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PARTS FOR GAMMA RADIATION DETECTORS MADE OF ELECTRICALLY CONDUCTIVE THERMOPLASTIC FILAMENTS BY ADDITIVE 3D PRINTING

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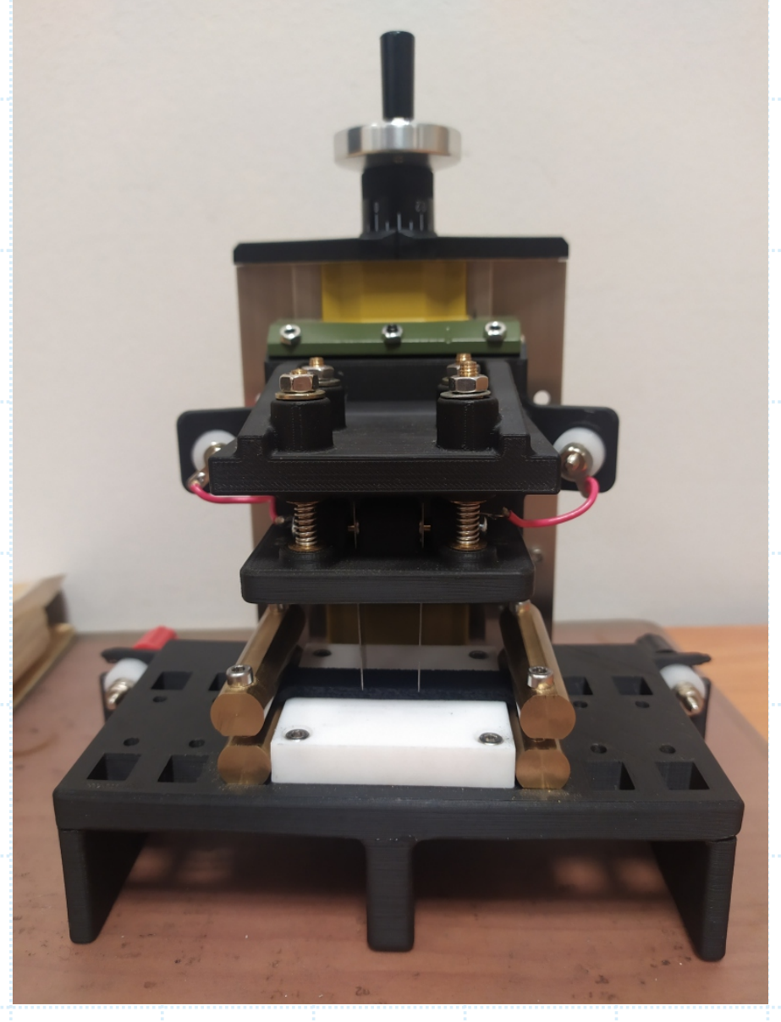
There are various methods of additive manufacturing or 3D printing has developed rapidly. 3D printing of a variety of thermoplastic materials makes it possible to produce complex-shaped parts faster and easier than traditional manufacturing processes such as turning, milling or casting. This opens up new possibilities for design, allows integrating the properties of different materials into one part without a special process of joining them.

