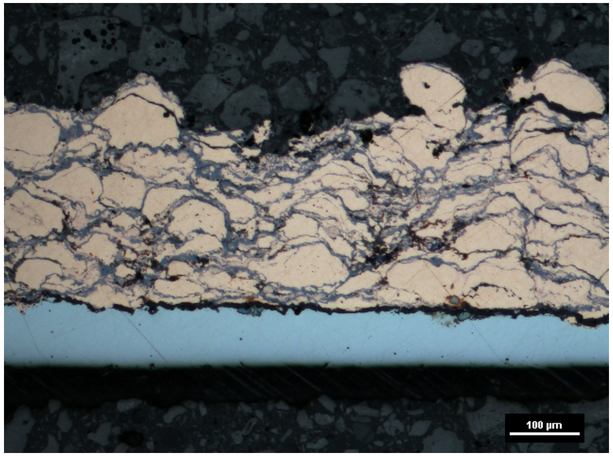
Detonation spraying

Powder particles can reach speed 1000 m/s
Spraying frequency: 4 Hz
Spraying distance: 160 mm
Powder particle size: 100 µm < D < 200 µm



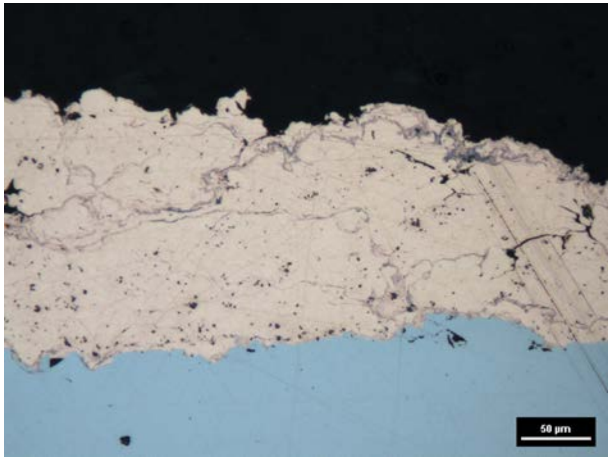
1- powder feeder; 2 – nitrogen; 3,10 – cooling system; 4 – security; 5 – propane-butane; 6 – oxygen; 7 – the ignition system; 8 – detonation chamber; 9 – barrel; 11 – substrate

Cu and Cu-C Coating



Cu coating

The pure copper powder is strongly oxidized during the process of spraying. A large number of oxides, which are included in the coating and are arranged in the bands between the copper grains, cause a significant decrease of the cohesion of the coating and make the connection with the substrate worse.



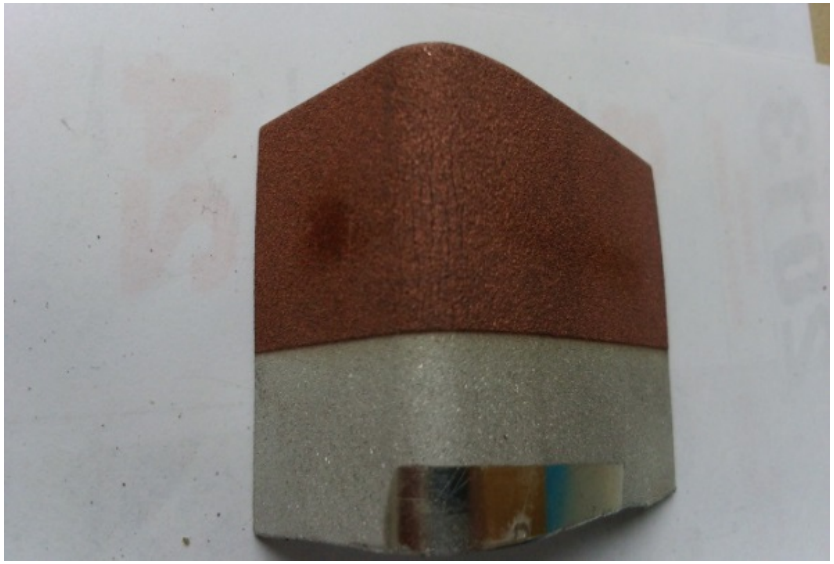
Cu-C coating

During the spraying of the copper powder with graphene, the carbon structures protect the particles of the copper powder against the excessive oxidization and thanks to this there are much fewer oxides in this coating than in the sprayed Cu powder coating.

