1. INTRODUCTION

The importance of the electronic interaction and randomness for the properties of condensed matter is well known [1]. Both Coulomb correlations and disorder are driving forces of metal–insulator transitions (MITs) connected with the localization and derealization of particles. In particular, the Mott–Hubbard MIT is caused by electronic repulsion [2], while the Anderson MIT is due to random scattering of noninteracting particles [3]. Actually, disorder and interaction effects are known to compete in many subtle ways [1, 4]; this problem becomes much more complicated in the case of strong electron correlations and strong disorder, determining the physical mechanisms of the Mott–Anderson MIT [1].

The cornerstone of the modern theory of strongly correlated systems is the dynamic mean-field theory (DMFT) [5–8], constituting a nonperturbative theoretical framework for the investigation of correlated lattice electrons with a local interaction. In this approach, the effect of local disorder can be taken into account through the standard average density of states (DOS) [9] in the absence of interactions, leading to the well-known coherent potential approximation [10], which does not describe the physics of Anderson localization. To overcome this deficiency, Dobrosavljević and Kotliar [11] formulated a variant of the DMFT where the geometrically averaged local DOS was computed from solutions of the self-consistent stochastic DMFT equations. Subsequently, Dobrosavljević et al. [12] incorporated the geometrically averaged local DOS into the self-consistency cycle and derived a mean-field theory of Anderson localization that reproduced many of the expected features of the disorder-driven MIT for noninteracting electrons. This approach was extended in [13] to include Hubbard correlations via DMFT, which led to a highly nontrivial phase diagram of the Anderson–Hubbard model with the correlated metal, Mott insulator, and correlated Anderson insulator phases. The main deficiency of these approaches, however, is the inability to directly calculate measurable physical properties, such as conductivity, which is of major importance and defines the MIT itself.

At the same time, the well-developed approach of the self-consistent theory of Anderson localization, based on solving the equations for the generalized diffusion coefficient, demonstrated its efficiency in the noninteracting case a long time ago [14–19]; several attempts to include interaction effects into this approach were made with some promising results [17, 20]. However, until recently, there have been no attempts to incorporate this approach into the modern theory of strongly correlated electronic systems. Here, we undertake such research, studying the Mott–Hubbard and Anderson MITs via direct calculations of both the average DOS and dynamic conductivity. Our approach is based on the recently proposed generalized DMFT + Σ approximation [21–24], which, on the one hand, retains the single-impurity description of the DMFT, with a proper account for local Hubbard-
like correlations and the possibility of using impurity solvers like NRG [25–27], and on the other hand, allows including additional (either local or nonlocal) interactions (fluctuations) on a nonperturbative model basis.

Within this approach, we have already studied both single- and two-particle properties of the two-dimensional Hubbard model, concentrating mainly on the problem of pseudogap formation in the DOS of the quasiparticle band in both correlated metals and doped Mott insulators, in application to superconducting cuprates. We analyzed the evolution of non-Fermi-liquid-like spectral density and ARPES spectra [22], “destruction” of Fermi surfaces and formation of Fermi “arcs” [21], as well as pseudogap anomalies of optical conductivity [24]. Briefly, we also considered impurity scattering effects [23].

In this paper, we apply our DMFT + Σ approach for calculations of the DOS, dynamic conductivity, and phase diagram of the strongly correlated and strongly disordered three-dimensional paramagnetic Anderson–Hubbard model. Strong correlations are again taken into account by DMFT, while disorder is taken into account via the appropriate generalization of the self-consistent theory of localization.

This paper is organized as follows. In Section 2, we briefly describe our generalized DMFT + Σ approximation with application to the disordered Hubbard model. In Section 3, we present basic DMFT + Σ expressions for dynamic (optical) conductivity and formulate the appropriate self-consistent equations for the generalized diffusion coefficient. Computational details and results for the DOS and dynamic conductivity are given in Section 4, where we also analyze the phase diagram of the strongly disordered Hubbard model within our approach. The paper ends with a short summary Section 5 including a discussion of some related problems.

2. BASICS OF THE DMFT + Σ APPROACH

Our aim is to consider the nonmagnetic disordered Anderson–Hubbard model (mainly) at half-filling for arbitrary interaction and disorder strengths. The Mott–