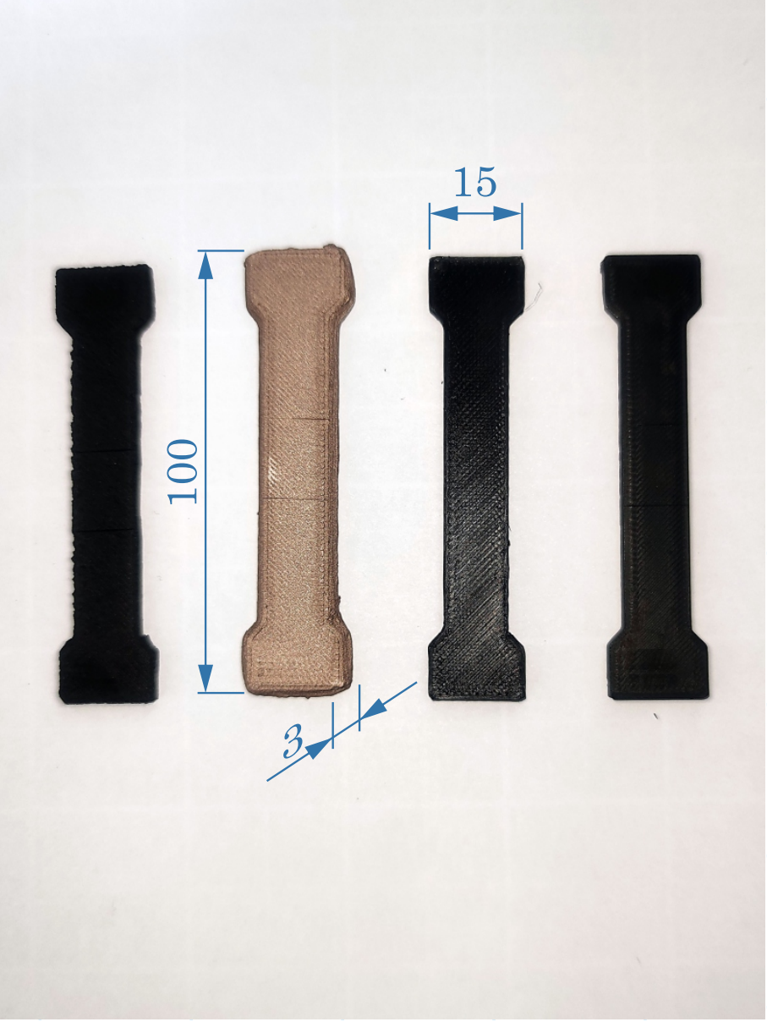
INVESTIGATION OF THE ELECTRICAL CHARACTERISTICS OF SAMPLES PRINTED FROM CONDUCTIVE FILEMENTS

Table. Comparative characteristics of some conductive filaments.