Bend test – Cu coatings

The test involved bending sprayed samples by 90°.

Cu coating on the S235JR steel after bend test

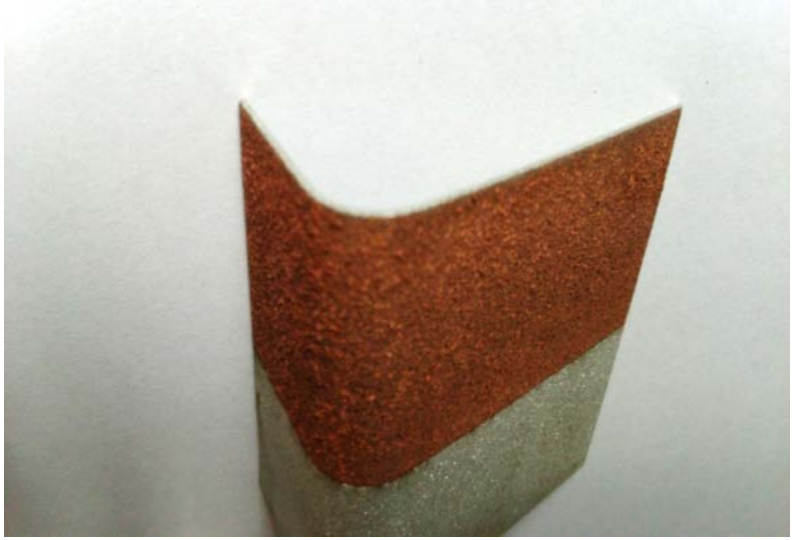


Cu coating on the Al alloy after bend test

The Cu coatings have cracked strongly. Additional Cu coating on the S235JR steel has separated from the matrix.

Bend test – Cu-C coatings

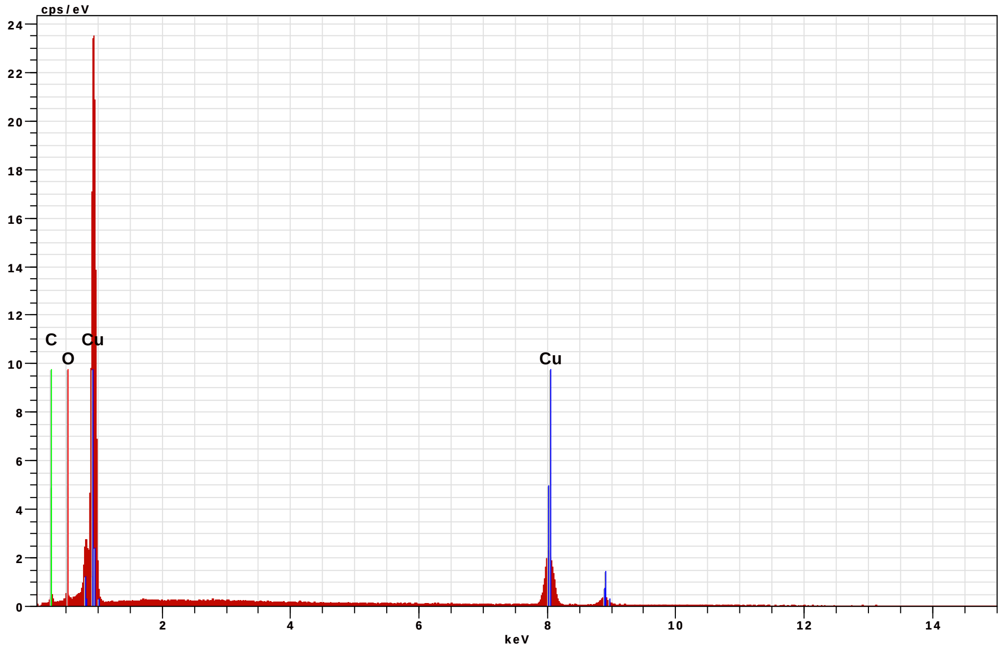
Cu-C coating on the S235JR steel after bend test



