Ir/Au - Proximity Phase Transition Thermometers for the CRESST Dark Matter Search

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The CRESST dark matter search experiment [1,2,3,4,5,6,7] presently is using sapphire absorbers with tungsten superconducting phase transition thermometers evaporated onto their surface. The fabrication of tungsten phase transition thermometers is practically limited to a few materials if not completely to sapphire, since for the right growing of the tungsten film, a certain crystal structure of the substrate and very high temperatures during fabrication are required.

For both, the investigation of possible backgrounds and for the elucidation of the nature of a Dark Matter candidate in case of a positive signal, it would be desirable to vary the absorber material. CRESST recently has developed detectors, capable of simultaneously measuring a temperature signal and scintillation light produced in the absorber crystal. Since the light output is different for nuclear recoils and electron recoils, one can distinguish Gamma- and Beta-background from nuclear recoils scattering event. The sensitivity for the search to particle Dark Matter candidates is increased by orders of magnitude. The scintillating crystal used as absorber is $CaWO_4$. To be able to produce a thermometer onto $CaWO_4$ and onto other target materials, the TUM group has developed Ir/Au-proximity phase transition thermometers, which are much less critical with respect to the substrate onto which they are fabricated as compared to tungsten thermometers. In order to use a new absorber material, one has to find the right ratio between the thickness of the Ir- and the thickness of the Au-film to get the transition to superconductivity at a temperature not much higher than 20mK, and the right fabrication parameters to have the transition in a temperature range as narrow as possible. Both parameters are important to get the detection sensitivity required for reading out large absorber crystals. In 1999 the TUM group could realize Ir/Au-phase transition thermometers on germanium, with a transition temperature of 21mK and a width of 1mK. Also for the GNO cryogenic detectors, the Ir/Au-thermometers are being used.

Some progress in the development at TUM of a light detector for the scintillating CRESST detectors has been made. CRESST so far uses sapphire absorbers for the light detection. To improve the light absorption, a thin amorphous silicon layer is evaporated onto the sapphire surface. To collect the high energy phonons created by the light absorption more efficiently, and thus being able to increase the size of the light detectors, it would be better to use silicon as an absorber, which requires Ir/Au thermometers. Besides Si, also GaAs absobers are under investigation. As the light collection efficiency is still low, special anti-reflection coatings will be tested to increase the absorption probability of a photon emitted by the scintillating $CaWO_4$ crystal. Great effort is spent on optimizing thermometer geometry and thermal couplings. Thermometer films with lower area are under investigation. This leads to a lower heat capacity of the thermometer and thus to a higher temperature signal. The TUM group succeeded to lower the transition width of our Ir/Au-thermometers substantially. Narrow transitions lead to a high signal to noise ratio which should even lower the threshold and the energy resolution of the light detectors. Recently an energy threshold for a light detector of only 10eV could be realized.

As soon as large $CaWO_4$ detectors are available, the efficiency of light production of nuclear recoils can be measured and calibrated. The TUM group is in the process of setting up a dilution refrigerator, pumped by an absorption pump. Since this refrigerator, which will be fully functioning within a few weeks, needs no gas handling system, it can easily be transported to the close by Munich Accelerator Laboratory, where the measurements will be carried with a pulsed neutron beam. Since the tungsten in $CaWO_4$ will be dominant in the coherent scattering of dark matter candidates, it is very important to calibrate the light output for nuclear recoils on tungsten. During the measurement with neutrons, thus scattering on Ca, O and W have to be distinguished. This will be done by the different energy transfers, if the neutron energy and the scattering angle are fixed. The neutron energy will be fixed, either by the production reaction, or by time of flight measurement.

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