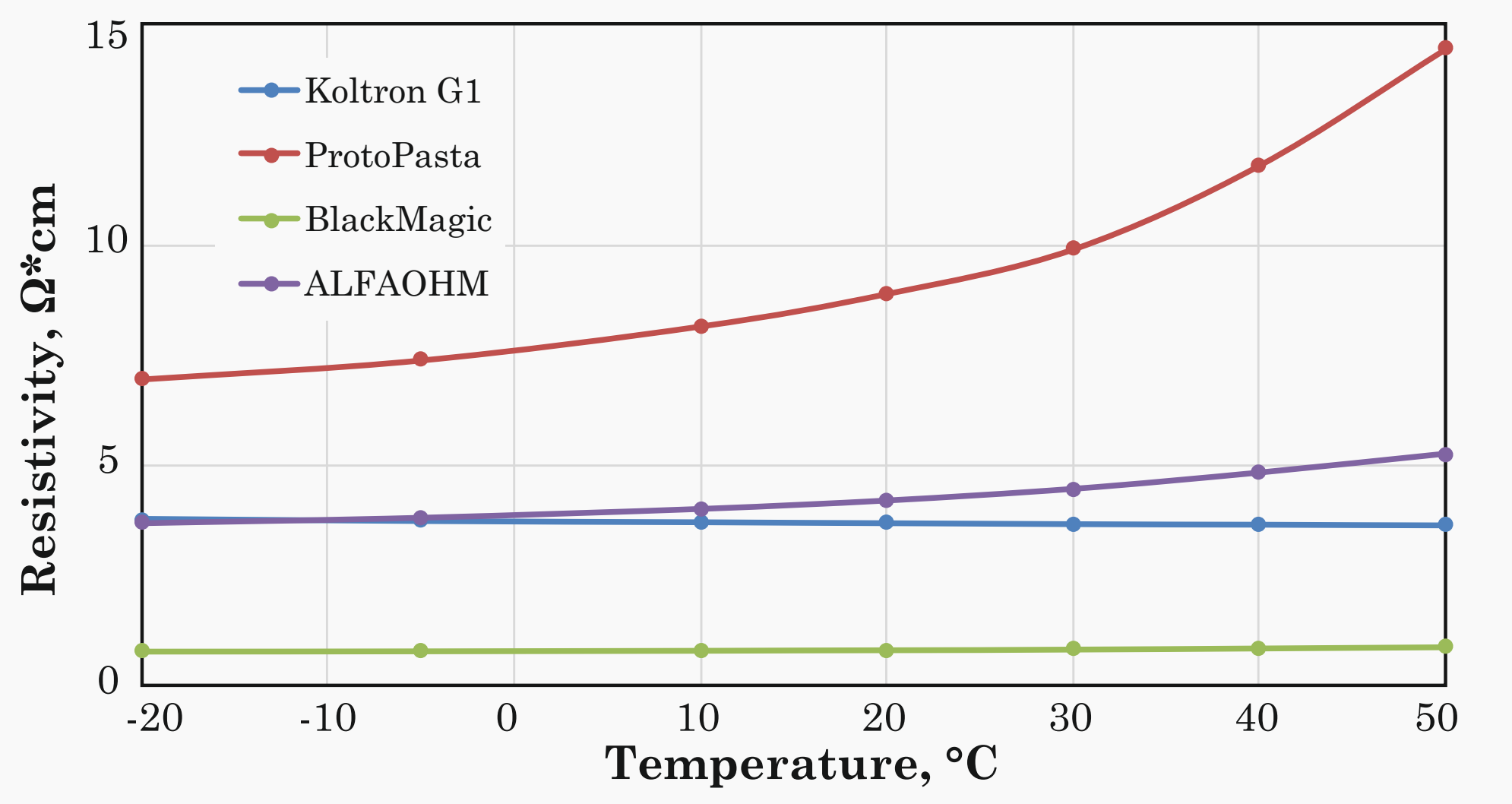
Name	Manufacturer, Country	Specific resistance, Ω*cm		Extrudes temperature, °C	Platform temperature, °C	Melting point, °C	Compositon	Approximate price per kg, EUR
		Manucturer specification	Measured by RITEC					
Electrifi	Multi3D, USA	0.006	n.a.	140-160	–	60	Polyester and copper	1670
BlackMagic 3D Conductive Graphene	Graphene 3D Lab, USA	0.6	0,82	220	50	50	PLA (Polylactic acid) and Graphene	850
AMOLEN 3D Conductive Black	Amolen, USA	1,5	74	220-250	0-50	~50	Conductive PLA (Polylactic acid)	130
Koltron G1	Add North 3D AB, Sweden	2.0	3,7	260 - 280	100	120-130	PVDF (Polyvinylidene fluoride) and AROS Graphene ®	1180
Conductive Filaflex	RECREUS IDUSTRIES, Spain	3,9	n.a.	245-250	50-60	230	TPU (Thermoplastic Polyurethane) and lampblack	150
ALFAOHM	FILOALFA®, Italy	15-20	4,2	190-210	0-50	~50	PLA (Polylactic acid) and carbon nanotubes	326
3dkonductive	3dk Trading GmbH, Germany	24	100	200-230	60-70	~45	Conductive PLA (Polylactic acid) and special carbon black	150
Protopasta Conductive PLA	Protoplant Inc, USA	30	8,9	215	60	50	PLA (Polylactic acid) and conductive Carbon black / Polymer	88



Measuring unit used for the resistance measurement.