Cu-C coating on the Al alloy after bend test

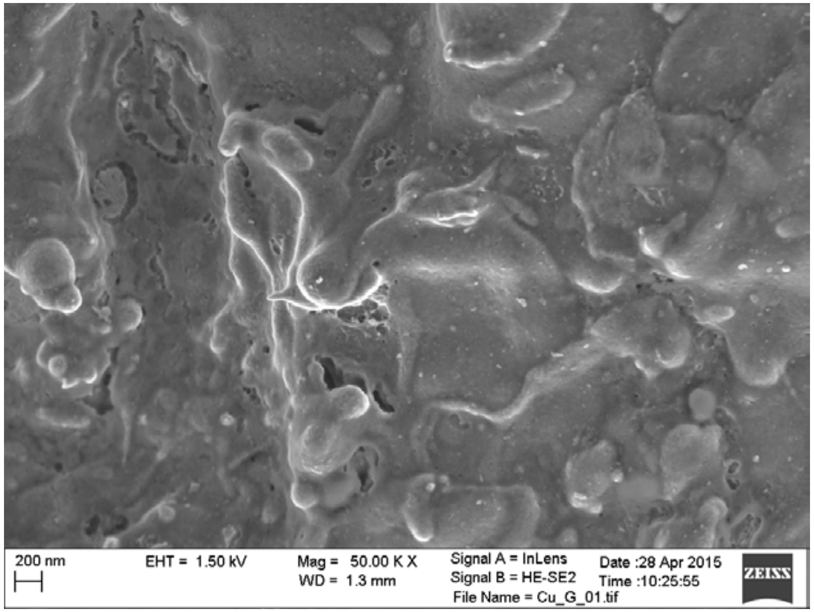
The bend test of Cu-C coating proves that the cohesion of the coating is good and that it is connected with the substrate well. This test showed good adherence and good deformability (there are no scratches and no cracks) of the Cu-C coating.

Cu-C Coating



Spectrum: Acquisition

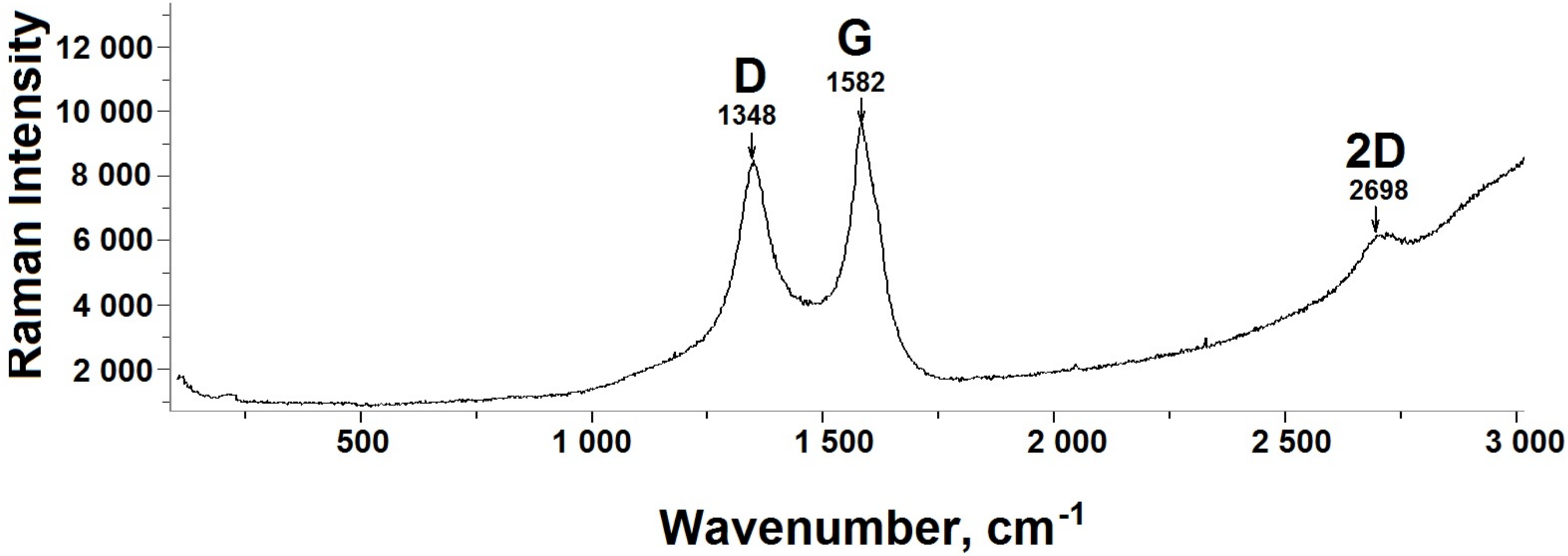
Element	Series	unn. C [wt.%]	norm. C [wt.%]	Atom. C [at.%]	Error (1 Sigma) [wt.%]
Oxygen	K-series	1.45	1.48	4.57	0.33
Carbon	K-series	5.50	5.60	23.06	1.12
Copper	K-series	91.29	92.92	72.36	2.98
	Total:	98.24	100.00	100.00	