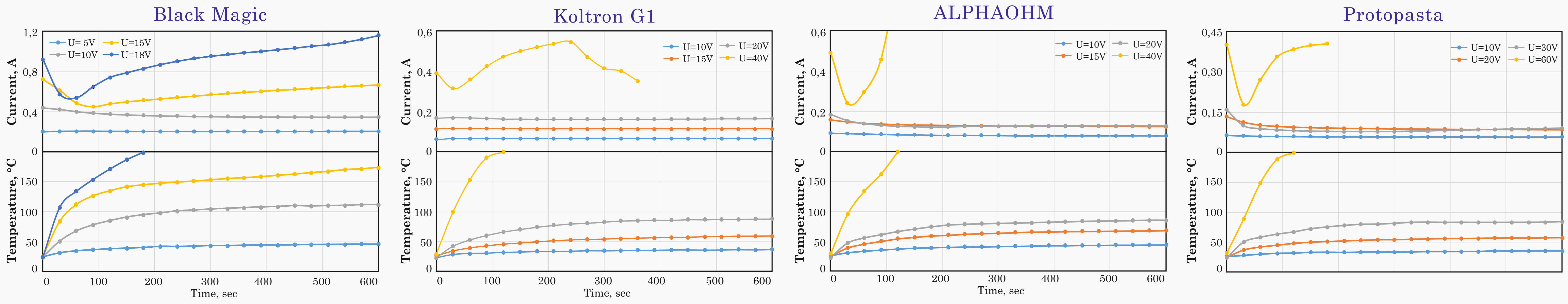
3D printed samples used for measurements.



Dependencies of the resistivity on temperature for different materials.

There are various materials on the market with special properties used for 3D printing via fused filament fabrication. One of them is electrically conductive filaments differing in their characteristics (resistance, composition, printing conditions, etc.), availability and price. The characteristics of some filaments from different manufacturers are presented in the Table. We fabricated and tested samples made of filaments with the low resistivity. Samples used for measurements and their dimensions are shown in the figure. The resistance of the samples was measured using the four-probe measurement method. A special measuring unit for fixing samples is shown in the photo. The temperature of the samples was controlled using a thermal imager. Measurements of the resistance of the samples at a fixed temperature of +20 °C were carried out in a thermally stabilized chamber. Samples made of the ProtoPasta, Blackmagic, AlPHAOHM and Koltron G1 were tested.

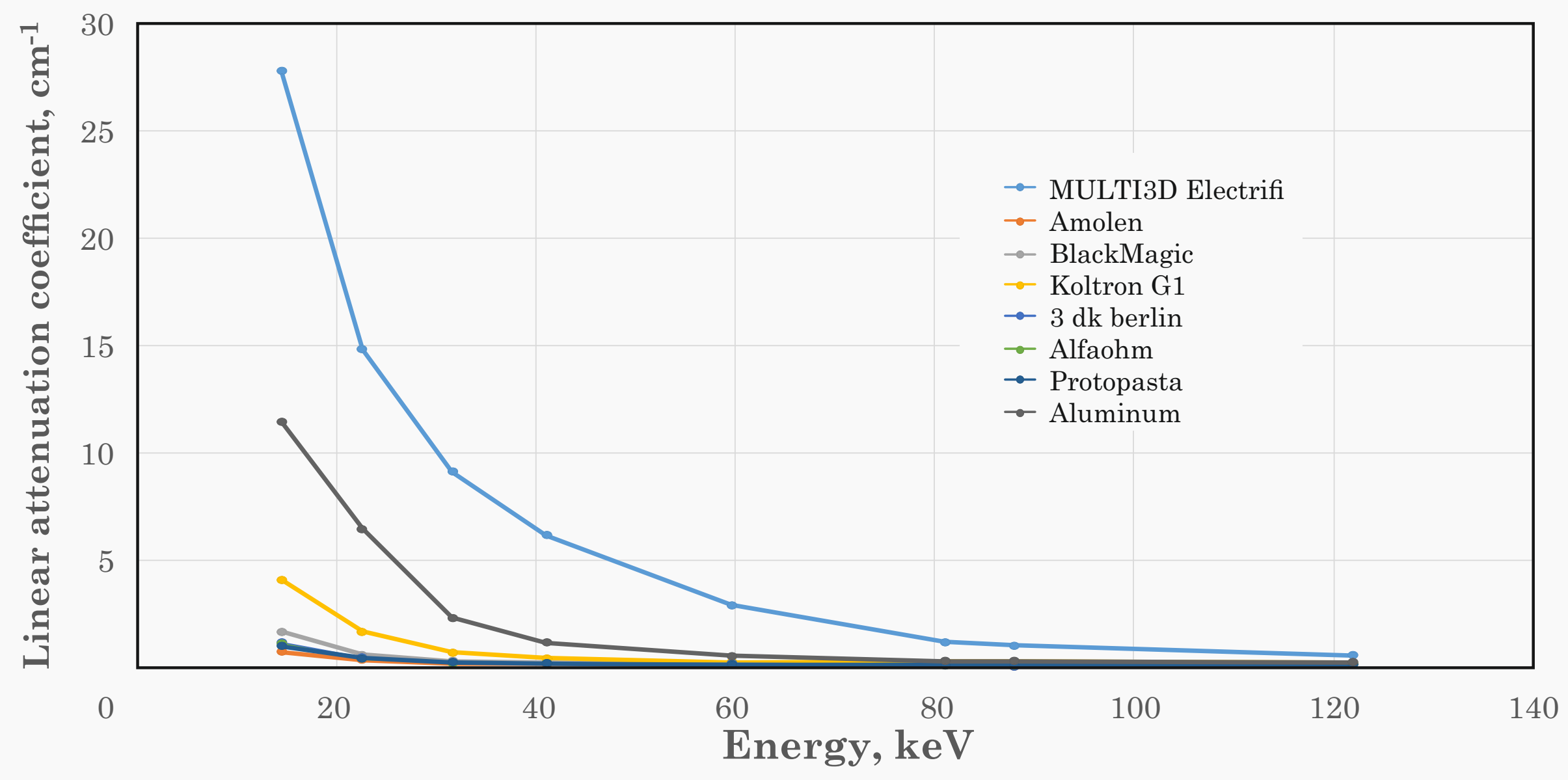
Strong heating of the samples due to a thermal action of the currents (according to the Joule-Lenz law), leads to softening and deformation of the samples, their separation and release of gases and, as a result, their destruction.



Dependencies of currents and temperatures on time.

EXAMPLES OF 3D PRINTED PARTS FOR PRACTICAL APPLICATIONS

Micro spectrometers with a housing made of aluminum (1) and with a 3D printed (2).



The linear attenuation coefficient of 3D printed windows made of different materials.

As a practical use of conductive filaments, some parts of housings for gamma and X-ray detectors were fabricated. One of the main requirements for such parts is to provide protection against electromagnetic interference. We tried to replace the metal housing of the detector with a 3D printed one made of a conductive filament. Micro spectrometer housings, previously made of aluminum, were manufactured using Protopasta and Black Magic. Tests of the micro spectrometer with the 3D-printed housing made of Black Magic show a possibility of replacing the metal case with a printed one. The housing made of Protopast does not give acceptable results due to a significant deterioration in the performance of the micro spectrometer when replacing the metal case with a printed one.

Another important requirement for housings of radiation detectors designed to detect low-energy gamma and X-ray radiations is the presence of a low-absorbing entrance window. In addition to low radiation absorption, such a window should provide reliable EMI shielding and mechanical protection, as well as protection from a visible light. To ensure low absorption of radiation in the entrance window, materials with a low atomic number and low density are used. The electrically conductive thermoplastic material, primarily based on a graphene, having a relatively high electrical conductivity and relatively low atomic number and density, could in principle be used as low-absorbing detector entrance windows instead of traditionally used aluminum or beryllium windows. Entrance windows made of various conductive filaments were fabricated and tested. The results of measuring of the linear attenuation coefficients of the input windows made of different materials for different energy ranges are shown in the figure. The linear attenuation coefficients of 3D printed windows made of filaments with carbon particles are lower compared to the aluminum windows.

MAIN RESULTS

- Resistivity of the samples made from different conductive filaments was measured. Some measured values do not match the resistivity values given by the manufacturers. This may be due to the difficulty of ensuring reliable electrical contact with the samples and with different modes of printing and measuring samples.
- All tested samples can be used as a heater up to temperatures of 50...80 ° C.
- Low resistivity filaments can be used to replace metal parts for EMI shielding.
- Graphene filaments can be used to make low-absorbing input windows for low-energy gamma and X-ray radiation detectors.

ACKNOWLEDGMENT

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