The SEM image of the Cu-C coating

The analysis of the chemical composition showed that there are: 92.92% of Cu, 5.60% C and 1.48% of O

Raman spectrum of Cu-C Coating

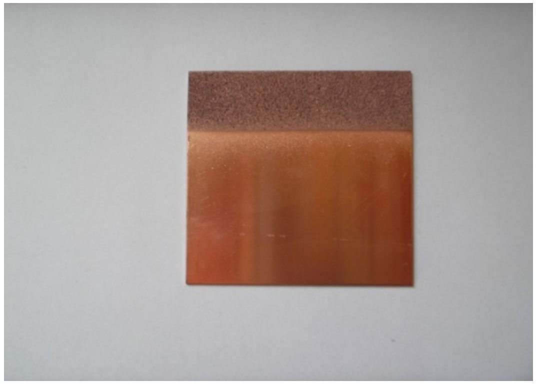


Cu-C Coatings

Substrate - Al

Substrate - S235JR steel

Substrate – 4H13 steel

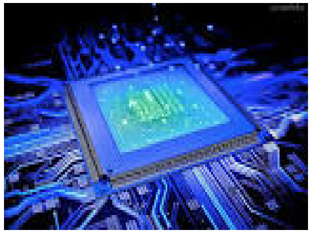


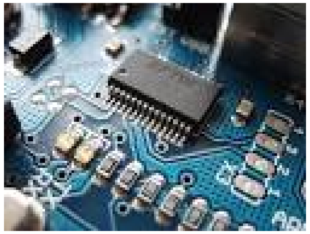
Substrate – Cu

Substrate - SiC

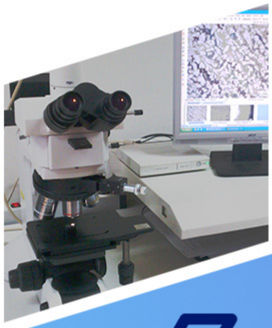
Conclusions

1. Institute of Precision Mechanics developed a low-cost manufacturing technology of the modern material which is Graphene 3D^{IMP}
2. Methods of spraying of copper powder with graphene were elaborated.
3. Composite coatings with the graphene dispersion phase are characterized by many advantageous properties:
   - increased hardness and abrasive wear resistance in comparison with the matrix material,
   - significantly better thermal and electric conductivity in comparison with copper,
   - increased corrosion resistance.
4. The use of composite coatings:
   - military technologies,
   - power engineering,
   - transport,
   - electronics,
   - others.






Thank you for your attention



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